The Author. of progress was good. A good deal had been said about the suitability of the dock to accommodate larger ships. Mr. Scott was right in supposing that it was quite possible for the "Imperator" to enter the dock, but his suggestion that she would lose half a day by doing so was misleading. The "Imperator" had hitherto picked up her passengers by tender at Cowes, which was only ½ hour distant from Southampton. The ships which entered the docks generally needed coal, water, or cargo, as well as passengers. The Author agreed with Mr. Meik that it would be useful if some shipowner could be induced to read a paper on the dimensions that were likely to be given to ships within the next few years. Meanwhile it might fairly be claimed that the White Star dock would meet all requirements for many years. It should be borne in mind that the increase in the size of ships did not always cause a dock to become obsolete. The old outer dock at Southampton, which was built in 1840, was still as busy as ever. Moreover, the London and South Western Railway Company had purchased 400 acres of land on the east bank of Southampton Water, where it would be possible to make docks to accommodate any ship that was likely to be built. It would be agreed that their enterprise in this matter was worthy of all praise.

Correspondence.

Mr. Best. Mr. A. T. Best asked what weight per cubic foot had been assumed for the concrete in the calculations in Appendix I for the wall (portion A); whether the assumption had been checked by weighing a sample of the actual material of the wall; and what was the corresponding figure for the concrete in the Empress dock wall. Further, was an allowance made (other than the assumption of a rather small angle of repose for the filling) for any pressure of water at the back of and underneath the wall. The walls were, at least in some cases, founded on and backed with sand, which would probably be saturated up to half-tide level or thereabouts.

Mr. Binns. Mr. Asa Binns observed that it was a happy circumstance that, immediately following the President's Address on the constitution of port authorities as affecting the organization and development of ports, The Institution should have the opportunity of discussing a description of the new works at a port which had shown remarkably rapid development since the docks were acquired by the London and South Western Railway Company in 1892. The Mr. Binns. success of the port was no doubt due in a large measure to its geographical position, its deep-water approaches, small range of tide, and excellent shelter; but it was also due, perhaps in an equal degree, to the fostering care of the railway-company, which had been able to borrow money at a low rate of interest to carry out these large works, looking for but a modest return on the expenditure so far as dock- and harbour-dues were concerned, but hoping to recoup itself by increased traffic over the railway. The character of the trade specially catered for, including passenger-traffic and the finer classes of cargo and perishable produce, was shrewdly calculated to increase the revenue from the railway, especially between Southampton and London. Southampton was unique among important English ports in that the water-level in the docks was subject to a tidal range. This was possible owing to the comparatively restricted range of 13 feet, as compared with 21 feet at London, $27\frac{1}{2}$ feet at Liverpool, and 40 feet at Avonmouth, which had enabled the Author to take better advantage of the very restricted area at his disposal. If a lock entrance had been provided capable of taking the "Olympic," there would have been very little space left for the dock. Of course, it must not be assumed that dispensing with a lock enabled the dock accommodation to be provided at less cost. As the depth of the walls of the dock below coping-level was increased by nearly 13 feet owing to the open connection with the Channel, and as the cost of such walls increased rapidly with the depth, it was quite possible that the extra cost due to the greater depth was more than the saving due to the omission of the lock entrance. Whilst it was difficult, especially for one who was not familiar with the local circumstances, to criticize the design of the walls, he would have preferred to see a vertical face down to the toe, instead of the batter of 1 in 10 shown in Fig. 3, Plate 2. He fully agreed with the Author as to the projection of the toe and the cant on the base of the wall. The former, however, had considerable influence on the cost of the wall, because of the increased width of the trench, and the fact that trench-excavation was usually much more expensive than excavation of the dumpling. With regard to the difficulties encountered at the south end of berth No. 43, it would be interesting to know the reasons for flooding the dock-area before the last 100 feet of the wall-foundations had been got in. They must have been weighty, because the danger must have been fairly obvious. It was, of course, very difficult to locate the exact course of a serious "blow," such as that referred to, and the danger to the completed portion of the wall was apparent.

Mr. Binns. Some years ago he was associated with new works where a dry dock was being constructed, with an entrance from a wet dock. The water was kept out of the new works by a coffer-dam spanning the entrance, and returned against the walls of the wet dock. The works were well advanced when a very serious "blow" occurred, the water finding its way under the wet dock's walls from a point about 160 feet away from the new dry dock's entrance, and in the course of about 4 hours the whole of the works were flooded. In that case it was necessary to locate the course of the "blow" and to devise measures for completing the works in the dry, which was effected by carrying a single-skin dam parallel to the face of the wall about 100 feet beyond the source of the "blow," and returning the dam not only to the face of the wall, but completely through it, and for about 50 feet landward of the coping-line. He did not suggest, however, that any such method would have been successful at Southampton, for only those who were in intimate contact with the work could judge of the best means of meeting such an emergency. The incident merely showed that under suitable conditions a less heroic remedy than the adoption of caissons had been found practicable. The use of Oregon pine piles for the entrance jetty (berth No. 42) was somewhat unusual for permanent work, as this timber was not always very durable. Probably the Author would have preferred pitch-pine, which he had used for the struts and walings. Mr. Binns doubted the wisdom of creosoting pitch-pine. If the timber were as good as it ought to be, it contained natural oils in such quantity that it would not absorb any considerable amount of creosote. Perhaps the Author would state how many pounds of creosote were absorbed per cubic foot of pitch-pine. The section of the jetty (Fig. 10, Plate 2) was shown symmetrical. As the outer face would be subjected to severe usage when acting as a guide-stage, while the inner face was sheltered, it would perhaps have been better to rake the back piles so as to make them more effective in resisting a blow due to a ship striking heavily against the face of the jetty. Such an arrangement had been adopted with satisfactory results on a guide-jetty at the entrance to one of the docks in London. Further, in the case of the double piles in front of the jetty, instead of driving these separately, as indicated in the Figure, the two piles were bolted together before driving, and shod with sheeting-shoes back to back. This had proved successful, and the two piles bolted together in this way were, of course, stronger than two separate piles in resisting a lateral blow. It was a matter of some surprise to Mr. Binns that the jetty had been stiffened by buttresses of concrete built at intervals around the piles, as he considered that such a jetty should be as resilient as possible. The momentum of a modern ship striking heavily against such a structure could be absorbed satisfactorily only if the jetty as a whole "breathed" to the blow. A rigid monolithic structure invited trouble both to the ship and to the jetty. He had had experience at a lock entrance with a dolphin consisting of a monolith of mass concrete 21 feet in diameter, surmounted by a bonnet of heavy timberwork. Within 5 years the concrete monolith was fractured just below the bed of the river, and the dolphin became a source of danger and had to be replaced. It would be of interest to know the total cost of the works described by the Author. The time taken to carry out the contract apparently exceeded 5 years, which seemed to be longer than necessary. Mr. Binns.

Mr. G. Woulfe Brenan considered that the toe in front of the dock-walls and the downward slope of the base were much to be commended in dealing with such a foundation, and were in full accord with the theory of stability. The resultant weight of the whole was thus kept well within the base, and the danger of softened material being forced up below the base by back-pressure was greatly reduced. Similarly the yielding of the subsoil at the front was arrested by the projection of the toe. This form of construction had long been adopted in reinforced-concrete retaining-walls. At the same time, it seemed to him that the weight and bulk of the wall were superabundant for its purpose. Given the full dimensions shown in the base-block of concrete as necessary to meet this case, would not a lighter structure—such as separate front and rear concrete walls, built up from the foundation block of concrete, and connected by cross walls filled between with hearting of built rubble packed with clay and sand in the interstices—have been more economical, and better on the inferior foundation of sand and clay? This suggestion, of course, would apply only to the walls built in the dry, and would be especially applicable if the walls were reinforced, and therefore of considerably smaller cross section. With regard to the use of 8-to-1 concrete for the interior of the dry-built walls, portion A, it had long been established in practice that so weak a mixture was unsuitable for marine work. No mixing of concrete materials was so perfect that no loss of cement occurred. Thus, what might have been intended and adjusted to be an 8-to-1 mixture would probably turn out to be no richer in cement than 10 to 1, and that mixture would certainly be pervious to water. Moreover, this was more likely to occur with a gravel-made concrete than with one made from broken granite or trap rock. In his experience no concrete was so good as that made Mr. Brenan.

Mr. Brenan. of an aggregate of crushed granite for sand, mixed with 2-inch cubes of broken stone. It also admitted of the use of a full proportion of "plum" stones, with great advantage both as to strength and cost. Large quantities of crushed-granite sand and chips were now prepared in the Highland granite-quarries for making concrete, and sold at 6*s*. per ton. The use of reinforced-concrete caissons for the foundations of the wall-piers was a satisfactory way of overcoming the difficulties of the foundation, but he considered that these also were unnecessarily heavy, and that they were more difficult to control and sink, with a thickness of 18 inches, which was unusual in reinforced-concrete work. With regard to the action of the tidal currents upon mass concrete laid under water, it did not appear from the Paper that protective canvas lining had been used internally on the outside shuttering of the wall. If this old and safe practice was not observed, inferior patches in the concrete were a natural consequence. He had noticed that within recent years this lining had been abandoned in favour of tongued and planed boarding, but the result was bad; horizontal strips of sand-washed or scoured cement, yards in length and up to 18 inches thick, were found on the surface, and these could not be permanently repaired, although they might be "patched up." In a large mass-concrete wall, of 5-to-1 mixture above or below water, protected by stretched canvas, there should be no such seams of washed-out cement. The *laitance* described by the Author was due in this case to defective deposition of the concrete weak in cement and to the scour of the currents. The lime was washed out of the cement and the deposit was merely the inert and insoluble clay, freed from chemical combination. The binding of the cement in dry lumps when dropped from the hoppers was due to insufficiency or over-absorption of water in the original mixture. Two or three minutes' travel of the concrete from the mixing-house should not cause it to "lump" if properly wet, in fact, it would only cause better admixture; but to remix it after arrival at the site of deposition was, in his opinion, to reduce the strength by 50 per cent. It would have been better to tamp it as it was being laid.

Mr Buchanan. Mr. G. C. Buchanan considered that the value of the Paper was reduced almost to nothing by the absence of any statement of the cost of the works. It should surely have been possible to say what the dock had cost complete and in working order, and also to give some details of cost; whereas the only information of the kind that was given was the lump sum cost per lineal foot of three types of quay-wall. With regard to the cranes provided, lifting 5 tons and

35 cwt. or 2 tons respectively, his experience at Rangoon of double-powered cranes was that they were a mistake, the number of lifts above 35 cwt. and less than 5 tons being so small that the higher power was seldom used. Perhaps, however, the conditions at Southampton were out of the ordinary. With reference to the bottom of the dock, and the advantage claimed that the mud deposited in the docks was of such a soft clayey nature that no damage was done to vessels if by chance they should touch bottom, whilst concurring in the statement, he would like to hear what shipowners had to say on this point, as, judging from his own personal experience at various ports, shipowners protested vehemently if their vessels touched the bottom, whatever the nature of the ground. Mr. Buchanan.

Mr. F. G. Carron inquired whether any attempt had been made to bed the blocks forming the faces of the walls which were built under water on mortar. The section (Fig. 8, Plate 2) indicated vertical joggles. Were these of concrete in bags, and were they found satisfactory in preventing the concrete hearting from being disturbed while setting? It would be seen from the summary of the considerations governing the design of the dock-walls, given in Appendix I, that the material at the back of the walls was not waterlogged, that was to say, the wall was not under hydrostatic pressure at the back, as it was in front. He considered that this was a point which could not be conceded in the case of several quay- and dock-walls with which he was acquainted. At the port of Pará, for example, the tide rose and fell in the filling behind the walls, and so resistance due to water-pressure could not be taken as a supporting force in calculating their stability. Surely, however, the force of gravity was the main consideration. This force, compounded with the lateral pressures behind the wall, brought the resultant thrust on the foundations, the force of gravity being the weight of the wall—partly in water, of course, in the case of walls with waterlogged backing. At Pará reinforced-concrete beams 32 feet by 3 feet 4 inches by 3 feet 4 inches were used to form the base of a wall which had a total height of 51 feet 6 inches. These beams were laid on foundation rubble prepared by divers, and they projected as a toe 5 feet in front of the ordinary block-work toe of the wall. They had served very well to distribute the pressure at the toe, and to act as cross ties at the base of the wall, which was of block work laid in sloping slices. Mr. Carron.

Mr. W. Dyce Cay agreed with the Author that it would have been better to build the walls for portion B entirely of blocks, instead of a block face and a hearting of concrete, deposited liquid in the water. He had found that, both in bridge-cylinders and in sea- Mr. Cay.

Mr. Cay. work, when liquid concrete was deposited in water by skips, layers of *laitance*, resembling cement-slurry before it was passed through the kiln, were formed. In the case of sea-works, however, good work had been secured by making the depositing skips large, so that the surface in contact with the water was small in proportion to the mass of each discharge, and also by making the concrete very rich in cement. It could be proved by a simple laboratory experiment that, when a soft paste of cement and standard sand was put at once on mixing into water in a shallow tank, and kept covered with water, it would not set hard unless the sand was in small ratio to the cement, say, equal or less in quantity, making concrete of 2½ or 3 to 1. It was mentioned by the Author that two blocks, cut from the heart of the wall built under water, showed a crushing-strength of 2,460 lbs. per square inch; it would be interesting to know whether this experiment was made immediately after the block was taken from the water, or if it had had some time in which to dry and set. While agreeing that blocks would have been best, Mr. Cay considered that building with concrete bags would have been much cheaper, and would have made as good work as the composite system which had been adopted. He had built several works on the bag system; but the one most resembling this work, though of much smaller size, was the Lerwick pier, of which a cross section was given in the Proceedings.[1] There the bottom was of muddy sand about 16 feet deep, which had to be dredged away before the rock foundation was reached. At the 60-foot wall across the end the depth was 28 feet below low water of spring-tides. A wharf he had constructed at Aberdeen[2] stood on sand and clay beds, similar to those being discussed, though not so fluid. The foundation was dredged with a bucket dredger, and it was piled and sheet-piled, using strong dollies with cast-iron jaws; 12-ton bags were set on the piles, with shingle placed beneath them and at the back of the wall. Although both these works were built upwards of 30 years ago, they still remained without defect. With regard to the difficulties encountered in sinking—"blows," leakage, and other mishaps—it was difficult to generalize, especially when considering a work of the size of this dock. He had had similar trouble, though on a smaller scale, in restoring the dock-entrance at Arbroath.[3] He put into the foundation a thick bed of clay puddle, through which piles and sheeting were driven,

[1] Minutes of Proceedings Inst. C.E., vol. clxxi, p. 80.
[2] *Ibid.*, vol. lxxxvii, p. 199.
[3] *Ibid.*, vol. clxv, p. 211.

and a bed of mass concrete resting on a jute carpet was placed on the top of the piles and clay, before he ventured to pump the water out again. Mr. Cay.

Mr. Colson. Mr. CHARLES COLSON observed that one of the most difficult problems in connection with dock- and harbour-works was the design and construction of wharf-walls. The physical conditions differed as a rule, materially if not entirely, from those appertaining to an ordinary retaining-wall. After completion, the conditions to which a wharf-wall was subjected were often onerous, and excessive surcharging was not uncommon; in fact, there was no feature or detail in connection with dock- and harbour-works which called for such a diversity of practice. Cases did occur in which the conditions admitted of the adoption of a similar design or method of construction; but this was not the rule. Again, personal bias had to be reckoned with. From this point of view, therefore, the most valuable part of the Paper was that dealing with the design, the conditions governing the different sections, the method of construction, and the rate of progress: and very valuable lessons were conveyed by these details. In this connection there were one or two assumptions whose value was somewhat overrated. In view of the conditions in regard to the foundation strata, the additional resistance, due to the sloping base, against forward movement was very problematical. He considered that, should there be any such tendency, the material in front would move horizontally with the wall. Personally, he would have more confidence in the greater dead weight of material which would have accrued in front had the base been horizontal from the extreme rear level, giving 5 feet extra depth, or even at a mean depth between front and back, as shown in Fig. 3, Plate 2, giving an extra depth of 2 feet 6 inches in front. In a foundation of absolute stability the conditions would be different; there the sloping base would have an appreciable value as affording additional resistance to forward movement. Its greatest value in any case lay in setting back the centre of gravity, and thus augmenting the turning-moment. Another consideration was the value to be placed on the ordinary backing material resting on the rear offsets, which, while it added somewhat to the dead weight of the wall for purposes of calculation, formed no integral part of the wall-section. In this case, again, the width of the offsets and the character of the material placed upon them would qualify the premises. On the whole, he considered that engineers would be well advised not to put too high a value on these two factors. The Author's remarks on depositing concrete under water were very valuable

Mr. Colson. and the facts recorded by him agreed closely with Mr. Colson's own experiences. Not infrequently, however, conditions obtained which justified and demanded the adoption of this method of depositing concrete, and he had often used it in such circumstances. On the general question of the numerous adverse factors attending the deposition of concrete under water, the most important were the loss of cement washed out on its passage through the water, and the screening which followed the discharge of the mass from the skip, when the larger stones rolled down the sides of the heap and formed at the base a deposit of coarse material with a deficiency of finer material and cement. This was a common result even when concrete was deposited in the dry from a skip or shoot; but there the defect could be rectified by remixing and trimming into place, an operation which could be done only very ineffectively under water. The surface of the under-water deposit became covered with the fine silty material referred to by the Author, composed of cement washed out of the concrete, dirt, and all kinds of impurities introduced in the ordinary course of operations. The removal of this silty deposit was an extremely difficult operation, and the result was far from satisfactory, as the stirred-up silt tended to lower the quality of the concrete generally, and any left on the surface prevented efficient adhesion of the following deposit. In the case of concrete work executed in the dry, the importance of perfect adhesion between successive deposits was so fully recognized that it was especially stipulated in specifications that all set surfaces of concrete should be thoroughly cleaned and prepared before further concrete was deposited on them. Again, the condition of the face to be exposed to the water after the removal of the casing was a matter of great importance. When concrete was deposited in the dry great care was required in manipulating that next the casing, to ensure a satisfactory surface. When the concrete was deposited under water the condition of the face on the removal of the casing was very problematical. He recalled, as a case in point, a breakwater commenced some years ago. It was situated in an exposed position, subject to strong winds and currents and a tidal range of 15 to 20 feet. The method of construction adopted was to deposit green concrete through the water within strong timber casings. The appearance of that structure at the present time was lamentable. However carefully, in fact, the timbering or other casing might be carried out, and however adequate as a whole, or perfect in detail, might be the appliances for passing unset or green concrete through, and depositing it under water, there must always be an element of uncertainty as to its quality, and consequently as to its true value as a structural expedient. The conditions to be met and the object to be attained were, of course, the chief factors determining a decision. Mr. Colson.

Mr. H. P. Ramsay Copeland observed that apparently no great reliance was placed upon the information derived from trial borings as to the sub-strata, and presumably the Author and the contractors preferred to rely upon experience of similar work in the vicinity or of other dock-works with which the names of the contractors were associated. Before commencing work in connection with the docks, attention was naturally directed towards rendering water-tight the enclosing bank, which had been built some time previously, and apparently with not too much care, having regard to the use to which it was intended to be put. It would be seen that in spite of the preventive measures adopted, a million gallons of water found its way into the workings and had to be pumped out daily. The cross section of the ground on which this bank was built showed that the sub-strata were peat, gravel, and sand, and it was not difficult to understand that the driving of sheet piling through these strata must have disturbed whatever equilibrium was in them. Further, as it was practically impossible to drive piling accurately and without deviation from the vertical, it was not surprising that these means were found ineffective. He doubted whether, if this bank had been considered as a defective reservoir embankment, many hydraulic engineers would have advised similar treatment. In the case of inrushes of water, dock-engineers relied upon sheet piling and powerful pumps; but there were several indications in the Paper that those means were not always reliable. For an outrush of water a hydraulic engineer relied upon clay puddle, and Mr. Copeland suggested that if a trench had been dug about 4 feet above high-water level and carried down to the sand, which apparently contained a certain amount of clay, and, on a footing of 2 feet of gravel concrete, clay puddle had been brought up to the surface, the enclosing bank would have been rendered as water-tight as was humanly possible. He suggested that the excavation of 30 feet of earth over the dock-area was the cause of nearly all the difficulties met with in the trenches, owing to the fact that the equilibrium of the highly sensitive substratum was destroyed by removing this weight from the front of the trench, and leaving it at the back. This conclusion was borne out by the Author's description of the sinking of 100-foot trenches in the solid from the original ground-surface to a depth of 73 feet without difficulty, because the equilibrium of the underlying strata had not been disturbed. This argument was also substantiated by the experience Mr. Copeland.

Mr. Copeland. of Mr. W. Duff Bruce in the case of the Kidderpur Docks,[1] where trouble occurred similar to that experienced in the White Star dock trenches.[2] Mr. Copeland therefore suggested that if, say, 50-foot lengths of trench, with intervals of 50 feet between, had been excavated in the solid, none of these difficulties would have been met with; and as the progress on this wall was at the rate of 70 feet per month, it would have been possible to construct the whole of the quay-wall north of the bank in 12 months. The excavation of the dock could have been commenced simultaneously with the trenches, and by beginning in the centre and working towards the walls there need have been no unnecessary delay, and the balance left in front of the wall could have been dredged out when the water was let in, assuming, of course, that the excavation had been finished before the walls. Further, the heavy additional expense entailed by the erection of the extra staging and shuttering the concrete wall above ground, would have been avoided. On p. 50 it was stated that the enclosing bank was cut, and the water was allowed to enter, before the completion of the walls. This led to the heavy expense occasioned by the use of concrete caissons and divers. Mr. Copeland was unable even to imagine why that was done. The sheet piling was regarded as infallible, and in this case, by returning it against the finished concrete wall, a joint was made which it was next to impossible to make watertight, unless the timbers were bolted through the wall—and even so there would be no guarantee, since timber would not bond with concrete. With regard to the patches and seams of rough and poor concrete, and to the formation of dry lumps during travel, surely the causes should have been discovered at the mixers by the concrete inspectors, without putting the contractors to the extra expense of remixing it on the site. It was difficult to realize how concrete with a proper proportion of water could form hard lumps after a journey of 500 feet in a skip; in fact, he would have thought that the vibration would improve it. The underlying principle of the Improved Construction Company's process for making concrete pipes was the agitation, on a shaking-table, of a mould filled with concrete; and the 2-metre pipes made by this process for the Baku waterworks were excellent. When the moulds were stripped, the surfaces of the pipe inside and out were like a plastered wall, and these pipes were not reinforced. With regard to the use of Thames gravel unscreened, the question of saving

[1] Minutes of Proceedings Inst. C.E., vol. cxxi, p. 100.

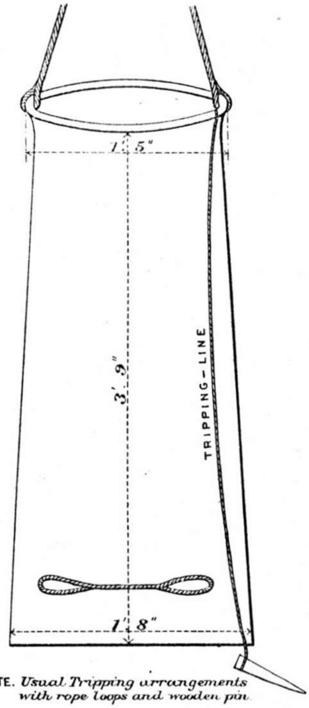
[2] *Ibid.*, pp. 98 and 99.

cement seemed to have been the guiding consideration, and it was also stated that the concrete was never stressed to its safe limit and was not required to be specially watertight. In the first place, he assumed that the specification determined in what proportions the different classes of concrete were to be mixed, and stipulated that the sand and metal should be gauged in cubical boxes, etc., and it was, therefore, difficult to understand why the question of using unscreened gravel should have been raised, as the same quantity of concrete had to be put into the wall, no matter of what it was composed. It was apparently a departure from the specification which was not anticipated when the contract drawings were made. With regard to the stanchness of the wall, there was great difference of opinion about the action of sea-water on concrete—as to whether the lime was replaced by magnesia—and in a work of this character it should be considered absolutely necessary to make the wall as homogeneous as possible. Whatever safe limit of stress the Author had in his mind was arrived at as the result of experiments on concrete made of the best materials and mixed in proportions of mathematical accuracy. Where he was relying on concrete made of Thames gravel, in which the proportions of sand and gravel in each gauging of concrete varied considerably, one being in excess of the other, the factor of safety might not exist, and the wall as constructed might be called upon to bear more than its safe limit. The high cost of the wall was stated to be due to the extraordinary difficulty of sinking through running sand, and the question arose whether more use might not be made of the experience gained by mining-engineers. It was always expected by them, when sinking deep shafts, that water-bearing strata would have to be pierced, and the most recently tested methods of carrying out such work were worthy of the consideration of dock-engineers. The two processes which had been proved to be reliable were Poetsch's freezing process and the grouting process. Little was known of either process in England, and there was no record of either having been tried there; but on the Continent they were in general use. Descriptions of both processes had been published in the Proceedings,[1] from which it would be seen that they had been used with complete success, and he suggested that if either had been used in the case of the White Star dock an immense saving would have been effected. Mr. Copeland.

[1] Minutes of Proceedings Inst. C.E., vol. cxxiii, p. 541; vol. clxiii, p. 419; vol. clxviii, p. 405.

Mr. Coulcher. Mr. G. E. B. Coulcher was especially interested in the work executed below water at berths Nos. 47, 48, and 49. The upward slope given to the header facing-blocks was ingenious and ensured the bed being properly filled with mass-concrete hearting. He preferred to use tripping bags for depositing concrete to form the foundations for block work, where such foundations were less than 15 inches in depth. It was usual to hang four or six bags—according to the width of the foundation—in a row on a beam, and if the divers were experienced men they were able to make a sound job, leaving a surface only slightly inferior to that of similar work carried out in the dry. He had found that usually, and especially in deep water, the concrete deposited from skips formed humps and hollows, and when these were screeded level the result was seldom satisfactory. A run of only 500 feet from the mixer on a more or less rough road was often sufficient to cause the concrete to stiffen in the skip, and to be discharged in lumps. Deep water was another cause tending to stiffen concrete, and sometimes in 35 or 40 feet of water it might be found that the concrete had come away from the skip in a single cube the size of the skip. When this occurred it should be left untouched and it would crumble gradually into an ordinary heap. To ensure the best results in deep water it appeared to be necessary to mix the concrete on the site as quickly as possible and to deposit it without any delay, as 5 minutes might be sufficient to cause the concrete to stiffen as described above. It was essential that only tripping bags of approved design should be used, otherwise the concrete might hang in them and have to be scraped out, to the detriment of the work. For some years he had used a bag designed by himself and shown in *Fig. 19* (p. 129). The special feature was the iron ring about 15 inches in diameter, instead of the usual straight bar, to which the canvas bag was sewn. After the bag had been filled, a flap of canvas was tucked over the top to preserve the concrete from wash while being lowered through the water to the divers. These bags ensured the discharge of the concrete with practically no loss of cement, and very reliable work could be done with them. With regard to the cement "settlings" mentioned by the Author, he believed that the greater part of these came from the concrete while it was actually being discharged from the skip; and that the amount of cement washed from the top of the skip, while it was being lowered through the water, was trivial and affected only the top ½ inch or so of properly-mixed concrete. Far more cement was washed out when the concrete was moved horizontally under water, and therefore the skip should be placed as nearly as possible over its final position before it was lowered into the water. From experiments he had made with "settlings" he had found that after several months, if not removed, they became very tough, and would resist the scouring action of sea-waves to a remarkable degree. Was there, in the older work at Southampton, sufficient evidence to show that it was safe to use lean concretes such as the 8-to-1 used in the recently-constructed quay-walls, in positions similarly exposed to the action of sea-water of considerable depth? His own experience suggested that, unless such concrete had been rendered impervious by the adoption of a facing of rich concrete, the sea-water might sooner or later set up disintegration affecting more or less the whole structure. At Buckie, where he was engaged in superintending the construction of harbour-extensions, a good example of defective concrete work might be seen in the old harbour, constructed about 35 years ago. The walls had cracked and bulged and in many places the face of the concrete had fallen completely away. He had recently had to repair a portion of the old north pier whose face had fallen into the harbour. This particular place was on the harbour side of the pier near the harbour-entrance and at a part not subjected to heavy wave-action. The damage extended from cope-level to about 11 feet below it, that was, from about half-tide level up to 5 feet above H.W.O.S.T., and the concrete appeared to be thoroughly decomposed and disintegrated. He had sent samples of this concrete to Mr. D. B. Butler, Assoc. M. Inst. C.E., for analysis and report, and with results of which the following was a short summary:— Mr. Coulcher.

Fig. 19.



NOTE. *Usual Tripping arrangements with rope loops and wooden pin*

Sample No. 1. Taken from the original face of the wall.

" *No. 2.* Taken from 3 to 4 feet inside face of wall.

Both samples were taken from the work at about high-water level of ordinary spring-tides.

Mr. Coulcher. *No. 1* was a hard concrete, rather dark in colour on the face, the interior being of a lighter colour to a depth of about 1 inch from the face, where the colour assumed a much bluer tint, suggesting some permeation of sea-water to this depth, the darker portion being apparently unattacked.

No. 2 consisted of a mass of aggregate covered with white incrustation and much white powdery material, and appeared to be a thoroughly decomposed and disintegrated concrete, leaving nothing but aggregate and a small portion of decomposed cement. Mr. Butler found by analysis that the fine matrix and cement contained the following percentages of lime, magnesia, and sulphuric anhydride :—

	Sample No. 1. Hard Concrete. Per Cent.	Sample No. 2. Disintegrated Concrete. Per Cent.
Lime	32·67	18·80
Magnesia	2·74	12·82
Sulphuric Anhydride . .	1·69	6·95

Deducting sand and extraneous matter, the calculated percentages of lime, magnesia, and sulphuric anhydride in the cement, or material other than sand and aggregate, were approximately :—

	Sample No. 1. Hard Concrete. Per Cent.	Sample No. 2. Disintegrated Concrete. Per Cent.
Lime	58·85	35·04
Magnesia	4·94	23·89
Sulphuric Anhydride . .	3·05	12·95

Mr. Butler in his report said :—

"The above shows that the cement in the good concrete has been but very little affected by the sea-water, its composition, with the exception of a slight excess of sulphuric acid and magnesia, being that of a normal Portland cement, especially having regard to the fact that this cement was manufactured some 30 years ago, and was probably considerably lower in lime, and higher in clay constituents than the modern product. The calculated composition of the disintegrated material is entirely different, and shows that a considerable portion of the lime in the cement has been displaced by magnesia and sulphuric acid, doubtless due to the effect of the sea-water. The ratio of lime to magnesia is about 3 to 2 instead of being about 20 to 1 as in normal Portland cement. The foregoing analyses seem to me to demonstrate very clearly that sea-water will attack porous unset concrete, and therefore the only way to ensure good and stable work, is to make sure that the mass is sufficiently impervious to prevent percolation ; sea-water will not attack cement to any serious extent when it has once set and hardened, unless it is so porous as to allow repeated percolation of fresh quantities of sea-water. Wherever possible, therefore, I am strongly in favour of the block system of building up sea-walls, so successfully adopted at Dover and elsewhere. In conclusion, I do not think the risks attached to the deposition of mass-concrete under sea-water are sufficiently appreciated, and, moreover, I feel sure that there is a good deal yet to be learned as to the behaviour of Portland cement when used under those conditions."

Sir Whately Eliot.

Sir WHATELY ELIOT considered that the Paper was a very valuable record of a work carried out successfully, although presenting more than the usual difficulties to be expected in the construction of extensive dock-works, the ground at Southampton being notoriously unstable and the cause of much trouble in the construction of former dock-walls. It appeared that in this case the chief difficulties were due to the circumstances connected with the site and the position of the enclosing embankment, rendering it impracticable to enclose the whole area of the works by a coffer-dam, and necessitating the construction of some of the walls under water. With regard to the method adopted for the construction of the south end of berth No. 43, where water had to be admitted to the trench, and concrete caissons were sunk successfully to the proper depth, a somewhat similar method had been adopted in a deep trench excavated through mud for one of the dock-walls at Keyham.[1] When the trench had been excavated to a depth of about 30 feet from the surface, the 6-inch sheet piles which had been driven down to firm ground to form the sides of the trench began to move inwards at the bottom, and threatened to collapse if the excavation were continued. Concrete cylinders were then sunk from the surface of the mud inside the trench down to the rock, a further depth of about 30 feet. The cylinders were 7 feet in external diameter, so as to fit between the struts in the trench, and four occupied the width of the trench. They were formed in rings 2 feet 6 inches deep, and after they had been sunk to the full depth required to reach the rock they afforded complete support to the sheeting. The excavation of the trench was then proceeded with, the rings of the cylinders being removed as the struts were placed in position. The cylinders were afterwards used elsewhere in the permanent work. This work, being executed in a dry trench, was a simple affair in comparison with sinking through water, as at Southampton. The walls comprised in portion B and constructed with concrete blocks in front and back with a filling of mass concrete, although completed successfully, did not appear to present a method of construction to be recommended. Even under the most favourable circumstances, with perfectly still water and no current, the deposition of concrete under water could not be depended on entirely for sound work. Concrete blocks throughout the whole width of the wall, shaped so as to bond into one another, would have formed a solid and massive wall, probably at less cost and with more expedition than by using concrete in mass. It was evident that

[1] Minutes of Proceedings Inst. C.E., vol. clxxii, p. 9.

Sir Whately Eliot. during the construction of the works many difficulties had been encountered owing to the depth of the trenches, the unfavourable nature of the ground, and the peculiarities of the site; and the patience and skill of those engaged in the operations must have been tried to the uttermost. The depth of water provided in the basin ought to prove sufficient for any ships that were ever likely to reach Southampton.

Mr. Ellis. Mr. SOMERS H. ELLIS expressed his appreciation of the very clear and instructive manner in which the Author had described the works. The bold and skilful methods adopted to meet the difficulties encountered were such as appealed to every dock-engineer, and this record of them was very valuable. One matter of special interest was the stability of the quay-walls against sliding. The sloping base was undoubtedly a helpful feature of the design, but, in view of the unsatisfactory nature of the foundation stratum, it seemed to him that some further safeguard might have been introduced. Two methods presented themselves, the first and most obvious being to drive raking piles under the forward part of the base of the wall, which would have had the further advantage of adding to the bearing-capacity of the ground over the area of greatest pressure. He could easily understand, however, that such a method would be adopted very reluctantly when dealing with foundations of this character, it being of the greatest importance to lay the concrete wall-base as soon as a deep trench had been excavated, without adding to the risk of "blows" by delay for pile-driving, with its accompanying vibration. The second method of reducing the risk of forward movement would have been to provide fairly heavy counterforts, spaced, say, 50 feet apart and bonded with steel rods or old rails into the body of the wall. Mr. Ellis had been impressed by the local stability which had been imparted to walls founded on a soft or slippery foundation by counterforts intended primarily for the support of cranes. He could recall several instances in which these counterforts had prevented movement in their immediate vicinity while intermediate portions of the wall had moved forward: one such case was a long quay-wall of the main basin at the Tranmere Bay docks.[1] This effect was still more marked (from the point of view of a spectator) in the three quay-walls of a small Admiralty basin at Hong Kong, which had moved forward in a double curve, each being held back at the centre by a counterfort carrying a light fixed crane. In practice the arresting effect seemed to be greater than

[1] Minutes of Proceedings Inst. C.E., vol. clxxi, p. 140.

theoretical calculation would suggest, and it might more than compensate for the extra cost involved, and the slight inconvenience caused by having broken lines to the back of the trenches. The late Sir Benjamin Baker once remarked that almost every existing retaining-wall (of more than a certain age) on a soft foundation would be found to have moved more or less out of its original alignment; and it would be interesting, at some future time, to learn whether the new quay-walls of the White Star dock had followed the example of the Empress dock walls in coming forward to a noticeable extent. Had the Author anticipated such a movement by setting out the walls on a slight concave curve, as was usual at Liverpool with walls not on a rock foundation? The fact that not infrequently forward movement took place in dock-walls after a lapse of time, might be accounted for by an argument in the Appendix. The Author gave the resistance to forward movement due to water-pressure as 22·8 tons, which no doubt held good when the wall was new and the backing was dry. But when in course of time the backing, especially if it were a porous material, such as the ship's ashes mentioned in the Paper, became saturated with water, it was evident that the resultant water-pressure in front of the wall must be diminished considerably, and in exceptional cases it might vanish entirely (except for its effect in adding weight to the earth in front of the toe of the wall); so that the Author would appear to have placed undue reliance on this factor as a permanent measure of stability. With regard to the driving of reinforced-concrete piles to carry the platform behind the pier-and-arch wall, were the heads of the piles damaged in driving, and what means were taken to avert such damage? Driving to a final set of $\frac{1}{10}$ inch with a $3\frac{1}{2}$-foot fall of a 50-cwt. ram seemed to be unnecessarily severe, and likely to shatter the concrete instead of causing further penetration. Mr. Ellis.

Mr. W. Henry Hunter had read the Paper with more than ordinary interest, and was sure that it would have permanent value in the Proceedings as a frank and faithful record of engineering operations carried out amidst adverse conditions, as well as of serious risks boldly faced and difficulties grappled with and overcome. The Author had abstained from any statement of the total cost of the works, or any suggestion as to the value of the land occupied by them. If reasons of policy were the cause of this abstention, there was no more to be said. But the value of the Paper, already great, would be increased if such figures could be supplied, as the cost per berth in the dock must have been very considerable. This was a case very much in point in the controversy Mr. Hunter.

Mr. Hunter. which had arisen between shipowners and dockowners with regard to the dues charged for the colossal passenger-steamers of the present day, especially as shipbuilders had reduced to a fine art the practice of building steamers in which the dead-weight capacity and general accommodation were at their maximum, while the registered tonnage, upon which ship dues were paid, was at a minimum. In connection with the question of cost, it was not clear why so short a dock was constructed 400 feet wide, as even with that width, when the adjacent berths were occupied, the berth at the north end of the dock would not be long enough for the accommodation of a modern liner. With regard to the ordinary section of the quay-walls, Mr. Hunter was in complete agreement with the Author so far as the slope from front to back on the foundation of the wall was concerned. In a case in which he was concerned where a similar slope was proposed in the design of a dock-wall, but was omitted in construction under the advice of superior authority, a forward movement of the wall had resulted which had caused no little anxiety and trouble. He also concurred in the somewhat unusual projection of the foundation beyond the face of the wall, as well as the steel reinforcement at the foot of that projection. These features of the design were, in his opinion, sound in principle and workmanlike in execution. He regretted, however, to be compelled to dissent from that element of the design which introduced the batter of 1 in 10 on part of the face of the wall. The Author stated that this batter extended from the low-water line downwards, but he seemed to have done himself an injustice in this, and to have represented the matter as worse than it really was, as Figs. 3 and 8, Plate 2 showed that the plumb portion of the face of the wall was carried down to a line about 6 feet below the level of low water. In Mr. Hunter's view the construction of dock-walls with a batter on the face was due to a mischievous tradition which had neither scientific basis nor practical value. Its effect was shown clearly in the section of the wall in Fig. 12, Plate 2, from which it appeared that for the safe berthage of a steamer in the new dock it was necessary to insert what was described as a "dummy" (presumably a timber fender with a thickness of 4 feet 6 inches) between the face of the wall and the side of the ship. Such fenders were doubly disadvantageous. In the first place, they necessitated a sensible increase in the radius of the cranes employed for loading and discharging cargo or baggage, and rendered it much more difficult for passengers to embark or disembark from gangways; and in the second place, which was more important, they caused concentration of load at the particular spot in the ship's side where it bore against the fender, instead of permitting the load to be distributed over as large a part of the surface as was possible. He considered that walls ought to be built in such a manner as to render it impossible for a vessel to bear against the wall below the level of low water, where nobody could see what was happening and where the landing edges of the vessel's plates were sure to be chafed and worn away. The face of the wall should be plumb, and the portion above low water should oversail in such a manner as to project beyond the line of the part below low water. He would suggest that, where the conditions permitted, solid dock-walls should be abandoned altogether in favour of piers and arches. In many cases, though not in all, this would reduce the first cost, while there could be no question as to the additional safety during construction, and as to elimination of the risk of settlement of the filling behind the walls, which was justly regarded by the Author as so serious as to lead him to adopt the temporary expedient of covering his quays, between the sheds and the back of the coping of the wall, with timber decking. Mr. Hunter feared that in the course of a few years this expedient would have a disastrous effect upon the appearance of the works. Solid dock-walls were in most cases extravagant, because such walls must be constructed in the dry, and therefore must be treated as retaining-walls which were subjected during the period of their construction to stresses which they would never have to withstand when the water had been admitted into the dock. The pier-and-arch construction was particularly suitable for such a case as the White Star dock, where the piers and the foundations of the sheds might have been combined in one structure, with advantage to both. The peculiar design of the hook bollards which had been fitted into the coping of the dock-walls was worthy of attention. So far as Mr. Hunter's acquaintance with bollards of this type went, the design was entirely original, and if the Author's personal and practical acquaintance with the business of mooring great Atlantic liners had not been so well known, it might have been supposed that the design of the bollard had been evolved by some one whose view was that such vessels were moored from one of their upper decks, and that it was desirable to secure the vessel to the bollards in such a manner as to keep her from rising during the period of flood-tide. Mr. Hunter.

Mr. D. C. Leitch considered that engineers who had been responsible for similar works would appreciate the difficulties and anxieties which attended the sinking, in ground such as that described, of deep and wide foundation-trenches. The Author was to be congratulated on his successful handling of the very serious Mr. Leitch.

Mr. Leitch. difficulties connected with the execution of portions of the work; and on his lucid and instructive account of the methods adopted. In some recent works a lavish and even wasteful use of Portland cement had been in evidence, but this could not be said of the works now in question, where there had been no unnecessary use of rich mixtures. It would, however, have been better to surround the reinforcement in the wall-foundation (Fig. 3, Plate 2) with concrete richer than 8-to-1, which could hardly afford complete adhesion or protection from rust. The calculations of stability for quay-walls given in Appendix I were dubious. They appeared to be based on the assumptions that water-pressure acted only against the face of the wall, and that the wall and filling were not submerged. It was usually impossible to prevent the access of water behind a quay-wall; it was certainly so with ground and concrete such as were described in the Paper. There could be no doubt that the standing level of the water in the ground behind the wall varied but little from that in front of it. It was, indeed, undesirable that it should be otherwise, as any considerable difference of level might cause holes to be scoured in the foundation below the wall. But, if this were so, the Author's assumption that water-pressure acted only against the face of the wall, and assisted to support it against the pressure of the ground, could hardly be sustained. In fact, the wall and the filling behind it up to low water of ordinary spring-tides might be regarded as submerged, and partly water-borne. The water-level behind the wall might not have so large a range as in front, and might, at low water, be a few feet higher. The filling between low water and high water of ordinary spring-tides might also be more or less retentive of water. These factors could hardly be estimated precisely beforehand, yet they might affect materially any calculations of stability. From the data regarding the wall shown in Fig. 3, Plate 2, the lateral pressure, including surcharge, appeared to be about 44 tons per lineal foot, allowing for submersion to low-water line. The load on the wall-foundation, with a similar allowance, appeared to be about 93 tons, and the maximum load 6·2 tons per square foot. Although the lateral pressure of the filling was not resisted by water-pressure, resistance was offered by friction on the foundation; also, and mainly, by the ground in front of the toe, a factor of which the Author apparently had taken no account. The Author appeared to claim that, because the walls were standing safely, the bases of calculation were correct. This did not follow, as errors might balance each other, and, besides the uncertain factors already referred to, nobody could say, within any but wide limits, what maximum load the foundation could bear safely, or what was the factor of safety with any given load. The maximum load per square foot on the foundation of the block-faced wall, Fig. 8, Plate 2, appeared to be higher than the figure given for the wall shown in Fig. 3. A better distribution of the load on the foundation, and some economy of material, would have been obtained by setting the wall farther back on its foundation, reducing the back offset from 4 to 2 feet, and stepping the back block-face at every alternate course, reducing the thickness of the wall to 18 feet at low water of ordinary spring-tides. The pier-and-arch construction, with a platform behind (Fig. 11, Plate 2), appeared to be not entirely satisfactory. Probably the platform reduced the lateral pressure on the wall by about 40 per cent., and there might have been special reasons for its adoption. Otherwise, it would apparently have been preferable to increase the depth of the piers from 35 to 45 feet, to reduce the thickness of the curtain-walls to 3 feet at the centre, and to omit the thicker lower portion. Without this portion the weight of the curtain-walls would be borne mainly by the piers, the distribution of the load on their foundations would be improved. It was not clear whether the piles under the platform were driven before or after the completion of the wall in front of them. If they were driven before, their safe load might be materially reduced by loosening of the ground at the back of the wall during its construction. If they were driven after, they would compress the ground and increase the lateral pressure against the wall in front. The reasons expressed by the Author for preferring a sloping base below the quay-walls seemed doubtful. The depth of the foundation at the toe should be adjusted in accordance with the maximum load per square foot to be provided for. Frequently the depth so arrived at was sufficient to secure the wall against being pushed forward, without any dipping of the base from front to back, beyond the small amount required for trench-drainage. If it were not sufficient, sloping the base, as shown in Figs. 3 and 8, Plate 2, increased the resistance of the wall to lateral pressure, with the addition of less concrete than any other method required. But the same end might be attained by making the whole foundation deeper and keeping the base nearly level. This required more concrete, but afforded a larger margin of safety for the load on the foundation at the toe, which was usually the principal source of anxiety. He agreed with the Author's view that a wall entirely of block work would have been better and cheaper than one partly of mass concrete: it would probably have been economical to use for it 10- to 12-ton, instead of 6- to 8-ton blocks. With more block work to Mr. Leitch.

Mr. Leitch. set, the extra cost of the plant would not have been higher per cubic yard; while, with larger blocks, the cost of moulding and setting, per cubic yard, would have been reduced. It would be interesting to learn how the Oregon timber piles of the jetty were guarded against the attacks of marine worms and insects, and why timber had been used. Apparently steel piles or cylinders would have been more durable. The stability of concrete buttresses, such as those described, seemed likely to depend in a considerable degree on the life of the sheet piling around them.

Mr. Olive. Mr. W. T. Olive considered that sufficient data were not given in Appendix I for full criticism of the walls of section A; he had, however, taken what he considered to be the weakest point of the wall, namely, at the level 56 feet below the cope, and had found that the single resultant was well within the stipulated 0·375, the greatest permissible deviation of the centre of pressure from the centre of figure, at the given bed or level, as laid down by the late Professor Rankine. The calculation did not take into account the water-pressure on the face of the wall, which undoubtedly helped to sustain it; but he was of opinion that it would be very unsafe to rely upon this, inasmuch as there must be a certain level of saturation at the back of the wall, due to water coming from underneath, and, by its upward pressure, virtually reducing the weight and consequently the stability of the wall, so neutralizing to an indefinite extent the face-pressure claimed (see Appendix I). Had the walls been built entirely of blocks, this objection would have been intensified, as the water would find its way through the wall itself. In his calculations he had assumed the following weights:—concrete 140 lbs. per cubic foot, and earth-backing 120 lbs. per cubic foot, credit being taken for the 392 cubic feet of earth on top of the two offsets at the back weighing 21 tons, equivalent in weight to 336 cubic feet of concrete. Similar calculations for the full depth of the wall, also not taking into account water-pressure on the face, or the advantage of the 10-foot depth in the earth at the front of the wall, showed a better result than in the former case, for the single resultant lay well within the middle third of the base. He concluded from this that the projection at the toe might safely have been omitted in the design, thus reducing what appeared to be an excessive width of trench involved thereby. He was aware of the tremors caused by the passing of heavy trains and had had occasion to load a well-designed retaining-wall, in boulder clay, supporting ground devoted to goods-traffic, on a stiff incline, running close to the top of the wall. The original ground-surface in front of the wall was lowered after the wall was built, for the purpose of constructing a new road running parallel with and close to the wall-face and at a somewhat lower level. The wall began to heel over, causing the batter of 1 in 12 to disappear and the face to come to the vertical. He overcame the difficulty by introducing blocks of brickwork at intervals at the inside of the top of the wall and anchoring them by long bolts passing right through the block and the wall, and he had found that plan quite effective. Mr. Olive.

Mr. H. CARTWRIGHT REID observed that the great depth of modern ships was rendering the provision of adequate harbour accommodation a very serious question. He believed the construction of a berth 40 feet in depth at low water of ordinary spring-tides was unique, and the reason why this depth was decided upon had not been made clear. According to Fig. 12, Plate 2, the "Olympic" drew 32 feet 6 inches. If the additional depth of the berth was intended to provide for future deepening of ships, the very large margin it gave had been provided at considerable expense when the cost of the bottom 5 feet of the walls was taken into account. He knew of no ship drawing more than 35 feet, and it was very unlikely that naval architects would make any serious increase on this, even if it were found that with large ships speed could be attained only when they were of deep draught. There must be a limit of depth, due to the natural formation of most of the harbours and also of considerable stretches of water, such as the North Sea, in which, over some areas, it would be difficult for a ship drawing 35 feet to be navigated safely at low water. No doubt it was an advantage to be able to berth ships like the "Olympic" immediately on their arrival, and for this reason a tidal berth had many advantages, while for the construction of a single berth it would no doubt be more economical to make it tidal than to construct an enclosed wet dock, such as those which existed in London and Liverpool; but if a considerable length of wharf had to be provided, an enclosed basin would be more economical, because a lower wall would suffice where there was not the range of tide. The 13 feet at the bottom of the wall was the most costly part of it. He was glad to see that the Author had had the courage to state in the Appendix his calculations for the stability of the quay-walls. Some of the particulars were not quite easy to follow, and Mr. Reid could not understand why, having adopted one portion of Rankine's formula, the Author had not adopted the other to give the resistance to moving due to the material in front of the toe of the wall. It would be advantageous if the Author would indicate how the calculation of 16·3 tons resistance, due to the slope of the foundation, had been Mr. Reid.

Mr. Reid. ascertained. The important feature of the Author's calculations was the assumption of the angle of repose of the material at the back of the wall, which was given as 26°. Mr. Reid believed that these assumptions were always based by engineers upon experience. It would be very useful if The Institution would collect data of this kind, so that the younger members of the profession might have the benefit of the longer experience of those who had dealt with such matters. On p. 68 the Author used 15° as the angle of repose, and it was not quite clear why he should change from an assumption of 26°.

Mr. Robson. Mr. J. J. Robson congratulated the Author not only upon the lucidity of the Paper, but also upon the general excellence of the design and the successful accomplishment of the work. He considered that the difficulties, which usually were inseparable from works of this character, had been surmounted with the skill derived from experience. The method of procedure adopted was correct, for it was obvious that the utilization of the river-bank which enclosed the site, to enable the greater portion of the work to be executed in the dry, was both convenient and economical. When the various stages of the work were considered, the time occupied in its construction (5 years) was not excessive. Had the work been expedited unduly it would have been at the sacrifice of economy. Nor was the total cost of the work excessive when the principal features of the scheme were considered, namely, the nature of the site and subsoil, the great depth of the dock, and the conveyance of the spoil a distance of 25 miles to sea. When the last point was considered, a certain element of uncertainty was introduced into the time of completion. The Paper had been prepared so carefully that little room was left for criticism. It was superfluous to discuss what might have happened had the Southampton docks been planned originally in a different manner. The designers must be given credit (having regard to the circumstances and means at their disposal) for arranging their work with the same consideration and forethought as was exercised in modern days. He would like to ask why the dock was made 40 feet deep, when the depth of the river was only 35 feet. The section of dock-wall shown in Fig. 3, Plate 2, had an excessive projection in front, particularly at the toe, considering the present sections of large ships with projecting bilges. Fig. 8 illustrated a very costly method of construction: the wall would have been much better and possibly cheaper if constructed in blocks above the level of the footings. Further, he could see no advantage in giving an upward splay to the heading courses: the bonding would have been better if the ordinary square header and stretcher courses had been adopted, beginning with a header course at the bottom and working upwards with two courses to each lift of concrete. The Author did not say whether these courses were bedded and grouted; being under water they were doubtless laid dry. On p. 50 it was stated that at that portion of the trench-work "sand" was encountered which ran between the runners, and he would inquire how this was kept out. Apparently it was done by filling the holes behind the timber with gravel or other good material, but surely this would be impracticable with an excessive quantity of water. In similar cases he had used successfully sacks of hay—sometimes nailing them over the surfaces of the runners. The timbering of the trenches deserved notice; it appeared to be substantial, although the method of insertion was open to discussion. The use of runners 4 inches thick by 24 feet long meant much labour in driving down. He considered it could have been executed more economically with 3-inch runners, in three settings instead of two, the runners being shorter. With a trench 42 feet wide "central" or "king" piles were absolutely necessary. He would limit the maximum width of a trench to be timbered without these piles to about 30 feet; and then half-timber struts should be used, with frequent cross struts to stiffen them. He observed that in places where the bottom of the trench was soft and the piles showed symptoms of rising, diagonal struts were introduced raking downwards, to prevent such action. This was a good method, and had it been adopted on other occasions some calamities might have been avoided. When timbering in sand or other dangerous material he had often made it a rule to lace the frames of timber together vertically with stout boards or planks, a precaution which had proved invaluable in keeping the timber in place. In timbering trenches too much care could not be observed by the engineers in charge, who too often left this matter to the gangers and timber-men, with their rule-of-thumb methods. Timbering was a class of work which was often difficult and dangerous, and required skill and courage; and young engineers should devote their special attention to it, so as not to be left entirely to the advice of such men in time of danger. Mr. Robson.

Mr. G. Hall Scott observed that the difficulties of the trench excavation seemed to be very similar to those experienced with the deep mud trenches at the Keyham Dockyard extension.[1] There it was found absolutely necessary, where centre piles were adopted, to provide bulkheads at about every 100 feet, and to limit the open trench to that length. If struts the full width of the trench were Mr. Scott.

[1] Minutes of Proceedings Inst. C.E., vol. clxxii, p. 61.

Mr. Scott. used and the centre piles were omitted, much longer lengths of trench could be worked even without bulkheads; and although the centre piles obviated the difficulty of placing long struts in position, it would seem better to bear with this difficulty rather than to adopt what really became a hinged strut, which was easily disturbed by either vertical or lateral movement. When movement once began, the struts as such became less and less effective as the movement continued, until calamity occurred. The trouble encountered at the south end of berth No. 43 was apparently due to letting the water into the basin before this part of the wall was built. He was diffident in offering criticism, not knowing all the circumstances of the case, but it would appear to be very risky to allow the water to rise in the basin while this trench was in operation, as a blow under the completed wall was almost inevitable. The blow having taken place, the Author had been wise in overcoming the difficulty by means of caissons. With regard to mass concrete deposited under water, he was glad to find the Author agreed that a better and cheaper wall would have been obtained by using block work entirely. In spite of every care, mass concrete deposited through water was never satisfactory, and it would be well if engineers set their faces absolutely against its use. He ventured to think that where work must be built in the water either block work, cylinders, caissons, or reinforced piles gave the best and safest results; but wherever work could be built in the dry by means of coffer-dams, better and safer results were obtained, and in most cases much money was saved. When tenders were invited for the work which formed the subject of the Paper, he visited and carefully studied the site. He then recognized that there would be trouble in making the enclosing bank watertight, and came to the conclusion that the employment of a coffer-dam composed of interlocking steel sheet piles, completely enclosing the site from Trafalgar dock to the end of berth No. 41, would prove a much more satisfactory method of dealing with the work. These piles would have penetrated the bed of ballast shown in Fig. 4, Plate 1, and thereby would have enormously reduced the general pumping; and as the surface of the ground at the site of the dam would have been dry at low water, a single-row dam could have been rendered perfectly tight. The cost of such a dam should not have exceeded £40,000. All the walls could then have been built in the dry at much less cost—probably £70,000 to £80,000, on the basis of the costs given for the various types of walls—and the money spent in endeavouring to make the enclosing bank watertight would also have been saved; and as the work would all have been of the same character, namely, wall in trench, less plant would have been employed, and considerable time saved. Mr. Scott.

Mr. Henry Wilding, of Southampton, considered that one of the great advantages of the White Star dock was that, owing to the design adopted, the absence of gates at its entrance, and its width, this dock would not be out of date even if the present extreme size of steamers were doubled. He wished to emphasize the importance of engineers exercising large foresight in the construction of docks and harbours whenever they were works looked upon as being of a permanent character. However, to anticipate future requirements in the matter of depth, as had been done in regard to length and breadth, the dock should have been so constructed as to permit of deepening to 45 feet below L.W.O.S.T., seeing that, having no gates, it could not impound water, and that extreme low water was sometimes 2 to 3 feet below L.W.O.S.T. Notwithstanding the great increase in the size of steamers, it still remained true that most passengers were not good sailors. Increase in the size of vessels diminished the discomfort of this large proportion of the travelling public. It was also true that where 30,000 tons of cargo had to be carried, if the harbour and dock facilities at both ends of the journey would admit, the load could be carried much more cheaply in one bottom than in three. Perhaps the most exhaustive inquiry during recent years on the subject of the probable size of ships was that undertaken by the United States for the purpose of carrying out the provisions of the Spooner Bill for building the Panama Canal. One result of this inquiry had been the provision of locks with usable dimensions of 1,000 feet by 110 feet; and at a recent discussion concerning dry-docking facilities for such ships as the "Olympic" and "Imperator," it was pointed out that the only dry dock available on the American continent was at Balboa at the Pacific entrance to the Panama Canal. In his opinion, however, the strongest evidence with regard to the progressive size of ships, and that which demonstrated most graphically the necessity for what he was now urging, was prepared by Mr. A. G. Lyster, President Inst. C.E., about 10 or 12 years ago. There was then, as now, a controversy concerning the future sizes of ships, and Mr. Lyster prepared certain curves based on the progressive length, breadth, and draught of water of steamers from the earliest times up to that date. The continuation of those curves showed what might be expected under similar conditions; and the expectations thus shown had been more than realized. If Mr. Lyster would Mr. Wilding.

Mr. Wilding. project those curves forward for another 20 years, Mr. Wilding thought he would be conveying the best indication that was possible now of what should be anticipated and provided for.

The Author. The AUTHOR, in reply, pointed out that he had already dealt with some of the questions raised, e.g., why the open excavation had been taken down to the 30-feet level before starting trench-work, and why the dock had been flooded before the trench-work was fully completed. He had also dealt with the question of using 8-to-1 concrete, which had proved successful at Southampton. With regard to the enclosing bank round portion A of the works, the puddle trench suggested by Mr. Copeland would have been very expensive and slow, as the gravel bed through which most of the water penetrated extended down to 35 feet below high-water level. Probably Mr. Hall Scott's suggestion that steel sheet piling might have been driven along the bank was a better one. It was very doubtful, however, whether Mr. Scott's proposal to enclose the whole of the works by a coffer-dam would have been economical. A long length of that dam would have had to be placed on ground which was about 22 feet below low water—not at low-water level as Mr. Scott assumed—and such a dam would be costly and difficult to construct. Several correspondents had challenged the calculations for the stability of the wall, given in the Appendix. In making these calculations the Author had assumed the weight of the concrete to be 140 lbs. per cubic foot, which agreed fairly well with the weights of actual samples. The nature of the backing varied considerably, and no doubt its lower strata were saturated with water. In order to allow for this, its weight had been assumed to be 120 lbs. per cubic foot, and its slope of repose 26° (2 to 1). The slope of repose of the material underneath the wall had been assumed to be 15° only, as it had seemed quite likely that the crushing-effect of the wall would reduce it to this figure. The resistance offered by the slope had been arrived at by multiplying the total weight on the base by the rate of slope ($\frac{1}{8}$). The resistance offered by the material in front of the toe had been neglected. This, perhaps, was an error on the safe side, but in the case of the material being softened by water the resistance would be very small. Mr. Olive thought the long toe might have been omitted, but if that had been done the pressure on the clay under the wall, which was now estimated to be 4·8 tons per square foot, would have been considerably higher, and the wall might have failed in consequence. With regard to the design and construction of the wall for portion A, the Author had studied the question of a hollow wall, but so far he had not succeeded in designing a satisfactory hollow wall which showed any marked economy. As to sinking the trenches by grouting or by the Poetsch freezing-process, it must be remembered that sinking a long and wide wall-trench 50 to 70 feet deep was a very different matter from sinking a mine-shaft of small area and great depth. In reply to Mr. Robson's question, when sinking a trench through sand, the water in it was generally controlled by sinking a small sump below the rest of the work, which dried the sand above it. When blows occurred behind the timbering, the water and sand usually came in rushes which ceased after a few minutes. The hole formed behind the timbering was filled with gravel or with straw. Mr. Brenan seemed to think that the walls of the reinforced-concrete caissons were too thick, but as they needed weight to sink them, and had to be filled with concrete eventually, this did not seem to be a disadvantage. With regard to the wall for portion B, the blocks were laid dry, except for a short length at the external corners, where each course was caulked and grouted by divers with neat cement. Various kinds of joggles were tried, and finally a square tapered joggle of concrete moulded in air was adopted, which gave satisfactory results. The Author agreed with Mr. Brenan that concrete laid under water behind shuttering was rarely satisfactory. The mass concrete in this wall, however, was not laid behind shuttering (except at the temporary ends) but behind the blocks, as shown in Fig. 8, Plate 2. The binding of the concrete into dry lumps was not due to its being mixed too dry, but simply to the shaking it received on the journey. Such shaking was doubtless advantageous provided the concrete was afterwards left undisturbed, but not when it had to be turned out again. The test block cut out of the under-water concrete was about 1 year old when cut out, and was tested about a fortnight later. With regard to the jetty berth No. 42 (Fig. 10, Plate 2), Oregon piles were used, because they were obtainable in longer lengths than pitch-pine. They were protected by creosoting under pressure. It was found that the Oregon piles absorbed about 8 lbs. of creosote per cubic foot, whereas pitch-pine absorbed only about 5 lbs. Mr. Leitch suggested that steel piles would have been more durable, but ship-owners generally preferred timber for a guiding-stage against which heavy vessels had to lurch. Greenheart was probably the best material for this purpose, as it resisted the attacks of marine insects very well; but it was now almost impossible to obtain it in long lengths. Some trials were made with Australian woods, but it was too early yet to speak of the results. Mr. Binns thought that the concrete buttresses would make the jetty too rigid, but it was The Author.

The Author. feared that timber alone would suffer severely from the glancing blows of a 40,000-ton ship. In reply to questions about the wall for portion C (Figs. 11, Plate 2), the reinforced-concrete piles were never seriously damaged by the driving. A sawdust helmet, above which was a short dolly, was used to protect the pile-head. Occasionally the concrete at the pile-head was slightly broken, but as this had to be cut away in any case to mould on the beams, no harm was done. Mr. Leitch seemed to think that the driving of the piles (which was done after the wall in front of them had been built up) would increase the lateral pressure on that wall: but piles driven into earth undoubtedly helped to prevent it from slipping, and if driven behind a retaining-wall it would seem that they should diminish the lateral pressure, not increase it. Mr. Hunter and others had condemned the face batter on the walls, and the consequent use of floating dummies. Dummies had some advantages, however, in a tidal dock, as they enabled the ship's side to be inspected and painted, and they also gave a better lead for the mooring-ropes. As to the general lay-out of the dock, the Author fancied that the Navigating Officers at Southampton would hardly agree with Mr. Hunter's view that the width of 400 feet was excessive. It must be borne in mind that, the dock being laid out for four berths, a vessel might have to pass in or out between two others. A large ship might have four or five tugs in attendance, and it was necessary to have sufficient room for all these craft. The reason why the dock was made 40 feet deep, while the approach-channel was only 35 feet, was that this arrangement permitted a vessel like the "Olympic," drawing, say, $35\frac{1}{2}$ feet, to lie afloat in the dock even at an extraordinarily low spring-tide, whereas the sailing-times did not require her to be in the entrance-channel at such tides, which occurred about 6 p.m. Mr. Wilding had made some interesting remarks on the dimensions of the ship of the future. It could be wished that shipowners and dockowners could come to some agreement on this point. It seemed to the Author that the cost of providing dock accommodation for ships increased more rapidly than the earnings from the increase in tonnage, and that if shipowners wished to greatly enlarge the dimensions of their ships the tonnage-dues would eventually have to be raised to meet the expense. In conclusion, the Author wished to thank the correspondents, who had contributed facts and criticisms which were of great value.

18 November, 1913.

ANTHONY GEORGE LYSTER, M.Eng., President, in the Chair.

The discussion on Mr. F. E. Wentworth-Sheilds's Paper, "The Construction of the 'White Star' Dock and adjoining Quays at Southampton," occupied the evening.

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25 November, 1913.

ANTHONY GEORGE LYSTER, M.Eng., President, in the Chair.

The discussion on the Paper on the White Star Dock, Southampton, was continued and concluded.

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2 December, 1913.

ANTHONY GEORGE LYSTER, M.Eng., President, in the Chair.

The Council reported that they had recently transferred to the class of

Members.

Athol Lancelot Anderson.
Francis Sylvester Grimston.
Frederick James Jones.
Charles Edward Larard.
Walter Patteson.

And had admitted as

Students.

William Scott Abbott, B.Sc. (*Birmingham*).
Hubert Percy Adcock.
Hugh Thomas Moffitt Angwin, B.Sc. (*Adelaide*).
Arthur Carlisle Atkinson.
Lancelot William Atkinson.
Alfred Bailey, B.Sc. (*Manchester*).
Alexander Barlerin.
Edwyn Ernest Hope Bate, B.Sc. (Engineering) (*Lond.*).
Frederick Berry, B.Sc. (*Manchester*).
Harry Michael Best, B.A. (*Oxon.*).
William James Purkis Bewley.
Hermann Emil Beyer.
Herbert Duncombe Bindley.
Melvyn Robert Kemp Bion, B.Sc. (*Manchester*).
James Briggs, Jun.
Eric Gordon Brown, B.Sc. (*Birmingham*).
Edward Lawrie Bremer Buchanan.
James Francis Burgess.
Charles Kingsley Johnstone Burt, B.Sc. (*Durham*).
Harry Vernon Butterfield.
Frederic Eugene Campion.
Herbert Stuart Cleghorn, B.Sc. (*Edin.*).
Alan Repington Collis.
Arthur Grevatt Connell.
Charles Gordon Towers Cooper.
William Harry Victor Corney.
Harold Darlington Henry Court.
Elwyn Thomas Davies.
Thomas Archibald Francis Dixon.
Percy Dobie.
William Douglas.
Reginald Drake.
Thomas George Royal Eagan.
Harry Elliott.
Fred Arthur Eustace.
William Fairley, B.A. (*Cantab.*).
Alexander Dale Ferguson.
George Axen Wallace Flynn.
Frederick James Gilbert Foot.
Cecil Walter George.
James Stanley Gordon.
John Leslie Grant.
William Henry Gratrix.
John Howard Grose.
Cyril Marriott Hake.
Arthur William Hall.
George Bridges Hardy.
Grainger Hope Hargreaves, B.Sc (*Manchester*).
John James Atkin Hayman.
Robert Hartley Heape.
Alfred Edward Holton.
Leonard Ralph Horne.

Students—continued.

ALFRED PROOM HUMBLE.
HOWARD CECIL LEE HUMPHREYS.
WILLIAM COUTTS HUNTER.
HERBERT GUY JACKSON.
JOHN DATE JOHNS.
MARTIN MARKER JONES.
EDMUND JOSEPH KEANE.
HERBERT HARDING KELLEY.
ARTHUR HENDRY LANGDON.
DOUGLAS WARREN LANSDOWN.
RALPH TOWLERTON LEATHER.
AUBREY LAURENCE LINGARD, B.A. (*Oxon.*).
RAE MACDONALD.
JOHN MACMURRAY, B.Sc. (Engineering) (*Lond.*).
STANLEY GEORGE MARRIOTT.
FERGUS MALCOLM GRAEME MCCONECHY, B.Sc. (*Manchester*).
WILLIAM FRANCIS MEAD.
FRANK LESLIE MORGAN, M.Sc. (*Birmingham*).
CLEMENT JOHN MORRIS.
ROBERT OGILVIE NIVEN.
LESLIE GEORGE PALING.
BENJAMIN NEEVE PEACH, B.Sc. (*Edin.*).
THOMAS ORMSTON CAVE PEASE.
PERCY GEORGE PICKWELL.
WILLIAM ROCHESTER POTTER.
MEREDITH BECKETT POWELL, B.A. (*Cantab.*).
FRANK LEONARD RICHARDS.
DARYL STEWART RICHARDSON, B.A. (*Cantab.*).
HAROLD BRINDLEY ROBB.
ROBERT BRUCE ROBERTSON, B.Sc. (*Edin.*).
ERIC ARTHUR ROBINSON.
HUGH KENNEDY RUSSELL.
AMOLAK RAM SETHI.
JOHN ROGNVALD SHENNAN, B.Sc. (*Edin.*).
EDWARD HEWSON SILCOCK.
LEONARD STEPHEN BARRINGTON SIMEON, B.A. (*Cantab.*).
ALWYN ECKETTE SIMPSON.
JAWAND SINGH, B.Sc. (*Glasgow*).
NARENDRA SINGH.
PERCIVAL THISTLEWOOD.
RONALD ORD CAMPBELL THOMSON.
FRANK THORNTON.
OSWALD TINDALL, B.A. (*Cantab.*).
HAROLD VINCENT TUNALEY, B.Sc. (Engineering) (*Lond.*).
FRANCIS UNDERWOOD, B.Sc. (*Birmingham*).
LANCELOT LESLIE VIGERS.
ALBERT NORMAN WALKER, B.Sc. (*Manchester*).
ALFRED ENGLISH WALKER.
THOMAS HART WATSON.
FRANK WALTER WATTS.
HENRY MORTON WEYMAN.
ERIC WILTSHIRE.
PERCY RAYMOND WORRALL.
MAURICE OKEOVER MOSTYN WYNNE.

The Scrutineers reported that the following candidates had been duly elected as

Members.

JAMES MCKECHNIE.
GEORGE SHAW.

Associate Members.

FREDERICK WILLIAM ANDERSON.
WALTER ANDREWS, Stud. Inst. C.E.
FRANCIS GRAHAM ARNOULD.
ARCHIBALD GEORGE GRANT BARCLAY.
JOSEPH JAMES BARNES, Stud. Inst. C.E.
THOMAS HENRY MAUGHAN BARNETT.
WILFRID PHILIP BARRON, Stud. Inst. C.E.
ERNEST BARRY, Stud. Inst. C.E.
JESSE HAIGH BAXTER.
ROBERT CHAPMAN BRIGGS.
WILLIAM HENRY BROWN, B.Sc. (Engineering) (*Lond.*).
ARCHIBALD GEORGE BUSH.
WILLIAM FRANCIS BYRNES.
COLIN WILLIAM BURNLEY CAMPBELL, B.Sc. (*Glas.*).
JOHN BALLANTYNE CARSWELL, B.Sc. (*Glas.*), Stud. Inst. C.E.
JOHN ALEXANDER CASKIE.
CLIFFORD STILWELL CHASTER.

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HAROLD PERCY CLARKE, Stud. Inst. C.E.
JOHN CLEMISHAW.
REGINALD ALFRED COLLETT.
FRANK JACKSON COLLIER, B.Sc. (Engineering) (*Lond.*).
ERNEST CONNELL, B.E. (*Royal*).
HARRY COTTAM.
PERCY CROOM-JOHNSON, Stud. Inst. C.E.
DOUGLAS CLEAVE CROSS.
EDWARD PERCY CURRALL, M.Sc. (*Birmingham*), Stud. Inst. C.E.
HUGH CHARLES DARBISHIRE.
HORACE FREDERICK DAVY.
ARTHUR LIONEL BROWN DAWSON, Stud. Inst. C.E.
GEORGE WILLIAM DODDS.
FRANCIS MICHAEL WALSHE DOWLEY.
AUSTIN HOOTON ELLIOTT.
ALEXANDER MACARTHUR FINLAYSON.
GEORGE FRASER.
GEORGE MCLEAN GIBSON.
KENRICK DENIS DURLEY GRAZEBROOK.
PHILIP DE HAVILLAND HALL, B.Sc. (*Glas.*).
GEORGE WHITFIELD HALSE, B.Sc. (Engineering) (*Lond.*).
WILLIAM ASHBURNHAM HARRIS.
ROBIN ARDEN HAYES, M.A. (*Cantab.*).
BASIL HEASTIE.
ALFRED RUSTAT HEMSTED, B.Sc. (*Durham*).
GORDON BURNETT GIFFORD HULL.
HAROLD VERNON HUTT, B.Sc. (Engineering) (*Lond.*), Stud. Inst. C.E.
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EDWARD WHITAKER IZARD, Stud. Inst. C.E.
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HERBERT FERRIER JEFFERSON, Stud. Inst. C.E.
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RICHARD DANIEL THOMAS JONES.
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GEORGE BERTRAM LEACH.
ROGER FERDINAND VOGEL LEECH.
ALBERT EDWARD LEEK.
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SHIRLEY ONSLOW LIMBY.
LLEWELLYN NORTH LLOYD.
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PETER DONALD MACFEAT, B.Sc. (*Glas.*), Stud. Inst. C.E.
EDWARD MCLAUCHLAN.
FRANK MAJER.
ROBERT ECKLIN MARRIOTT, B.Sc. (*Glas.*), Stud. Inst. C.E.
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HARRY MILLS, Stud. Inst. C.E.
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LEONARD MOULD ROBINSON.
CHARLES GEORGE GORDON ROBSON.
THOMAS GUTHRIE RUSSELL, B.Sc. (*Glas.*).
FREDERICK WILLIAM SCOTT, M.E. (*Royal*).
HENRY HENDERSON SIMPSON, B.Sc. (*Edin.*).

Associate Members—continued.

JOHN REID SMITH, Stud. Inst. C.E.
ERIC HAMILTON SMYTHE.
WILLIAM FRANK STANTON, B.Sc. (Engineering) (*Lond.*).
GEORGE STEWART, Stud. Inst. C.E.
THOMAS BRUCE STEWART.
HENRY CURRAN STURGEON.
OLIVER HENRY TEULON.
GEOFFRY BARRY POOLE THOMPSON.
RICHARD ALAN STUART THWAITES, B.Sc. (Engineering) (*Lond.*), Stud. Inst. C.E.
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JAMES URQUHART.
LOUIS JOSEPH ADOLPHE VALLET.
WILLIAM GEOFFRY WARD, B.Sc. (Engineering) (*Lond.*).
ANGUS RONALD WHEATLEY, B.Sc. (Engineering) (*Lond.*).
HERBERT LEE WRIGHT, Stud. Inst. C.E.
KENINGALE BERTRAM WRIGHT, B.Sc. (*Glas.*).

Associate.

CUSACK WALTON, *Captain* R.E.

(*Paper No. 4068.*)

"The Transandine Railway."

By BRODIE HALDANE HENDERSON, M. Inst. C.E.

THE idea of connecting the railways of Argentina with those of the countries on the western slope of the Andes was first brought to the notice of the public as long ago as 1854, when a suggestion was put forward to connect the Caldera-Copiapó line with the Argentine railways at, or near, Córdoba. Nothing came of this project, and another scheme was brought forward about 1870, the originators being Messrs. Juan and Mateo Clark, who were also the originators and constructors of the railway from Buenos Aires to Mendoza. The 1870 project was to connect the Cuyo provinces of Argentina with Chile by means of a railway from Mendoza via the Uspallata Pass to Santa Rosa de los Andes, a station on the Chilian State Railways (Figs. 1 and 2, Plate 3). The Cuyo provinces of Argentina had drawn their supplies from, and carried on trade with, Chile over the Uspallata and other passes for many years.

Other projects for joining the two countries are still under consideration, most of which, however, are for crossing the Andes at considerable distances to the north or south of the Transandine Railway. To the north, the main range of mountains is, generally speaking, divided into several subsidiary ranges and, to the south, it is also split up into various ranges or ridges, the passes in the south being generally at considerably lower elevations than the Uspallata Pass, which was the one adopted for the Transandine Railway after investigation of many alternative routes. Since