Mr. Cleaver. ampton when on a visit there in the summer of 1911. Experience at Port Talbot confirmed Mr. Sheilds's statement as to the insufficiency of the older estimates of the amount of pull on a bollard. In all specifications for wharves, jetties, etc., Mr. Cleaver always specified a maximum pull of 100 tons. With regard to reinforced concrete, timber fenders were fixed in front of all concrete wharves, etc., at Port Talbot, as a certain amount of wear and tear on the face of such structures was inevitable, and it was naturally much easier to repair timber fenders than concrete piles. He also adopted timber piles for fenders in each instance, so as to avoid the necessity of making attachments between the fenders and the concrete piles except at coping-level, which, of course, was an easy matter. Any fender damaged or moved, therefore, did not carry any portion of the concrete structure with it—at all events not under water. Timber dolphins, etc., were also placed at the ends of structures where a vessel was liable to collide with them, for the same reason that it was easier to repair timber than concrete. The ratio of the timber involved in these precautionary measures to the concrete was still so small that it did not affect the claims made in favour of using concrete for the permanent primary structures.

Correspondence.

Mr. Binns. Mr. ASA BINNS observed that the construction of the new dock at Methil had apparently occupied about 5 years, at a total cost of about £700,000. No doubt the comparatively slow progress of the work was due to its inherent difficulties, such as the exposed situation and the unexpectedly bad foundations, which had caused serious delays and changes in design. These delays were probably unfortunate from the point of view of the railway-company, who would otherwise have had the full benefit of the new works considerably earlier, during a period of great commercial prosperity. Judging from the general plan, and without knowledge of local conditions, it seemed possible that the great advantages to be derived from a lock entrance would have gone far to justify the additional capital cost. With regard to the design of the dock-walls, it might have been preferable to keep a vertical face, and to shorten the radius of the toe. The batter on the wall was certainly very slight, but it must be remembered that ships could not count on a higher water-level than high water of ordinary neap-tides, and with a deeply laden vessel the bilge-keels would probably come abreast of the curved toe. Approximate unit costs for the various sections of the work would be very useful, and there were several points of design on which further information would be helpful. The concrete rib under the centre-line of the entrance was an unusual feature, and he would like to know why it had been put in. As the sluice-culverts opened at right angles to the gate-recesses, it appeared probable that, owing to the nature of the bottom, the effective sluicing of the gate-platforms would not be necessary. The side walls of the entrance being faced with 18 inches of masonry, he assumed that a concrete face was not considered durable enough to suit local conditions. Cast-iron roller-paths were liable to break, and were extremely difficult to repair, so that, generally speaking, the additional cost of cast steel was probably well warranted. Had there been any reason, other than its greater durability, for the adoption of greenheart for the jetties, instead of cheaper timbers? He was not sure that the composite character of the jetties would prove an unmixed blessing. Timber fenders would get damaged, and the danger to ships bringing up heavily against the steel channel braces and ties required to be carefully guarded against. With reference to the hydraulic pipes would the Author be good enough to say why steel tubing had been used instead of the usual cast iron. The pipes were unusually large for so small an installation, but that was no doubt a good point. It was noticeable that return water-pipes were used, which was by no means the invariable practice where fairly clean water was available from the dock. The concrete described was of unusually good quality for heavy mass-work. If any experiments had been made to ascertain the volume of the interstices in the broken stone, perhaps the Author would kindly give the figures, and say whether the cement was in accordance with the British Standard specification. Mr. Binns.

The Paper on the Port Talbot docks was very suggestive. There were docks in use at present which were constructed more than 100 years ago, and instead of complaining of the limitations of such docks, traders should rather marvel at the degree to which they had proved adaptable to modern requirements. It was somewhat surprising that the Author had considered it worth while to provide fender-chains for the protection of the lock-gates. Mr. Binns was inclined to think that if the occasion arose, due to some mistake in the human factor, the resistance offered by the fender-chains would not prove of much use against a heavy ship under way. Perhaps, however, the Author could cite instances to support his action. The

Mr. Binns. scouring-effect of sluices was far-reaching, but it necessarily depended upon such factors as the depth and size of the sluice-openings, and the shape of the lock-entrance. He had known a cavity 10 feet deep cut out of a hard ballast bottom outside a concrete apron, although the apron extended 120 feet from the gates. While admitting this danger, it was difficult to agree with the Author's view that the apron should be extended in all cases to a point beyond the limits of the entrance-jetties. For instance, at Methil such an extended apron would be out of the question.

Mr. Carey. Mr. A. E. Carey stated that the method of disposal of spoil from the excavation of the channel at Port Talbot, by means of a pump dredger, had been adopted on an English harbour recently carried out by him. The contractors had to fill up a tract of marshy land adjoining a river-mouth, and they decided to eject the dredged spoil through floating pipes carried over the top of the river-wall. The plant adopted did not prove satisfactory, and a lawsuit was the result. The maximum distance the spoil was to be thus ejected was 150 yards. The deposit in question was glacial drift, and the case put forward by the makers of the plant was that, owing to the presence of peat and occasional boulders, the method adopted was unsuited to the material to be pumped. An 18-inch pipe was used, the couplings of which frequently gave way. From this and other causes the quantity of spoil ejected on the land was far short of that guaranteed by the makers of the plant, namely, 140 cubic yards of solid matter per hour. The ratio of the solid matter to the total discharge averaged 12 per cent. In this instance difficulties arose from three causes: inefficiency of the plant for eroding and cutting up the spoil, bad jointing of the floating pipes, and lack of power. At Port Talbot, apparently, the spoil consisted exclusively of sand. The question of the landward disposal of intractable dredged material by this system was one which might well form the subject of further discussion at the Institution. With regard to inducing increased scour by mooring craft to act as groynes in a channel, Mr. Carey had made use of this expedient on several occasions, and the results had been mentioned in previous discussions at the Institution.[1] A small bar in advance of a shallow harbour might often be lowered and regulated by the simple expedient of mooring a barge on it on the ebb-tide and athwart the stream: a pool would be formed round this barge, and the bar would be lowered temporarily. The design of the mooring shown in Fig. 7, Plate 3, was cheap and effective.

[1] Minutes of Proceedings Inst. C.E., vol. cxviii, p. 127.

At the Alexandra Dock, Cardiff, one of the moorings, then recently fixed, was lifted bodily by a ship. In that case a single screw-pile was used, and the casualty naturally caused doubt as to the stability of all single screw-pile moorings in any dock-bottom of similar physical character. Mr. Cleaver's apology for the use of reinforced concrete in the construction of jetties and wharves was unnecessary, as this material had been employed on so many occasions in the manner indicated. Undoubtedly it possessed many advantages. If the structure was properly designed and built, its stability and life were assured: the only serious drawback he had found in this class of work had been in connection with the repair of damage due to collision. The difficulty of ascertaining the actual extent of the injury and the cost of making good the damage could not be overlooked as serious factors of design. With regard to the new engine-house, if the Author could suggest any means by which the condensation of moisture on the walls of warehouses and similar structures so built could be counteracted, the suggestion would be of real value. Ordinary brickwork built facing the sea was incapable of resisting the percolation of moisture during gales. The moisture passed through the brickwork and streamed down the walls inside. Rendering the outer surface helped to make such a wall watertight, but it was desirable also to weather-board the walls if a really dry building was required. The sweating of reinforced-concrete buildings and the means of its abatement were subjects which required much more discussion than had yet been devoted to them. The Author's observations on the effect of scour near sluices afforded a fresh demonstration of the futility of artificial scour for maintaining a uniform depth of water in a harbour. The remarks in the Paper on the subsidence of a railway embankment reminded Mr. Carey of a curious problem he had to solve a year or two ago. Alongside the River Thames it became necessary to fill a disused "fleet" severed by the construction of a railway. Filling was accordingly tipped on to this swampy ground, but the subterranean water was thus merely driven back to a limited area, which became a highly dangerous bog. Ultimately he overcame the difficulty by sinking concrete pipes vertically down to bog-level. By weighting with block chalk the ground around the escape-holes so provided, the imprisoned liquid was forced to the surface, geyser fashion. Mr. Carey.

With regard to Mr. Blyth's Paper, the reason for the adoption of small concrete bags at the toe of the Methil sea-wall was not very evident. Why could not this wall have been constructed below low-water level in a piled trench in the ordinary way? Apparently the bags used were of 5 or 6 tons weight. At

Mr. Carey. La Guaira 12-ton bags had been used for founding the quay-walls in the sea, but they had proved far from satisfactory. Wherever a shifting and variable foundation existed, he doubted the expediency of using small concrete bags. Had the work shown in Fig. 3, Plate 1, had to be done in Holland, probably a reinforced-concrete facing would have been substituted for the concrete-block pitching on the inner face of the sea-wall. In many places in Holland this cheap method of construction had been adopted successfully in similar situations of great exposure.

Mr. Cay. Mr. W. DYCE CAY, from his experience of carrying out sea-works on the east coast of Scotland, did not think that the storms which caused several disasters in the construction of the new dock at Methil were at all unusual, or that their effect on the works was more damaging than might have been expected. He observed that the underside of the platform-beams of the goliath staging was only 13 feet above high water of spring-tides, and that it was supported on trestles and wrecked two or three times by the winter storms. The sea-staging he had used for building the breakwater at Aberdeen was 26 feet above the same level, and stood on masts of Oregon pine, and though the seas were heavier, no damage was done to it. Again, the sea-wall and the east-dock quay at Methil had had to be made stronger and thicker during construction, and it was to the lowness of the parapet—only 15 feet above high water—that he attributed the disaster to the dock-wall, due to green seas coming over the parapet, which, he thought, ought to have been 10 feet higher, and might yet require to be raised. He was glad to observe that the system of constructing the foundation and under-water parts of breakwaters with concrete bags of large size, which he introduced at Aberdeen harbour in 1870, had proved to be useful and even essential on the Methil sea-wall. He thought the plan of surrounding the bed of a block of mass-work, to be formed under water, with a wall of concrete bags was a practical improvement on the usual system of using shuttering. The skip used for lowering the bags seemed to have given satisfaction and to have been found better than an iron skip. Slight objections might be taken to it, e.g., that the bottom of the skip, with its ropes and screw clamp, required to be rigged afresh after each block was deposited, and that it might not be so safe for the divers below as an iron skip. He had published drawings of various skips, namely, of 5 tons and 16 tons in the Proceedings,[1] and of 9 tons in the Transactions of the Royal Scottish Society of Arts.[2] The last was used in building the

[1] Minutes of Proceedings Inst. C.E., vol. xxxix, p. 127.

[2] Trans. R. Sc. Soc. of Arts, vol. xii, p. 128.

Lerwick pier, and the only suggestion made by the superintendents in regard to it was that, instead of the bow girder for lifting it across its centre, they would have preferred four chains, one attached to each of its four corners, their free ends being brought together when lifting, and thrown to one side when filling. Mr. Cay.

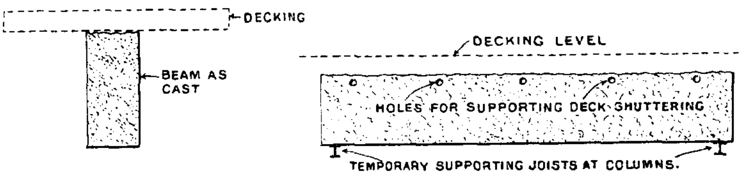
Mr. Robert G. Clark, having been acquainted with Port Talbot docks for more than 18 years before the new works were taken in hand, was in a good position to appreciate the value of Mr. Cleaver's Paper, which was of a kind very helpful to those engaged in similar work. In the time of the old docks—before 1903—Port Talbot earned rather a bad reputation among shipowners owing to the bad entrance and channel; but after the construction of the new south breakwater and the north pier, designed by the late Mr. P. W. Meik and the late Mr. J. A. McConnochie, the conditions were so improved that shipowners regained confidence, and they now sent their larger ships regularly to the port. The silting of the channel was no doubt due to the exceptionally fine sand, and until the slag retaining-wall was extended towards the nose of the north pier from the point A (Fig. 1, Plate 2), there was a large stretch of sand bounded by the north pier and by high-water mark of spring-tides, which could and always did gravitate towards the dredged channel. Mr. Cleaver was to be congratulated on his ingenious method of pumping the sand through the old south breakwater, thus placing it out of the silting zone, as the breakwater would act as a retaining-wall. The water from the River Avon might have been helpful if it could have been held back on the flood-tide and released on the ebb-tide, but this would have been very expensive, if not impossible. In times of flood the River Avon carried much matter in suspension; and when directed against the incoming tide the river-water lost its force and became comparatively slack, with the result that the matter in suspension was precipitated and formed spits or shoals. Looking back, it appeared that if the north pier had been constructed originally in a line almost parallel to the old south breakwater, in the position now occupied by the slag retaining-wall, and brought up to the dock-gates entrance, it would have prevented any sand from silting into the channel, and the river could then have been diverted to the north side of this pier and kept within the Port Talbot Company's boundary, or almost so. This would have saved the cost of the retaining-wall, which was about 1 mile in length, and would have reclaimed ground near the entrance of the locks, which was always valuable. The River Avon did at one time make an effort to run parallel to the Victoria Road from the point of the dam and the Mr. Clark.

Mr. Clark. gasworks, and that was the reason why the slag retaining-wall was carried up so far. The fact that screw moorings had been pulled out rather indicated that they should have been sunk deeper, but there was no question that, unless there were a large number to be put down, the plant-costs of screwing were excessive. Some years ago Mr. Clark had had some screw moorings put down in the lower reaches of the Thames, and the actual costs might be of interest.

25 feet of $2\frac{1}{4}$-inch stud-link chain	Total weight, $3\frac{1}{2}$ tons.
Two lengths 48 feet of $2\frac{1}{2}$-inch stud-link cable	
One triangle	
One buoy link	
Six $2\frac{3}{4}$-inch shackles	
One $2\frac{1}{2}$-inch shackle	
One buoy 9 feet long and 6 feet in diameter	2 tons.

The Thames Conservancy provided the two screw moorings and fixed them complete with chains, etc., at a cost of £104, the total cost being £241. This was an exceptionally strong mooring, which at high water had about 40 feet of water above it with a strong tide, and it had not given the slightest anxiety; but the screws went down into the chalk. However, Mr. Cleaver's type of mooring was not strictly comparable with this, as the conditions in a dock and in a river differed considerably; but his costs were low, and in the circumstances there was no doubt that the piled mooring he had designed was very efficient. The examples of reinforced-concrete construction cited by the Author fully justified the confidence he had originally placed in this material, and it would be interesting if he would give some comparative figures as to the first cost and the cost of maintenance. Mr. Clark agreed that, where possible, moulding blocks or members beforehand and assembling them subsequently was not only economical but also often made for sounder construction. This was especially the case in tidal waters. The structure must, however, be designed with this method of construction in view. In dealing with a structure originally designed to be built monolithically, it was no use taking out various members and constructing them separately, as it might lead to trouble and to the setting-up of stresses for which the structure had not been designed. Some years ago he designed a pier on the Thames to be built in this way, making blocks up to 3 tons and beams up to 5 tons in weight, and its construction was carried out quite successfully and economically; but an interesting point was brought to light which served to show that, unless specially designed for these conditions of construction, the structure might have had excessively high stresses in some parts and have been hardly stressed at all in others. The columns of the pier were placed 25 feet apart between centres crosswise Mr. Clark. and 28 feet longitudinally, and the beams were made about 26 feet long. All the columns and beams for the decking being cast in standard moulds on shore, it was possible to span the distance between a pair of columns without intermediate shuttering. The beams were also cast with holes in them to support the shuttering for the decking (*Figs.* 2), which would be an economical arrangement. In designing this structure the beam was considered as a tee-beam in which the decking, which was 5 inches thick, would take the larger part of the

Figs. 2.



compressive stresses. By the method of construction adopted, however, the decking was not put on the beam until it was in position, and therefore the top of the rectangular beam was in initial compression, as it was supported at each end and had to take the entire weight of the wet concrete forming the decking, with its shuttering. Therefore, after the concrete in the decking had set, the top layer of the original beam, which was the underside of the decking, was, under normal conditions, stressed more than the top layer of the decking, which under ordinary conditions of construction was the part most highly stressed, being farther from the neutral axis.

Mr. D. C. Leitch observed that the concrete used in the new Mr. Leitch. dock at Methil was stated to have been composed, except in special portions of the works, of 1 part by volume of cement, 2 of sand, and 4 of broken stone. It would be interesting to know the reasons for using concrete of uniform composition under such widely varying conditions. With the proportions stated, there would be about 62½ per cent. of mortar in the concrete, which appeared to be more than was desirable, except where displacers formed a considerable portion of the mass. He would suggest that, for concrete deposited under water and not in bags, 1 part of cement, 1½ of sand and 4 of broken stone would have been preferable ; while for bag-work, 1 part of cement, 2 of sand and 5 of broken stone, yielding concrete with about 50 per cent. of mortar, would have given results at least as good, at less cost. For blocks and mass concrete above water the

Mr. Leitch. latter composition, with 15 to 20 per cent. of displacers, or concrete composed of 1 part of cement, 2 of sand and 6 of broken stone, without displacers, had been largely used in similar work, with good results. The quay-wall, as originally designed, appeared to have had ample stability against such an accident as that which partly destroyed it, provided that the water-level in the dock was not much below sea-level. Under normal conditions it would not be so, and the occurrence of a storm of exceptional severity, before the water could be allowed to rise in the dock to the level of the sea, must be regarded as peculiarly unfortunate. The risk seemed to have been one which the engineers were fully justified in taking. If the thicker wall had been built in the first instance, and no heavy gale had occurred during the period of construction, it would perhaps have been difficult to defend the course taken.

With reference to the Port Talbot docks, it appeared to him to be doubtful whether the reinforced-concrete dam would materially affect the silting-up of the channel, beyond the quantity deposited on its up-stream side. The dam seriously reduced the channel available for flood-discharge, and might cause erosion of the banks, or a rise of the flood-level beyond what would otherwise be reached. Possibly trouble with riparian owners above the dam was not likely to arise. It did not appear from the Paper whether or not the dam was entirely above the level of high water of spring-tides. If not, it would have a prejudicial effect on the volume of tidal water, and would tend to increase the silting-up of the channel. The mooring shown in Fig. 7, Plate 3, had no doubt ample strength so long as the mooring-chain lay in the plane of the paper as shown. But with the mooring-chain turned through 90° in azimuth, while making an angle with the vertical, it seemed not so satisfactory, the transverse strength of the yoke-bar, which appeared to be about 3 inches by 3 inches, being hardly equal to the stresses arising under such conditions. The engine-house panels of hollow concrete blocks, 4½ inches thick, 12 feet wide, and 35 feet high, formed a remarkable piece of work. Their weight could add but little to their stability against wind-pressure. The bending-moment due to a wind-pressure of 14 lbs. per square foot would hardly be much less than 170 foot-lbs. per foot of height of panel and might be considerably more, involving tensile stresses of probably not less than 50 lbs. per square inch in the mortar joints. The successful substitution, in running sand, of cast-iron pipes for stoneware pipes, was interesting. Usually, in ground of this character, cast-iron pipes, unless supported at the joints by piling or other special means, were affected by settlement almost as much as those of stoneware.

Professor LUIGI LUIGGI considered that it was often more difficult to construct or alter small harbours than large harbours. In the case of the latter funds were generally forthcoming to the necessary amount, whilst for a small harbour the engineer, besides having to fight the sea, had to contend with financial difficulties. In the cases of the new dock at Methil and the improvements at Port Talbot, the technical difficulties and the necessity of keeping expenses low had both been met. At Port Talbot especially, very ingenious arrangements for strengthening the bollards and for new moorings had been required, which were well worthy of praise: interesting were also the various makeshifts adopted for dredging the entrance-channel without disturbing the navigation. But it was especially in the works at Methil that the greatest difficulties had occurred, and they had been surmounted with great skill. Although in general concrete bag-work was not to be recommended when concrete blocks, built in proper yards, could be adopted, still there were cases where lack of funds prevented the use of costly lifting-machinery, and where plastic concrete—deposited either in situ or as bag-work—had to be resorted to. But in these cases the risks of damage from rough seas must also be taken into account, and also the fact that it was impossible to deposit concrete under water, even in bag-work, without deterioration of the concrete, either through the chemical action of the sulphate of magnesia on the fresh cement, or through the resulting porosity of the concrete, due to the impossibility of tamping it under water. This tamping was left to be effected by the weight of the overlying concrete, with results which were very uncertain. In order to lessen these drawbacks, a larger amount of cement should always be used: the greater expenditure would be amply compensated for by the better results. Further, wherever possible, a certain amount of pozzolana or trass should be added to Portland-cement concrete. The usual practice in Italian harbours for concrete laid under water was to adopt a mixture of 1 part by volume of ordinary lime, 2 parts pozzolana, 3 parts gravel or ballast, and 100 to 200 kilograms of Portland cement for every cubic metre of concrete. This formed mass concrete which kept plastic for 6 to 8 hours, allowing ample time for it to be properly pressed—not tamped—into every corner of the cavity to be filled; or it could be laid in bags, if it were a case of bag-work. Very little was washed away by the surrounding water, and after 12 to 20 hours it did not suffer any further damage, even from the wash of waves, and gave almost as good results as ordinary concrete laid in the open for block-work, etc. The practice of using for sea-works concrete made only of Portland cement, sand, and gravel or broken stone, was looked upon with suspicion or disfavour in Italy, where pozzolana was abundant; and this was due

Prof. Luiggi. not only to the higher cost of Portland cement, but also especially to the danger of decomposition of the cement in sea-water. The excellent results that pozzolana concrete had always given in sea-works—as proved by the mole of Nero, at Porto d'Anzio, near Rome, or of Hadrian, near Bari, which were still in existence although nearly seventeen centuries old, and by remains of many other Roman harbours—were explained by the fact that pozzolana contained a large amount of free gelatinous silica ready to combine with the free lime that unfortunately was always present in Portland cement—even the best. Thus, when pozzolana was added in mixing Portland-cement concrete, there was always present a large excess of silica over this free lime, and the result was a kind of acid mixture, instead of the basic mixture that was the consequence of the free lime in cement. This acid concrete resisted better the decomposing action of the sulphate of magnesia of sea-water, which acted on the basic mortar of the concrete, decomposing it and causing free or inert magnesia to be found and sulphate of lime, which had a tendency to crystallize and expand, the consequence of the expansion being disintegration of the concrete. Portland-cement concrete, with an addition of one-eighth to one-tenth by volume of pozzolana, gave no signs of disintegration in salt water, even after about 30 years' exposure in the harbours of Genoa, Civita Vecchia, Naples, etc. At present a large graving-dock designed by him was in course of construction at Venice. It was 850 feet long, 40 feet deep on the sill, and 120 feet wide at the entrance, and the concrete used, which, for the sake of rapidity, was made of Portland cement, instead of the usual lime and pozzolana, mixed in different proportions, as shown in the following Table, according to whether it was more or less exposed to salt water:—

	Outer Skin, 6 Feet thick, in Contact with Salt Water.	Internal Mass, forming the Body of the Graving-Dock.
	Kilograms.[1]	Kilograms.[1]
Portland cement	400	250
	Cubic Metre.	Cubic Metre.
Pozzolana	0·150	0·070
Sand	0·450	0·440
Gravel or broken stone (maximum diameter, 2 inches)	1·000	1·000

The admixture of pozzolana to Portland-cement concrete was becoming very usual in Italy and was adopted also for reinforced-concrete

[1] The quantities stated form about 1·1 cubic metre of concrete.

Prof. Luiggi. piles, floating caissons, hollow concrete blocks, etc. The mixture most commonly used was:—

	For Pile-Work, Subject to Blows.	For Floating Caissons.
	Kilograms.[1]	Kilograms.[1]
Portland cement	500 to 600	350 to 400
Pozzolana	150 ,, 200	100 ,, 150
	Cubic Metre.	Cubic Metre.
Sand	0·400	0·400
Gravel or broken stone (1 inch diameter)	0·800	0·800

This excess of cement, in comparison with ordinary practice, was justified by the fact that reinforced-concrete piles were subject to heavy blows when driven; and in the case of floating caissons the cost of the extra quantity of cement was so small in comparison with the expenditure on reinforcement, moulding-boxes, and labour, as to be negligible—especially when the great expense that would be entailed for repairs should the concrete disintegrate under blows or by the action of sea-water was borne in mind. The admixture of a larger proportion of cement and the use of pozzolana, or trass, or tufa, for making the concrete less permeable and more resistant, both mechanically and chemically, for works exposed to the action of sea-waves, was becoming popular, not only in Italy where it originated, but also in Germany and Holland; and the practice was followed also for ordinary hydraulic work not in contact with sea-water. As an example of this practice abroad, he might mention the important aqueduct of the Los Angeles waterworks, in California, in course of construction. Excellent results, both technical and economic, were being obtained on this work by adding tufa to the cement, and regrinding them together, the resulting concrete being more plastic and less permeable, and costing 20 to 33 per cent. less. A good account of these works was to be found in the Proceedings of the American Society of Civil Engineers.[2] He had also explained the use of such concrete in a Paper presented to the Society of Italian Engineers and Architects.[3]

Mr. McClean. Mr. W. N. McClean stated that the approach-jetty to the deep-water entrance-lock at Barry was founded on concrete bags laid by divers in a grip excavated in the marl rock. This was not a very exposed place, being within the breakwaters. These bags

[1] The quantities stated form about 1·1 cubic metre of concrete.

[2] Proc. Am. Soc. C.E., vol. xxxviii (1912), p. 1191.

[3] "Precauzioni per assicurare la impermeabilità delle opere in cemento armato." Annali della Società degli Ingegneri e degli Architetti Italiani, 1912.

Mr. McClean. formed an excellent foundation, and the wall thus constructed actually retained the water behind it when the tide receded. The concrete was made with broken stone, and soon after the commencement of the work it was found that the concrete was greatly improved by washing the broken stone before mixing. He examined these bags a year or two after they were deposited, and the concrete in which washed stone had been used was then in perfect condition, whereas in that made with unwashed stone there was often a fine white deposit around the stones. He would like Mr. Cleaver to say whether the reinforced-concrete dam across the river reduced the tidal flow to any great extent. If so, did the reduced scour affect adversely the depth of water in the channel and on the bar outside? With regard to fender-chains to protect lock-gates, he had had considerable experience with these chains at Barry and at Avonmouth, and considered that they were undoubtedly very useful. There seemed to be some prejudice against them originating with dock-masters. It was necessary to design the chains so that they could be raised and lowered easily, and be kept clear of propellers. This object could always be attained by careful design in the first instance. Mr. Cleaver had adopted a type of fender-chain designed by Mr. E. F. McCourt, Assoc. M. Inst. C.E., and Mr. McClean after many careful experiments. It was a combination of boom and chain, and commenced to extend just before the yield-point of the steel or wrought iron was reached. At Port Talbot no arrangements had previously been made for installing chains, and it was to be hoped that there would be no trouble in raising or lowering the chain. It was only necessary to watch medium-sized ships entering a large lock where there was much difference in the level of the water, in order to realize that some efficient form of protection was required nowadays for the safety of the shipping in dock. Where fender-chains were installed they were generally placed at each end of the lock, outside the gates; they should really be placed within the lock itself, as the signals should be sufficient protection against a ship approaching the lock when the gates were closed. The fender-chains adopted by Sir John Wolfe Barry generally extended under a 40-ton pull, and, with 30 feet paid out, gave a resistance equal to 1,200 foot-tons. In the chains for the Panama Canal the pull was 100 tons, and the extension, he believed, was 70 feet, giving a resistance equal to 7,000 foot-tons. A rigid chain of the same size would probably not exert a resistance of more than 200 foot-tons. In the Welland Canal, where there was only a small difference of water-level and the gates were comparatively small, spare gates were stored, and they had been used several times.

Mr. H. H. G. MITCHELL considered that the particulars of the nozzle used by Mr. Cleaver on the pipes of the suction dredger at Port Talbot were very interesting, and it would add to their utility if he would state the size of the dredger and the maximum height of the swell, from trough to crest, in which the dredger with the improved nozzle could be worked safely. In Madras a great deal of attention had been devoted to the question of working suction dredgers in a swell. By interposing a pipe in the form of an oscillating arm between the ship's side and the ordinary universal joint on the 20-inch side suction pipes of a 900-ton dredger, it had been found possible to work her safely in a 6-foot swell. The moorings at Madras consisted of a bridle of 2½-inch chains attached to screws 4 feet in diameter; these screws were sunk 15 feet into the sand in a few minutes by aid of a water-jet, and had never been known to draw, even in the days when the exposed eastern entrance was open and 6,000- to 8,000-ton boats were lying at the moorings in heavy seas and strong winds. Where clay was mixed with the sand, screwing, as described in the Paper, was resorted to; but Mr. Cleaver's method of preparing a mooring with piles and concrete would probably be equally efficacious and more economical. Mr. Mitchell.

Mr. W. T. OLIVE considered the general design of Methil dock No. 3, together with the railway service, to be excellent from a traffic point of view. The earlier docks, Nos. 1 and 2, cost £92 10*s.* per lineal foot of quay, whilst in the new dock (No. 3) this figure appeared to have been greatly exceeded. The single sea-wall—the most important work—was to have been, he gathered, 8 feet thick at quay-level, with counterforts 5 feet wide and 30 feet apart. The equivalent thickness of uniform wall without counterforts would have been 9 feet at quay-level. The ratio of the quantity of masonry in the counterforted wall to the quantity in the equivalent uniform wall was 265 : 270, showing a small saving of material. Yet it appeared that eventually the counterforts had been done away with and the wall thickened, making the top not 9 feet but 11 feet in width; and in 1910 further strengthening was effected, increasing the top width to 17 feet. The tying of the upper part of the wall to bag-work by pairs of old rails 15 feet apart, afterwards altered to rolled joists 12 inches by 6 inches 5 feet apart, and also the raising of the bag-work to 5 feet 6 inches above low water—pointing to a general strengthening of the work—were due no doubt to the experience gained in the storms of 1908; yet they presented a contrast with the much lighter section of the old east sea-wall protecting docks Nos. 1 and 2, which had stood well for many years. Again, after the storm of the 18th January, 1912, the Mr. Olive.

Mr. Olive. east quay-wall of dock No. 3 was increased in thickness by 6 feet, the whole quay was covered with 2 feet of concrete, and 450 additional 50-ton blocks were added outside the sea-wall. In regard to the steel channel-bars used as ties in the timber jetties, an expression of opinion would be valuable as to the relative merits in such situations of steel and wrought iron, from the point of view of corrosion. He desired also to be informed whether any proposals had been made for flushing the docks from the River Leven, which, rising in the Ochil Hills in Kinross, had a fairly large catchment-area, or for other means of changing the water occasionally. It had occurred to him that as Thornton was the heart of the coal-district from which supplies were brought, and as the doubling of the railway between Thornton and Leven had cost £40,000 and 12 miles of sidings had been constructed a mile away, it might have been economical in first cost and handling to have canalized the rivers Ore and Leven between these places and provided barge-basins at the dock-site, if such were feasible; but as he had no personal knowledge of the local conditions this proposal might be entirely impracticable.

With regard to Mr. Cleaver's Paper, the line of the leading lights indicating the entrance-channel pointed due west by north and struck land only 8 miles away, to the north of the Mumbles, or midway between Mumbles Head and Swansea; which proved the entrance to have been arranged judiciously, having regard to the heavy weather to which the Bristol Channel was subject. He noted the advantage of the construction of the slag training-wall in maintaining the depth of the entrance-channel and causing rapid accretion at the back of the wall to the north, making ground which should ultimately become valuable. As to the dam placed on the river below the public road-bridge, might not the very erection of this dam, with its 9 feet of silting-up in a short time, have been the actual cause of the three or four floods not previously experienced in 30 years? For it was admitted that the river-bed above had been raised so as to have practically no fall. Distinctly, in Mr. Olive's opinion, it should have been furnished with automatic tilting gates or regulating-sluices, which would have allowed flood-water to pass off at a lower level. Neglect of such precaution, *mutatis mutandis*, had caused the Cape Government a loss of £35,000 in the Supreme Court case Roux *v.* Colonial Government (May, 1901), in regard to the Kenhardt half-mile earthen dam 23 feet high, where the facts were that during a flood sluices were closed that should have been opened, and the dam was consequently ruined and abandoned. Also in the case Louw *v.*

The Minister of Lands (October, 1912), where, owing to inadequate provision of spillways to deal with floods at a dam on the Zak river, the Government were mulcted in £600 and costs for damage to crops. With the object of trapping silt, alternatively to constructing the dam illustrated in Fig. 2, Plate 2, a side depositing-basin taken out of the left bank might have been made 2,400 feet up-stream from the dam and just below the intake near the Mansel works, where the river was much wider than above the weir. This would have necessitated only the sluing over of some railway-lines, and the sand deposited by floods upon a prepared stone-pitched floor could have been carted out by an inclined road and tipped where it was wanted, namely, into the adjacent large area to be reclaimed south of the Burrows works and within a radius of 1,200 feet therefrom. Mr. Olive had such a contrivance for many years below Crabtree's Weir on the Medlock at Manchester, to obtain deposited river-sand for building purposes. He considered the moorings were very satisfactory in respect to both simplicity of design and manner of fixing, and he also approved the method adopted for strengthening the anchorage of bollards; but he did not concur in the matter of repairs to the viaduct in respect of the new 3-inch drains for the following reasons:—(1) In the existing position one pipe at each pier was sufficient, in place of the two proposed. (2) The outlet was less conspicuous at the soffit of the arch than at the face of the pier. (3) The drainage should be from the sides towards the middle of the bridge, for capillary attraction had to be considered in the spandrel-walls and the pilasters of refuge-recesses. (4) Any obstructions would occur in both cases from the inside or inlets, and not at the outlets of the 3-inch drain, the former being the points to which access would be required. (5) He considered a simple inspection-chamber, with cover, at sleeper-level at each pier would suffice, instead of a travelling stage slung over the parapet, which would only give access to the outlets. Mr. Olive.

Mr. C. O. Ridley wished to draw attention to the behaviour of the Mannesmann steel pressure- and return-water piping, which was in position on the length of the east wall of the Methil dock carried away by the storm in January, 1912, as mentioned on p. 104. Between the south-east corner of the dock and hoist No. 14 there was a length of about 360 feet of 9-inch pressure-piping and a similar length of 12-inch return-water piping. Between hoists Nos. 14 and 13 there was a length of about 300 feet of pressure- and return-water piping of the same sizes. The whole of this piping was carried bodily into the dock when the wall gave way. The pressure-piping was made up of standard 36-foot lengths and one or two specials, seventeen Mr. Ridley.

Mr. Ridley. lengths in all being involved. The whole of this was recovered, and of the seventeen lengths eight were found to be damaged by bending. Of these eight lengths, four were easily straightened, but the other four had to be shortened, the total loss in piping cut off amounting to about 50 feet. None of the flanges or flange-bolts was broken, but one flange was torn bodily off the pipe and another was partly torn off. Of the return-water piping twenty-seven standard lengths of 27 feet 3 inches each were involved and a few specials. All these were recovered; only four were damaged, one so severely that it had to be entirely replaced. The other three only required to be shortened slightly, and were worked in again. The whole of the return-water joints were made with "lead wool," and only a few of them drew. He considered that these results were remarkable, as the 9-inch pressure-pipes were only $\frac{13}{32}$ inch thick, while the return-water pipes were $\frac{1}{4}$ inch thick. He had no doubt that if they had been of cast iron, few, if any, of the pipes could have been used again.

Mr. Roberts. Mr. A. H. ROBERTS congratulated Mr. Cleaver upon placing on record his experience in a spirit which was in accordance with the professional aim of profiting by all knowledge gained. With regard to the training-works, it was satisfactory to know that the slag wall had fulfilled its purpose. He considered that this result was due in some measure to the character of the copper slag used; it was very heavy, hard, and angular, and these qualities gave it a cohesive effect. It was also apparently entirely immune from the destructive influence of weather, salt water, etc., and was in these respects much superior to ordinary rubble. Mr. Cleaver's design of suction-nozzle was ingenious, and in Mr. Roberts's opinion met well the difficulty mentioned, which was not confined to Port Talbot. Fig. 5, Plate 3, did not demonstrate the necessity of the middle set of discharge-pipes, but seemed to show that the two outer sets would have sufficed. Probably considerations of local or temporary convenience accounted for the use of the middle set. The design of the moorings was ingenious and, since it met all requirements, could not be described as expensive. Regarding reinforced-concrete work, although Mr. Cleaver's views, as to the independent construction of beams and diagonals and subsequent placing and jointing, were not in accordance with prevailing practice, Mr. Roberts considered that they had much to recommend them; and for the insertion of bracing under water the method was a valuable one, subject, of course, to proper safeguards and extreme care in jointing. The hydraulic mains successfully laid in deep water were presumably of cast iron in 9-foot lengths. If any settlement or disturbance took place in the bearing-rails the joints might give trouble. It would seem desirable to fill the trench with, say, road-metal, with a view to protect the pipes themselves from disturbance, and prevent the softening or deterioration of the clay forming the dock-bottom. As to the prevention of scour at the sluices, there could be little doubt that the right thing had been done in depositing the copper slag in front of the apron. But he disagreed with the statement that the undermining would have been avoided if the apron had been carried out farther in the first instance. The outer end of a smooth concrete or masonry apron was always the point where scour and consequent undermining took place. Had the apron been carried farther out in the first instance, he believed that the same trouble would have occurred, only farther out. The horizontal travel of water produced little effect compared with a vertical drop, and he was of opinion that every concrete apron (except, of course, where the bottom of the channel was rock or other very hard material) should have in front of it a length of rubble. The copper slag used at Port Talbot was exceptionally good material for this purpose. He was about to carry out the repair of an apron which had suffered in a similar manner, although it had done duty for nearly a century. A row of piles would be driven across the outer end of the apron, and the latter made good against the piling with concrete: on the other side an extended apron of rubble would be provided, to break the destructive fall of the water off the present apron and distribute it into comparatively slack water. Piling was necessitated by the scour which had taken place. The new sidings at Port Talbot were extensive, and the grids appeared to be conveniently devised to meet traffic-requirements. He was of opinion that the Port Talbot Company had been well advised in installing a belt coaling-plant. It was necessarily an experiment, but considerable advance had been made in this direction on the east coast of England, and there was every justification for putting the system to a practical test in South Wales. It had been stated that the breakage of the coal was more extensive with a belt plant than with a hoist; but he had had occasion to consider the point carefully, and was of opinion that in this respect there was little to choose between the two systems. The principal differences in breakage occurred after the coal left the shoot. The Cordeaux fuse appeared to be practically ideal in the matter of safety, and in conjunction with ammonal for large or important blasting-operations it had a useful future before it. Mr. Roberts.

M 2

Mr. Walker. Mr. E. G. WALKER considered that the clearness of Mr. Blyth's description would be enhanced if he would add to the Paper a plan of the dock estate, and particularly of the foreshore on the site of the new dock, as it existed before the commencement of the new works: such a plan would render a number of descriptive passages in the Paper easier to follow. It was not clear what procedure had been actually followed in building the new sea-wall. On p. 80 it was stated that the superstructure was formed of mass concrete in situ on a bag-work foundation; but from the next page it appeared that part of the sea-wall above the bag-work was to be constructed of concrete blocks weighing about 10 tons. Was it to be understood that this second method was substituted for the first after the change of design was made? If so, how much of the wall had been constructed by the first method? He asked these questions with a view to ascertain Mr. Blyth's experience of the use of shuttering in a situation which seemed to have been very exposed. The subject of shuttering was not much referred to in the Paper, although it was stated on p. 85 that its use under water was unsuccessful—an experience which Mr. Walker believed to be not uncommon. In this case, where the work was subject to the full force of heavy seas, a face of block-work backed with mass concrete would seem likely to present less difficulty on the whole than mass-work throughout. In the altered design of the sea-wall, 12-inch by 6-inch by 44-lb. rolled steel joists were adopted, in place of old rails, for bonding. Weight for weight, the joists gave a more economical employment of the metal, but he thought that the facilities for getting, cutting, and handling old rails would have rendered their employment preferable, even though it involved the handling of a greater weight of material. He would ask therefore what had been the reasons for making the change. Though perhaps not strictly within the limits which Mr. Blyth appeared to have set himself, a little more information about the gate-operating machinery and the mechanical plant in general would add interest to the Paper. In view of the economy usually obtained by the use of concrete-mixing machines, the proportion of hand-made concrete used on this work, namely, about 50 per cent., seemed high, unless special conditions not mentioned in the Paper had prevailed. There appeared to have been great risk of subsidence in various parts of the property, and he presumed that this had been one of the considerations leading to the decision to use steel pipes for the hydraulic mains; also that the long pipes used (36 feet) cost considerably less for the laying and jointing than the shorter and heavier cast-iron pipes. Further information on these points would be of value.

Mr. Walker

Mr. Cleaver was to be congratulated upon putting before The Institution a Paper of a kind all too rare; for the smaller, but not less difficult, problems of dock-maintenance did not find in the literature of the subject a place commensurate with their importance. The device of moving the tugs and dredging-craft into special positions in order to scour away banks in the channel, was simple and inexpensive, but unless the draught of the vessels was large in comparison with the clearance below them, it seemed hardly likely that the procedure would be effective. The moorings, whilst excellent so far as the strength of the anchorage was concerned, seemed to be open to one rather serious objection. The V-shaped bar to which the mooring-shackle was attached stood necessarily well out of the concrete base, exposed to the action of the water and to accidental damage. Should this bar have to be renewed it would be no light matter to replace it, as a large part of the concrete base would have to be broken up in order to get necessary attachment to the old-rail crossheads. He suggested that a more substantial connection, e.g., one made of old rails bent as required, would resist the corrosive action of the water better than the comparatively light round bar shown in Figs. 7, Plate 3. He regretted that Mr. Cleaver did not state the precise nature of the defects which showed themselves in the original bollards. From the arrangements adopted for strengthening them it would appear that the trouble he had to contend with was bodily overturning of the bollard and its concrete base. This defect could be remedied at no great expense, though with proper care in design in the first place it should not arise. But there were cases in which little attention had been given in the original design to the pulls that were likely to be applied to the bollard during its life. Of course, nearly all the loads which come on to bollards in general acted in a direction inclined but slightly to the horizontal; and to provide for these it was only necessary to carry the post sufficiently far down in the concrete, the back vertical face of the latter being made as deep and as wide as would allow the horizontal pressure exerted on the surrounding earth to be brought within reasonable limits. The pull on the mooring-rope of an exceptionally large and high ship might have an appreciable vertical component, but this would never be likely to be commensurate with the resistance of the bollard. It often happened, however, that temporary arrangements had to be devised for dealing with special loads, and the apparent strength and weight of bollards was apt to cause undue confidence in them as anchorages for guys, hauling-ropes, etc., sometimes resulting in rather costly accidents. He could recall an instance in which a bollard failed from such a cause, with nearly fatal results to

Mr. Walker. one of the men engaged on the work. In this case, a strong horizontal pull, produced by anchoring a heavy lifting-tackle to the bollard, was combined with the tension of a 6½-inch wire hawser acting at about 30° to 40° above the horizontal. The bollard might almost be said to have been designed to assist its failure, for, although embedded about 6 feet in the concrete, its section, which was square, tapered about 1 in 8 from ground-level to the base, and it was without flange, foot, or rib of any sort. Hence, as soon as any force sufficient to break down the adhesion between the iron and the surrounding concrete was applied, the bollard gave way. This taper towards the base was not uncommon, and he believed it to be a bad feature. If the bases and foundations of bollards were more carefully designed to resist the forces likely to be applied to them, strengthening should not be necessary. Among the reasons that had been given for the use of reinforced concrete for jetty- and wharf-construction, Mr. Cleaver's was probably unique. The possibility of such an accident as he described was a very good argument in favour of the adoption of reinforced concrete. His conclusions in favour of building up reinforced-concrete skeleton structures piece by piece, instead of forming the members in situ, was, however, open to criticism. In the first place, work that was to be built up must be designed less economically if its strength was to be equal to that of monolithic work; for, in order to ensure the same rigidity and stiffness, it was necessary to make larger joints, involving more steel and concrete, than were required where bars could be carried through continuously, or bent over to join up in the case of a diagonal intersection. And, in any case, it was difficult to make a joint between two or more built-up pieces which was as efficient as one constructed continuously. The problem of bonding new concrete with old was difficult enough when it was merely a case of, say, joining up one week's work on a continuous reinforced-concrete floor with the previous week's: when two or three pieces of set concrete, each exposing a hard surface on four sides and an end, had to be joined together by freshly-made concrete, often under conditions which made efficient tamping difficult, the bonding problem presented itself in an acuter form. Again, in the generality of cases, the steel could not be used to as great advantage, for the benefit of carrying a bar from one member well into the next, and thus binding the various portions of the work securely together, were entirely lost, and reliance had to be placed instead upon short lengths of bar suitably bent and secured to the bars that were to be joined—in any case a less efficient connection. In jetty and quay work several members—diagonals, horizontals, and verticals, in different planes—often met in one Mr. Walker. intersection, where it was practically impossible to make a joint in any other way than by moulding it in situ. In such cases it was necessary, as Mr. Cleaver stated, to fall back on monolithic construction. Beams when constructed in situ might be treated as continuous, or partly so, over a number of spans, but there was little justification for doing this if they were made on the ground and built into place afterwards. It was true that the cost of centering was less, but where the same design was repeated through a number of panels the same centering could be used several times over. Supervision, to be effective, should be as thorough for the one method as for the other; and, in general, the proportion of defective members in a job was so small as to render convenience in replacing them of comparatively small account, especially when considered as a factor in influencing a contractor's tender. He believed that reinforced-concrete structures should be monolithic wherever possible, and the concrete should be laid as continuously as circumstances would permit. This would give a stronger and stiffer structure than the method of making separate units and assembling them afterwards. He would like to ask whether any difficulty had been experienced in making tight joints under water between the consecutive groups of hydraulic pipes; also whether Mr. Cleaver had yet had any experience of a vessel colliding with the fender-chains, and if so, what the behaviour of the chains had been under such circumstances. The introduction of coal-conveyers into South Wales would be watched with interest. In the earlier days of the conveyer it was not always as successful as was anticipated, but improvements in belts and in details of construction had greatly altered this. As the character of the coal in South Wales was such as to render the use of conveyers more desirable there than on the North-East Coast where they were now being increasingly employed, it seemed likely that the numbers in South Wales would increase—perhaps even to the displacement of the present tips, although the various anti-breakage arrangements that had been devised had done a great deal to prevent damage to the coal in handling, and thus to render the working of the tips satisfactory.

Mr. Hall Blyth, junior, in reply, stated that the concrete rib Mr. Blyth. under the centre-line of the floor of the entrance-gates, for which the rock had been excavated, had been put in mainly to tie the concrete floor to the rock. Greenheart had been used for the jetties, after experiments had been made with it and with other kinds of timber, owing to its greater durability and freedom from attack by the teredo. There was no possibility of ships being damaged by

Mr. Blyth. bumping against the steel-channel braces of the jetties, as before that could happen, the fenders and half the thickness of the front piles of the jetties would have to be destroyed. Mr. Ridley's remarks regarding the Mannesmann pipes sufficed to show the superiority of these pipes over cast iron, even at the higher cost. All the cement used had had to comply with the British Standard specification. Mixing 2 cubic yards of absolutely clean selected stone, 1 cubic yard of sand, and $\frac{1}{2}$ cubic yard of cement, all carefully measured, gave a block of concrete containing 2·33 cubic yards. In practice, where a certain amount of sand must be mixed with the stone, the general result, using a 1 : 2 : 4 mixture, was found to be that the increase in bulk was represented by the volume of the cement, and all the sand was taken up in filling the interstices of the stones. He thought Mr. Carey had misunderstood the procedure in building the sea-wall. The main bag-work foundation of the wall was built on the solid rock, which was cleared for that purpose, and afterwards, where the sand had collected some way up the bags, two rows of toe bags were laid on the outside. As the sand was washed away by storms, these sank gradually to the rock, and were then in such a position as to prevent any scour from taking place should any of the rock on which the main wall was founded prove to be soft. He did not think that even had Mr. Cay's suggestion of raising the parapet of the sea-wall 10 feet been carried out, the damage done in January, 1912, would have been avoided. During January, 1913, a storm, fully as severe as that of January, 1912, occurred at Methil, and the 50-ton blocks which had been placed during the summer all along this part of the wall, so broke up the seas that in comparison with the previous year very little water came over the parapet; and what did come over found its way to the dock without doing the slightest damage, owing to the concrete covering on the quay. Mr. Olive appeared to be surprised that the new dock had cost more per lineal foot of quay-space than either dock No. 1 or dock No. 2. Considering the greater depth of the dock and the much superior equipment, however, this could hardly be wondered at. The steel channel-bars of the jetties were all above low-water mark, and therefore could easily be repainted or tarred from time to time. Had they been below low water, wrought iron or greenheart would, no doubt, have been used. Mr. Olive only needed to visit the district to be convinced of the futility of his suggestion as to canalizing the rivers Leven and Ore. In the original design the sea-wall above the bag-work was to be of mass concrete. When the contractors started the work, knowing the difficulties of shuttering, they

Mr. Blyth. suggested using blocks instead of concrete in situ. This was agreed to, but, as stated in the Paper, the accurate setting and grouting of these blocks was both difficult and slow, and finally, after only a few weeks' work, block- and mass-work alternately was used, with one small exception, throughout the wall. When an attempt was made to build the whole wall in mass concrete it was found practically impossible to keep the shuttering in position, but with block-work and mass-work alternating, the shuttering was in comparatively short lengths, and no difficulty was found in securing it, even in rough weather.

Mr. Cleaver. Mr. CLEAVER, in reply, stated that Mr. Clark's suggestion that the river should have been divided from the channel in the first place by a pier approximately in the position of the existing slag wall, had been discussed on more than one occasion, but although it would undoubtedly reduce silting, it would have certain objections which would possibly more than balance its advantages. In the first place, the extra cost of such river-diversion would be very heavy, and its almost sole advantage of reduced silting had been secured to a large extent by means of the dam at much less cost. On the other hand, in its present position the river might prove very useful later on below the dam for river-wharves, etc., and one of the most important advantages of its present position was the fact that it formed a very effective wave-trap and prevented a severe run against the gates in stormy weather, the run as a matter of course continuing up the river towards the weir and gradually dying out. The dredging-plant at Port Talbot owned by the Company consisted of a bucket dredger capable of dredging to a depth of 32 feet at about 500 cubic yards per hour, on which had been installed the sand-pumping plant mentioned in the Paper. This latter plant was composed of an ordinary centrifugal sand pump with a 20-inch suction and 20-inch delivery, direct-driven from a small vertical tandem steam-engine. The original estimated output at full speed was 600 tons per hour, assuming 15 per cent. of solid matter, in the discharge, but he considered that in practice the maximum output would not be more than 400 to 500 tons per hour. The bucket dredger was of rather unusual design, with a very high ladder-tower, being originally arranged to discharge over a stern shoot in addition to the port and starboard shoots. This made the dredger top-heavy, and it was therefore not possible to work the plant in heavy swells. He believed that the nozzle, as designed by him, could be employed in swells of 5 to 6 feet, even without the intermediate joint in the pipe, if fitted to a properly-designed and self-contained sand-pump hopper dredger; but at

Mr. Cleaver. Port Talbot it had not been possible to work in a swell of more than 3 feet to 4 feet as a maximum. Mr. Carey was right in assuming that only sand and silt had been dealt with by pumping in the channel at Port Talbot. The 18-inch pumping-plant mentioned by Mr. Carey must have been very inefficient. Mr. Cleaver had recently carried out under contract dredging and reclamation inside Port Talbot docks, where the spoil consisted of clay, peat, and gravel, containing a very large percentage of boulders, some of them measuring nearly 12 inches cube: about 150,000 cubic yards of this spoil had been pumped ashore by a 22-inch pump, and carried to a point 500 yards from the pump, most of it having been discharged at the rate of about 200 cubic yards per hour. The actual dredging was done by a bucket dredger, depositing into ordinary dumb barges, which were afterwards towed to the pump mentioned above. With regard to the middle discharge-pipes of the pontoons referred to by Mr. Roberts, assuming that the dredger commenced pumping at the outer sections with the discharge outlet attached to the seaward end of the old breakwater, the dredger would pump for a short time in the position shown on the plan, and over the full width of the channel at that radius. Immediately this portion was completed, one pontoon would be disconnected and moored alongside, the dredger outlet being connected with the next pontoon, and the process would be repeated at a shorter radius, and so on until four or five pontoons had been disconnected. By that time there was not sufficient flexibility in the remaining pontoons to permit of proper manipulation, and the strain on the connections was thereby very great, so that it was found impossible to dredge the area contiguous and opposite to each outlet-pipe. In order to do this particular portion opposite the seaward and landward outlets, the end of the pontoons had to be connected with the middle outlet, so as to get sufficient length of pontoons to afford the necessary flexibility. With regard to Mr. Walker's remarks as to sluicing in the channel, during the sluicing-period at low water of spring-tides all the craft were aground, so that the question of draught did not enter into the matter. There was practically no flow underneath under the circumstances, all the water having to flow past the ends of the barges, tugs, etc. Mr. Leitch had evidently not quite realized the conditions under which the dam in the River Avon had been constructed, and its position in relation to other structures. The sill of the main intake-weir, about ½ mile farther up the river than the dam, was about 3 feet above H.W.O.S.T., or 38 feet above the bottom of the entrance-channel. Although the bed of the river below the weir was originally much above the level

Mr. Cleaver. of the channel-bottom, the drop of 38 feet in less than $\frac{3}{4}$ mile caused the gradient to increase week by week, and in flood-time a great deal of the banks was scoured away, the scour increasing as the gradient increased. As the river-bed became deeper, it also became narrower, and instead of reducing the area for flood-discharge, as Mr. Leitch assumed, the dam increased it, as the lip of the dam was much wider than the river-bed itself would have been. The material deposited on the up-stream side, about 150 feet wide, and averaging about 9 feet in depth and about $\frac{1}{4}$ mile long, was a very considerable amount saved from going into the channel, leaving out entirely the other more important considerations which, as stated in the Paper, had led to the construction of the dam. The primary result of the silting-up had been not simply the retention of that amount of material, but the restoration of the river-bed to its original level or even higher, and the velocity of the flood-water between this dam and the upper weir had been in consequence so much reduced as to eliminate entirely the scour which had previously given so much trouble. Mr. Leitch was right in the assumption that there were no riparian owners in this case. The sill or lip of the dam was about 13 feet below high water of spring-tides, that was, only 16 feet above low water of spring-tides, and about 16 feet below the sill of the main intake weir, so that its construction did not materially affect the volume of tidal water. With reference to Mr. McClean's remarks, there was no bar outside Port Talbot entrance-channel, and the mouth of the channel could not in any case be affected by the low dam, the distance being too great. Mr. Olive's suggestion that the dam might be the cause of floods not previously experienced for 30 years could only have been made in complete ignorance of the district. One of the three or four floods alluded to in the Paper (namely, that of September, 1909) was of such a character that a mere tributary of the River Avon, at a distance of 12 miles from Port Talbot, demolished nearly a dozen cottages, and carried away bodily a lattice-girder main-road bridge and abutments; and the Avon itself. at a place 3 miles from Port Talbot, scoured out a high embankment, and overturned a Port Talbot Railway retaining-wall 180 feet long by 17 feet high and 8 feet thick. When the flood reached Port Talbot it overflowed the banks and flooded the streets and houses of the lower portion of the town of Aberavon to a depth of about 4 feet, causing immense damage. The levels given above would show that even after the silting-up behind the dam to a depth of 9 feet, the subsequent reclaimed and almost level bed of the river between that and the main weir would still be at least 16 feet below the weir-sill, Mr. Cleaver. over which the floods would have to come first, so that under no possible circumstance could the construction of the dam affect any flooding of the river adversely or otherwise. The banks on both sides of the dam were about 20 feet above the lip of the dam. To fix gates or sluices in the dam, as suggested by Mr. Olive, would have resulted in doing exactly what it was desired to avoid. The conditions in the cases of damage mentioned by Mr. Olive were quite different from those met with at Port Talbot. Mr. Olive's suggestions for a catchment-area below the weir and for disposing of the silted material from time to time were practical and sensible; but they would not apply at Port Talbot for the following reasons: Sluing the railway-lines over would have meant interfering with an important main line and some costly property; ample material for reclamation could be procured at Port Talbot for less than half the cost of carting material from the river-bed; and the dam on this proposed site would not have prevented in the slightest degree the scouring away of the foundations of the main road-bridge from Victoria Road, for the restoration and saving of which the dam was primarily intended. As to the strength of the bow or triangle in the mooring, when the mooring was constructed the iron bow was only allowed to project above the concrete just sufficient for a reasonable play of the first link, so that if the pull was transverse, instead of as shown in Fig. 7, Plate 3, the extra stress was trifling. The minimum diameter of the iron used had been 4 inches, and he now specified nothing less than 4½ inches. Considering that the cable used was only 2½ inches in diameter, and that it was the largest yet adopted under similar circumstances, a 4½-inch triangle with a 4-inch link inserted in it—all in practically fresh water—was not likely to require renewal during this generation. The results stated by Mr. Mitchell in regard to driving mooring-screws into pure sand by water-jet at Madras were remarkable, although the conditions in sand were quite different from those obtaining in gravel and clay. The trouble with the bollards in each case had been that the bollards and concrete blocks had a tendency to overturn bodily, with the result that, even if the bollard did not give way entirely, the ropes slipped off when ships were moored very near to the bollard, owing to the almost vertical pull in the case of ropes from light vessels of large freeboard. If tee-headed bollards had been inserted in the blocks, instead of pear-shaped, the risk of this would have been obviated. He was surprised to hear from Mr. Walker that bollards were in existence which tapered inwards from ground to base. It would be simply courting disaster under certain circumstances to erect such a cast-iron bollard in

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concrete, no matter how large the block. With regard to reinforced concrete, he agreed with Mr. Walker that supervision should be just as thorough whatever method of construction was adopted, but Mr. Walker appeared to have overlooked the fact that in complicated structures it was impossible to exercise the same careful supervision when the work was done entirely in situ, and a mass of work was hidden by timbering, shuttering, etc. Under such circumstances a great deal had to be taken on trust. On the other hand, if suitable members were made on the floor beforehand, the portions eventually boxed in and rendered inaccessible were reduced to the minimum. In constructing in units instead of in situ, a great deal of discretion must be exercised, and the question whether the design admitted of such arrangement must not be overlooked. Mr. Clark's point, as to the effect of the method of constructing a reinforced-concrete floor on the distribution of the stresses in it, was well worth consideration, as it was just such a contingency that was likely to be, and usually was, overlooked. If, however, the fact was borne in mind, and care was taken that no dead load was put on the floor until the concrete was matured, there was no objection to such a method of construction, as of course the weight of the wet concrete floor and of the shuttering would not stress the upper fibres of the beam to anything like the total load for which the beam and floor as a tee-beam would be calculated. This assumed also that the top face of the beam was left very rough, so as to key with the decking, as it would be if beam and deck were made in situ. He did not suggest that every individual beam, or other member of a reinforced-concrete structure, should be made separately and afterwards built into the work. That was often impracticable or undesirable; but his experience was that with careful study of the details of reinforcement the work would often be simplified and improved by making certain members beforehand. As to the comparative cost of reinforced-concrete structures, he could only say that the first cost of the various jobs at Port Talbot was no more than if they had been constructed of timber, and the maintenance-costs had been practically nothing, although it was rather early to consider maintenance after only 6 or 7 years. As to the submerged hydraulic mains, the bottom of the trench consisted of very hard boulders, gravel and sand, so that settlement was never likely to take place. The trench was afterwards filled with sand, as being the most economical material to use and the simplest to deposit, and up to the present it appeared to be quite effective. As Mr. Roberts rightly assumed, the mains were made up of cast-iron pipes 9 feet long. No great difficulty was experienced in making the

Mr. Cleaver. joints under water; it was simply a matter of employing a really competent and trustworthy diver. The remarkable stability of the 4½-inch panels of the concrete-block walls of the new power-station was due, in the Author's opinion, to the great reduction in the number of joints, each block being about 2 feet 6 inches long by 9 inches deep on the face, and to the fact that the hollow spaces in the blocks formed a very efficient frog if the joints were properly flushed. With reference to condensation on the inside of concrete-block walls, etc., he had found that efficient ventilation was about the best preventive under most conditions. With regard to water percolating through brick walls of ordinary thickness when exposed to the sea, he had at first experienced the same difficulty with the 4½-inch concrete-block walling; in fact, during very severe weather, the inside walls of the most exposed portions were streaming. Instead, however, of the trouble being constant or becoming worse, as in the case of brick walls, the concrete-block walls improved as the concrete matured, the pores appearing to "take up" or close, and at the present time the trouble had practically ceased, comparatively little moisture having come through even during the severe weather of the present winter. This referred to walling which had not been treated in any way, being built with blocks just as they left the machine. In a later extension of the new power-station, however, the construction of the blocks had been modified in the following manner, with the result that no dampness had ever appeared inside that building at the commencement or since, notwithstanding that, in this case also, the walls were only 4½ inches thick. When the blocks were removed from the machine, instead of stacking them immediately to dry, as previously done, the front face of each block was trowelled over with a thin coat of neat cement grout worked into the block when quite green. The grout was kept near the machine, so that it took only a few minutes to treat each block, the extra cost being therefore small. The result was not only satisfactory so far as waterproofing was concerned, but the appearance of the face of the block was greatly improved. No hair cracks had since appeared on the face owing to the grout being worked into the face of the block while in a green or moist condition. In the latter case great care had been taken that the cement-compo joints were properly made, as he believed that the dampness found in the original building was due partly to defective joints, and not entirely to the porosity of the blocks. He could not at the moment give detailed instances of ships colliding with lock-gates, but two cases occurred at Barry dock about 7 years ago, when the fender-chains were undoubtedly of service in reducing the way on steamers and thereby diminishing the ultimate damage; one serious case of collision with gates occurred a few years ago on the Manchester Ship-Canal, and another, he believed, on the Sault Ste. Marie Canal; and he believed there had been instances at Liverpool, Swansea, and elsewhere. Fortunately, they were very rare, and there had been no case of a vessel colliding with the fender-chains or gates at Port Talbot. He was not at all anxious to put the efficiency of the fender-chain there to such a test, and would much prefer to see the chain rust away for want of use—other than hanging across the locks. But the results were so serious when collisions did occur, that the provision of any reasonably effectual preventive was only a wise precaution. In one of the cases at Barry, when the S.S. "Buckingham," of about 3,000 tons, ran into the lock-gates at a speed of about 3 to 4 knots per hour, at the angle at which the vessel was moving she would, if there had been no fender-chains, have struck one of the gates near the centre, and would have carried away the connecting-rods, etc., and possibly ruined the gate. The fender-chain, however, was up and it not only reduced the actual force of the collision, but also deflected the course of the steamer so that she struck the mitre-post, and the damage done was much less than it might have been. His views regarding aprons in front of sluices appeared to have been somewhat misunderstood. He did not for a moment contend that undermining of the apron would be lessened by its extension, as it was almost impossible to prevent this where water flowed over the end of any hard substance on to material of less density. What he meant was that the inevitable scour at the end of a short apron undermined and damaged the sheet-piling, etc., of the adjacent timber pier-heads, which damage would not take place if the apron were extended to a reasonable distance. Cases of such long jetties as those at Methil were very rare. What he had had in mind were jetties 100 to 150 feet long, as generally adopted. In every such instance the direction of the jetties bell-mouthed towards the channel, and the width between the heads beyond a distance of about 100 feet from the gates would be such that no serious damage would occur from scour. It was undesirable to limit the length of the apron to about 50 feet, and thereby injure the foundations of the jetty beyond. Scour would still take place in front of the apron, but it would be less in extent in proportion as the width of the apron was increased. Mr. Roberts's method of piling, etc., in front of an old apron would undoubtedly prove quite effective. With regard to the iron drain-pipes, the water in the adjacent docks Mr. Cleaver.

Mr. Cleaver. was always at a uniform level, and although the pipes were laid in running sand when the trenches were open, owing to the bottom of the trenches being below dock water-level, yet immediately the trenches were filled again the sand would become dead, and the pipes would lay perfectly solid without any support at the joints. The collapse of the original earthenware pipes had been due not to movement on their beds but to the pressure of cover from above. To Mr. Olive's objections to the viaduct repairs he would reply: (1) Where the immediate release of surface-water was imperative, as in this case, two short outlets were obviously better than one long one from the point of view of avoiding accidental stoppage, even if one pipe would be sufficient to carry the water away—which he did not admit. The viaduct was on a gradient, and some of the water from the railway might pass over the viaduct (in spite of cross drainage to intercept it); hence the necessity of making sure that the outlets were ample. (2) A drain-pipe through the soffit would pour on to a public main road, and would not be less conspicuous than in the pilaster. (3) If the concrete and asphalting, etc., were properly carried out, as it should be in such an important structure as a high viaduct, the water could get clear away, and there would be no water to cause capillary attraction in spandrel-walls and pilasters, which was really proof of defective drainage. (4) and (5) The inspection-chambers suggested by Mr. Olive would form a serious obstruction to the flow of the water, and would also render it much more difficult to lay a neat and effective lining of asphalt, even had there been room to insert them. The filling of large clean boulders could easily be removed should it be found necessary at any time to inspect the inlets of the pipes. Slinging a stage occasionally over the parapet was a simple matter, and it would be much easier to work a small rod up the pipe from outside than to work one down the pipe from inside a necessarily small inspection-chamber.