Discussion.

The Author introduced the Paper with the aid of a series of lantern-slides.

Mr. Harold Savage observed that a considerable quantity of exposed structural steelwork had been used in conditions in which corrosion might be expected to be severe and rapid, and he wondered why steel had been chosen instead of reinforced concrete, even admitting the increased first cost of the latter and the higher cost of foundations arising from the extra weight.

On p. 15, *ante*, one figure was given showing the results of tests made by Pre-Piling Surveys, Ltd ; but further figures would have been of interest, unless all the pre-piling survey results were very similar—which he found it rather difficult to believe in view of the nature of the site.

Although he had used in-situ piling in circumstances where that seemed to be essential, he had a strong preference for pre-cast piling wherever it could be used. The Author had mentioned the difficulties of using pre-cast piling, but they were not insuperable. The trouble with any form of in-situ piling was that if the piling gang were not completely consistent in their work all the time, discontinuity in the pile might result and that discontinuity would be revealed only if there was any occasion to do some excavation afterwards, when it might be found that in some cases there was necking in and in other cases complete discontinuity.

From the Author's statement on p. 15 it rather appeared that a good deal of reliance had been placed on the 3-foot-thick ballast bed maintaining both its thickness and its level, since it was not possible to see what was being done underground in the way of forming a bulb on the bottom of the pile. The answer might be that if the ballast bed were pierced and the bulb formed below it, that was almost as good. The Paper indicated, however, that faith had been placed in forming a bulb on the toe of the pile at the top of the 3-foot ballast bed, and Mr. Savage considered that that gave rather a narrow margin.

He doubted whether the grouting carried out after the bulb had been formed on the pile shoe would, in fact, bond with the pile. If practicable, he preferred to put a tube down through the shell of a pile before filling it. He believed that some discontinuity would be inevitable between the surrounding grouted ballast and the bulb formed on the shoe of the pile.

With regard to the statement (p. 17) that every track was thoroughly tested before being opened to traffic, first with light and then with heavy engines, he was rather alarmed at the result of the test in which one cast-iron pile settled suddenly a distance of nearly 1 foot. Presumably the test was something approximating to the working load, and there was no factor of safety. Even though the difficulties might have been considerable, it would have been preferable to test the piles by means of jacking

to anything up to twice their working load. Information as to the working load would be of interest. The Author had referred to pressure-pile testing by jacking under a load of 50 tons How did that compare with the working load ?

The method of measuring the deflexion was rather rough and ready in view of the small degree of movement which had to be measured.

With regard to the construction of a signal-box on a reinforced-concrete raft, Mr. Savage wondered why, if the ground conditions on the site of the box were similar to those over the area of the station, piling had not been used, since, if those conditions were similar, an appreciable amount of settlement of the raft might be expected, which might cause trouble.

The Author had made a reservation with regard to the cost figures given, and Mr. Savage hoped that nobody would attempt to use them for estimating purposes. Without a fairly complete knowledge of the conditions under which the work had been done, the figures were of no value.

Mr. G. B. R. Pimm observed that the Paper was another thrilling chapter in the grand story of the fight the Railway Companies had made in repairing war damage. He used the term " Railway Companies " advisedly, because they had been the Railway Companies at that time.

He had himself been interested in the preliminary testing of the ground ; and he congratulated the railway engineers very heartily on their courageous decision to use the type of piles described. Whilst he could not agree entirely with Mr. Savage that in most circumstances precast piles were preferable, he appreciated Mr. Savage's reasons, and he therefore felt the decision of the railway engineers was courageous and that credit was due to the contractors for having used the piles successfully.

The nature of the ground had been described. The alluvium counted for absolutely nothing ; then there was the gravel, which possibly was variable, and the Bagshot sand. Once the impermeable surface above the sand had been penetrated with a bore, sand in suspension was brought up, and if it were left to settle, probably something like 9 feet of sand settled out of about 30 feet of water. He quoted those figures from a similar formation nearby. Such conditions called for the greatest care in carrying out the work, since once the sand came up trouble would arise.

Admittedly, if the gravel could be passed through with such a pile, a better bearing value would be obtained ; but the problem was to stop in the gravel and utilize the bearing value of the 3-foot thickness, which was very adequate, having regard to the very compact sand below it, and he congratulated the engineers on the way in which they had met that problem.

Mr. Peter Ryba observed that the great difficulty of the job, from the point of view of the Pressure Piling Company, Ltd., had been the necessity of securing piles either from the top of the platform, which was about 20 feet above mud-level, or from a staging underneath the platform in the case of piles which came directly under a cross member. In addition, it

had been found that, naturally enough, water was present in the boring, which necessitated the use of an air-lock to ensure that the concrete was poured under dry conditions. Therefore, it was not possible to sink piles to a greater depth than 60–65 feet, and that had been agreed upon as their final length, so that the piles stopped in the 3-foot layer of ballast. The ballast was not particularly good, since it was rather loose, and the Company considered that there was a certain element of doubt whether it would be able to sustain the working load. As a result of tests carried out prior to the grouting, the Company had been asked to pour grout into the ballast by means of the 2-inch pipes described in the Paper. That was not done to grout up the piles, as Mr. Savage had suggested, but in order to consolidate the layer of ballast immediately underneath the piles: and it had proved extremely successful, as tests showed that a settlement of only $\frac{1}{25}$ inch was obtained under a load of 50 tons.

With regard to Mr. Savage's preference for driven piles, Mr. Ryba wished to defend the bored pile; he did not think that a 60-foot driven pile could be sunk underneath the platforms. The bulb which was put in at the foot of the pile in the ballast was pressed only with compressed air and the grout could not displace the soil. Therefore, he felt that the bulb could not have penetrated the layer of ballast. A further disadvantage of the driven pile was that although a pile was driven to a set, there would be no knowledge of where it stopped and what was underneath it. In the case under discussion, the strata for each pile had been seen, and it had been possible to vary the length without undue difficulty. As had been pointed out, some waisting could occur; but that was extremely rare and no failures due to waisting had been experienced by the Company.

The sum of 87*s.* 10*d.* per foot represented the all-in cost paid to the Company. Of that sum, something like one guinea per foot was the cost of the grouting and a further 9*s.* per foot was the cost of all the testing and extraneous items. The cost of the piling actually worked out at approximately 57*s.* 10*d.* per foot, including the erection of stagings, etc., and, although that was extremely high, he considered that it was not excessive having regard to the conditions. He was surprised that the cost of the driven piling was rather higher; that was unusual, but might have been due to the particular nature of the job.

Mr. J. H. Mahy observed that he believed that the piles were purely friction piles; perhaps that was why the Author had not mentioned the information obtained in driving them when considering the type of piles to be used underneath the Harbour station.

According to the results of pre-piling surveys, the value of friction was very small indeed, and if the new piles had been friction piles, would they generally have withstood the bumping of ships?

He was rather puzzled about the depth of the screw piles in the old work. The Author had stated that the piles were believed to go down to about 60 feet below sea-bed-level; but the new footbridge piles were

driven to about 55 feet below the sea-bed and the bored piles showed gravel at about 55 feet. Mr. Mahy had had no experience of driving screw piles, but he knew that it was very difficult to bore through gravel and he doubted the practicability of screwing a screw pile through gravel.

A point which might have some bearing upon that was the question why the footbridge piles were of pre-cast concrete and the other driven piles were of steel. The Author had not given the reason for that. Moreover, the steel piles were driven considerably deeper than the footbridge piles. Perhaps there might have been some notion that, where the steel piles were to be driven, the layer of gravel might peter out, thus not allowing bored piles to be used; and there might also have been some indication that they would have to be deeper than the other driven piles.

With regard to the repair of screw piles, the Author had stated that in suitable cases they were filled with concrete, but he had not mentioned whether any reinforcement was put into the concrete. The operation was similar to that of putting the reinforcement in a pressure pile. The diameter of the tubes seemed to be about 16 inches and, if there were blockages, perhaps they could be pushed down or, alternatively, the reinforcement could be put down as far as possible, and would certainly be better than nothing. Such reinforcement might have obviated the failure under test which was reported in the Paper.

The load underneath the collar which was used as a precaution would be about 1 ton per square foot. It was not stated exactly what the load on a pile would be, but the pressure piles were tested to 50 tons; apparently there were two pressure piles underneath one screw pile, and with a test load of twice the working load, that would mean about 50 tons on the screw pile and 50 tons on the collar. On such bad ground a load of 1 ton per square foot might lead to quite rapid settlement, and the removal of the live load might not perhaps remove much of the load from the pile. What would be the plan of campaign if such a thing were to happen?

In grouting the base of the pressure piles a 2-inch tube was driven down on either side. How had that tube been driven down and, particularly, how had it been driven down straight? Such a tube might deflect several feet in being driven, and that would be a serious matter.

Mr. E. J. C. Reed observed that, generally speaking, the work described in the Paper had been carried out from the land towards the sea, which fortunately during the whole time had not been really rough; and since the harbour was very well protected, the water was never more than choppy even in the worst weather.

One trouble had been the almost complete lack of storage room. Everything had to be brought into Fratton yard and then once a day a few trucks at a time were brought in for off-loading. The trucks had to be turned round quickly and it was not permissible to retain them in Fratton yard for any length of time. The contractors, therefore, had to

plan their programme very carefully so that the material came in when it was wanted and for the place at which it was wanted. Deliveries during stage 1, up to the 1st June, 1946, were fairly good, but in stage 2 they were not so good, chiefly owing to the late delivery of rolled steel from the mills.

A good deal of surveying work had had to be done before any of the steel could be fabricated for the deck. The railway staff had marked the central line of the track on heavy cross girders, whilst Messrs. Dorman Long & Company had taken a large number of dimensions and cross dimensions in order to determine the length of the cross girders and rail-bearers, especially on the curved portion, and had obtained an exceptionally good alignment.

Much useful information had been obtained from the pre-piling survey. Proceeding seaward, the layer of ballast and the layer of the Bagshot sands became lower. Mr. Reed had tried to obtain some information about the depth of two of the old piles. Some of the girders had been taken off and, as the piles on that particular site were hollow, it had been possible to measure down to the bottom of them. He could not give their actual depth, but he could state that they did not even reach the layer of ballast, and were still founded about 6 feet or more above it. He considered that it would have been very foolish to found the pressure piles anywhere but in the ballast, and the Pressure Piling Company had been very insistent upon that. Below the ballast there would be about 8 feet of fairly hard mud, and below that there was sand. Borings had been made into the sand, and in each site it was known where the sand actually was. In every case the sand boiled up into the tube. If a pressure pile were taken down to the sand, boiling up in the tube would occur, and, with the soft bottom, it would be necessary to hammer the pile afterwards to consolidate the sand.

Tests made on the first two piles before they were grouted had shown rather more settlement than was liked, since it meant that from time to time it might be necessary to pack up the girders off the piles in order to restore the rail-level. That was undesirable, and therefore the Pressure Piling Company had agreed that the ground should be consolidated. The Contractors had two pipes (each with a loose pointed shoe), one on either side of the pile, down to the ballast, the level of which was easy to determine. After that the tube was lifted about 4 or 5 inches so as to clear the shoe, and then the grout was forced down under a very low pressure. Mr. Reed believed that to be the secret of the success achieved because, instead of blowing a hole in the sand, the grout permeated all round in the ballast. The good result was very evident from the marked difference in the subsequent behaviour of the pile under the heaviest locomotive load. There could be no question that it strengthened the bearing capacity of the pile very considerably, and all the piles were similarly treated.

The Author had stated that for the footbridge piles two pre-cast sections

were joined together. Mr. Reed agreed that it was right to have the bottom part pre-cast, but he would have preferred the other part to be cast on from that to the top instead of having to make a joint between two pre-cast sections. The joint had been made successfully, and in the end they had come outside the ordinary line of the pile on each side by about 4 inches, with additional reinforcement, and care had been taken to see that the concrete came hard up against the under-side of the top section.

In driving those piles care had been taken to safeguard the joints as much as possible; insistence had been placed on the driving being effected with a very small drop until near the final set, when the full 4-foot drop was given. Mr. Reed could not say what had happened to the pile that was broken, because he had not been there; but he considered that if re-driving was necessary after a fair period of rest with a pile, it should be done with a very small drop and driving should be continued until the pile started to move: if it did not start to move, one ought to think again, and not drive it any more. If any doubt remained as to the bearing capacity, a test should be made on the pile.

All the driven piles were taken down to the sand, the position of which was known from borings. Seaward the friction was less and the pile pulled up sharp; it was known from another boring that the sand was about 18 feet thick, and it was very resistant to driving. Inland the friction was considerably greater.

Mr. Conrad Gribble observed that until the middle of 1946 he had been in charge of the work at Portsmouth, and before the war the Southern Railway Company had done a great deal of work at Portsmouth harbour. Many piles were driven for the new station buildings and for the jetty, all pre-cast piles, ranging from 60 feet to 65 feet in length—and they had proved quite satisfactory.

The only case in which screw piles were driven was not at Portsmouth, but on the other side of the Solent, at Ryde, where a new jetty for an extension of the pier station had to be made in the same strata. After being driven a certain distance the screw piles had tended to rotate without sinking and it had been necessary to add a considerable quantity of kentledge to cause them to continue to sink. They had been entirely satisfactory, and no settlement had occurred. If he remembered rightly, those piles were 50 feet or 60 feet long.

One feature of all the piles driven, both at Ryde and at Portsmouth, was that sometimes a pile would not give the set required. It was found, particularly at Ryde, that if driving were stopped for a week, the pile could hardly be moved and that further driving was unnecessary. That was due entirely to friction in the silt and sand.

With regard to Mr. Savage's comment about the type of structure, it should be borne in mind that the object of the work was not to renew the whole of the station. Mr. Gribble had often wished that no viaduct was there and that the whole site had been filled when the railway was con-

structed. The piles carrying the station had given trouble in the past. A section of the piling across the station was liable to settlement and had to be packed up periodically. It would have been very desirable to build a more permanent type of structure, but that simply had not been possible. Time did not permit of rebuilding the whole structure in reinforced concrete ; it was necessary to make as much use as possible of what was left, and to renew the station very much in its present form. The precaution was taken, however, of making it fireproof by building concrete platforms and a roof of steel and non-inflammable materials.

It would be understood that all the repairs to the girders where the webs were buckled would not have been carried out if it had been possible to obtain new steelwork. The reason for salvaging girders was that time was vital ; the management had given orders that the station should be ready for traffic by a certain date, and that had to be done.

At the site of the signal-box the ground had been carefully examined and was considered to be capable of bearing the box, which was a very considerable structure, with a concrete raft : that had proved quite satisfactory, and was far quicker and cheaper than a piled foundation would have been.

The Author, in reply, stated that Pre-Piling Surveys Ltd. had made a number of graphs which gave valuable information, but limitations of space had prevented reproduction of more than a typical example. Mr. Savage's alarm at the result of the loading test in which a pile settled nearly 1 foot could not be greater than that of the Author, who had been under the engine ! The pile in question, which was near the place where a bomb had fallen, was suspect, and was examined very closely, and a fracture was found just above the flange joint at about mud-level. The fracture was repaired and stood all right. Digging to a depth of about 6 feet all round the pile showed no sign of any other damage, and the conclusion was arrived at that the pile was sound. It was impossible to say what had happened to the screw blade beneath, because it was not possible to get at it, and that was the reason for a loading test. The engine weighed 135 tons and the load on the pile was about 50 tons at the time of the failure.

The general working load on the piles varied considerably, but in the case of a single track, as in road No. 3 the load was between 50 and 60 tons per pile. On roads Nos. 1 and 2, where a centre pile came between the two tracks, the load was heavier—in some cases more than 100 tons per pile : that was by far the heaviest load.

In measuring the deflexion of the piles by level and staff, the level was stood well away from the road which was being tested, in order that it should not be affected by the possible settlement. That method had been found to be reasonably accurate, and the Author had no reason to be dissatisfied with it.

He agreed with Mr. Gribble and Mr. Reed that driven piles taken

down into the sand were very satisfactory. He would have liked to use those throughout, but it should be realized that at the time of carrying out the work on stage 1, the fate of stage 2 had not been settled. All the old roof steelwork was there, and it would have been very difficult to drive piles. The steel piles were driven after all the roof steel had been removed, and the driving was therefore a much simpler operation.

He had examined the driving records of the landing-stage piles which were driven in 1936–37 ; but the jetty piles did not carry a track load and their load was more or less distributed. They were not driven to the same set as the track piles had to be and, although he would not say that they were purely friction piles, more reliance was placed on friction than in the case of the track piles.

With regard to the point about the footbridge piles being driven apparently at a higher level than the old piles, the ground sloped downwards to the sea, and the nearer the piles were to the land, the less was the depth to which it was necessary to drive them.

Pre-cast concrete piles were used for the footbridge and steel piles elsewhere. The reason for using the steel piles was that four piles were wanted in a hurry, and Messrs. Dorman Long made the steel piles and drove them in a very short time. A removable cap was placed on the top of each pile and, the pile was driven without any trouble or damage ; when the cap was removed the head of the pile was perfectly sound. All joints were site welded. The piles were filled with reinforced concrete because it was realized that corrosion would occur in time ; consequently, if the steel shell rotted right away, a pile would still be left.

The concrete collars, 7 feet 6 inches square, were put on as a temporary measure. It was considered that if any pile was going to fail, it would do so soon, and it was believed that the collar would hold up long enough for the load to be removed. The collars were a safety precaution and they were not intended to last for longer than the preliminary period during which sudden pile failure below the sea-bed-level might take place.

The effect of heat on the girders had not been mentioned in the discussion. The girders had been heated to a very considerable degree during the fire, and that aspect had been investigated in three ways. Test-pieces taken from girders damaged beyond repair were broken on a testing-machine ; microphotographs were examined and reported on by the Railway Company's chemist, and loading tests were carried out on selected girders. The laboratory results revealed perfectly normal wrought-iron characteristics ; the average properties of the metal were well within the normal limits for wrought iron, and during the site tests the girders behaved in a fully elastic manner, with no residual stresses after removal of the load.

Finally, although the Author had been privileged to present the Paper, the completion of the work had been a matter of teamwork, and he wished to express thanks for the willing assistance and co-operation he had received from all those who had been associated with him.