

Discussion

Mr J. L. Raitt who had been the member of the Directing Staff of the Civil Engineer-in-Chief's Department responsible for works items at R.N. Air Stations, said that the three fundamental requirements for carrying out the work by direct labour—namely, (a) a capable engineering staff ; (b) adequate and suitable mechanical plant ; and (c) a supply of suitable labour—had all been available.

As a result of the war in the Far East, the Department possessed adequate mechanical plant of a heavy civil engineering type, but it was in varying condition owing to financial stringency on repairs ; and it had been necessary to purchase some special machines as a charge to the job.

There were about 160 main items of heavy plant comprising excavators, tractors, dumpers, concrete-laying and finishing plant, rollers, compressors, cranes, pumps, and the necessary transport vehicles.

One of the first requirements at Belfast had been the setting-up of a local plant-repair depot capable of doing all the normal running repairs and some larger ones. It included a large workshop, a machine shop, a welding and blacksmith's bay, a general store, an inflammables store, a plant and spare-parts store, and offices. They had occupied a covered area of about 16,000 sq. ft. There had also been about 6,000 sq. ft of hard standing, and 1,000 sq. ft of concrete wash-down area.

Those facilities had been under the direct charge of a civil engineer and manned by one foreman of plant, one leading man or chargehand of plant, one leading fitter, five fitters, one turner, one welder blacksmith, and about 70 artisans and operators.

Details of all the types of plant used and of the difficulty (arising out of their extended use) of keeping them running, would be too extensive to present.

Practically all those machines had been charged to the job on a weekly rate basis which approximated to two-thirds of the Contractors' Plant Association rates.

Some weekly consumption figures were as followed :—

Diesel oil :	750 gal per week
Petrol :	750 " " "
Heavy-duty oil :	40 " " "
Gear-box oil :	40 " " "
Spirex extra-pressure oil :	5 " " "
Gas Oxygen :	4 bottles per week (480 cu. ft)
Acetylene :	2 " " " (400 cu. ft)

Some details of costs were given in Tables 2, 3, and 4.

The repair figures given in Table 4 represented 85% of the total cost of plant repairs, the remaining 15% being for miscellaneous repairs and non-weekly-rated plant.

That cost represented 3.15% of the total cost of the work (£701,000) executed between April 1952, and June 1954, and he thought that it was a very reasonable outlay for a highly mechanized job with very hard conditions for many of the machines.

TABLE 2.—COSTS OF EXCAVATION OF QUARRY REFUSE
(Average rate of working machines with crowd shovels : 45 cu. yd/hour)

All-in cost of operating machines per hour		Remarks
Item	Cost : s d	
Repairs and renewals	4 3	Cost of excavating and loading at quarry : $\frac{20.25}{45} s = 5s 4d$ per cu. yd, excluding royalties
Fuel and lubricants	1 4	
Operator's basic wage	3 8	
Weekly rate of plant	11 0	
Total	20 3	

TABLE 3.—CONCRETE MAKING AND LAYING COSTS
(Output 120 sq. yd/hour 8 in. thick = 27 cu. yd/hour)

All-in costs per machine-hour worked			
Item	Repair costs :	Fuel costs :	Totals :
	s d	s d	s d
Batching plant	14 9	7 10	22 7
Machine laying :—			
Distribution	2 3½	1 2	11 3
Vibro-finisher	2 2	1 5	
Joint-cutter	3 0½	1 2	
Totals	22 3	11 7	33 10

Note :—Repair and fuel costs combined = $33s 10d \div 120 = 3s 4d/sq. yd$ to be added to labour and materials and depreciation for unit cost of concrete.

Mr L. J. Colyer said that the decision to extend the runway had been made in the early part of 1952, and shortly afterwards the Admiralty had agreed to make the existing runway and the extension strong enough to bear the weight of the Comet. At that time very little had been known about the strength of the existing runway, the bearing capacity of the sleech base, and the composition of the 200-ft-wide embankment which had been tipped by the Belfast Harbour Commissioners. A series of plate

TABLE 4.—REPAIR COSTS OF MECHANICAL EQUIPMENT

Machine	Percentage of available working time spent under repair	Cost per hour worked:	Hours worked	Remarks
		<i>s d</i>		
Excavators	8.5	4 2	16,700	Fair and reasonable
Dozers	19.5	5 4	20,000	All experienced heavy wear on tracks and transmission. Cost and incidence considered high
Rollers	13	1 7	22,000	Clutch and transmission troubles due to bad ground, etc.
Compressors	12.5	1 8	10,000	Normal
Concrete-laying Machines :—				
Distribution	}	2 6	6,500	New machines
Joint-cutter				
Vibro-finisher				
Batching plant	4.6	4 9	5,500	Clutch trouble and top overhauls due to inexperienced operators
Portable mixers	12.5	3 9	3,500	Normal
Dumpers	8.9	1 4	35,000	
Total for all heavy plant	11.1	2 10	118,500	Reasonable in the circumstances

bearing tests had been put in hand on the existing runway and the sleech base, and mobile tests had been made in various places along the embankment of town refuse.

The results of those tests had been that :—(a) the existing runway had been found capable of supporting aircraft of approximately 50,000 lb. all-up weight ; (b) the safe bearing capacity of the sleech had been found to be only 200 lb/sq. ft at a deflexion of 0.1 in.; and (c) the embankment of town refuse had been found to be extremely variable and in its original state totally unsuitable to act as a base for a runway without further compaction and filling.

From those test results it had been reasoned that it would be necessary to spread the 50,000-lb. wheel-group load of the Comet over an area of approximately 400 sq. ft to ensure that the sleech was not overstressed and, in order to achieve that large spread of load, it had been considered necessary to provide twin 8-in. concrete slabs laid in 20-ft × 20-ft bays with joints staggered on shallow filling on top of the sleech as the basic minimum. That design basis had worked in conveniently with the existing runway where the original bay sizes had been 40 ft × 20 ft, but had to be varied on the first part of the extension in order to reduce the size of the slabs,

thereby minimizing the danger of the slabs cracking into quarters. The spread of load from those smaller slabs had been increased to the desired minimum by laying the slabs on 3 ft 6 in. of compacted hardcore, which also provided a satisfactory foundation for the operation of the concreting plant.

At the design stage it had been considered possible that the intersection of the edges of the upper and lower concrete slabs might prove to be a point of weakness in a pavement laid on such a weak subgrade, and provision had been made in the design for a third slab to protect that potential weakness; it had, however, been decided to make tests during the course of construction and to omit that third slab if possible. The subsequent plate bearing tests on the twin-slab pavement had shown a nearly uniform strength at the edges, corners, and centres of the slabs, and adequate overall strength to bear the weight of the Comet, so that the third slab had been omitted.

As an alternative to the twin-slab concrete pavement, it had been considered necessary to have at least a 10-ft-thick flexible pavement in order to spread the load, and, in the case of the remainder of the embankment, that depth existed. However, since the embankment consisted of uncompacted town refuse of a very variable nature, it had been considered necessary to strip off the top 4 ft of the embankment and to compact the remainder as well as possible, excavating all soft spots and refilling with compacted hardcore where necessary, and then to replace the top 4 ft of the embankment with compacted hardcore, finishing off with a tarmac-and-asphalt surface.

The graph shown in Fig. 3 had been followed closely on site; further compaction and excavation, and back-filling of soft areas had been undertaken when the values were not reached at any level; and, as would be seen from the results given in Fig. 9, the required strengths had been obtained.

Mr Collyer said he had deliberately omitted any reference to Load Classification Numbers because he considered that with a very deep flexible pavement the effect of different sizes of tires and groups of wheels was to a great extent lost in the large dispersal of loading which took place and that, as a consequence, the only important design factor for those deep pavements was the total load from the wheel group. Likewise, plate bearing tests made on the twin-slab pavement at Belfast with similar loads carried on various sizes of plates and groups of plates had shown a similar deflexion of the concrete pavement, which again indicated that all-up weight and not Load Classification Number was the most important factor for those types of pavement on very weak subgrades.

Mr D. H. Little said that the things that interested him most were the sleet and the twin slabs. The word "sleet" was peculiar to Belfast, but the material described occurred throughout the world. The same seam ran across the north of the British Isles and reappeared in the Glasgow

and Edinburgh districts. It was found as alluvial silt in the River Thames, at Portsmouth, at Chatham, at Plymouth, and in the Bristol Channel; similar material was found in Sierra Leone, and in Shanghai.

The Authors had stated that the shearing stress ranged from 70 to 350 lb/sq. ft, but he would have said that a fair figure was 150 lb/sq. ft, and that the safe bearing pressure on a foundation should not exceed, say, 3 cwt/sq. ft. Sleech was thus a very fluid material, and yet, by using twin slabs, it had been possible to build a runway on it to take a load of 72,000 lb.

The function of a twin slab in concrete was to eliminate the edge- and corner-load effects, leaving only the centre-load effect to be considered. It could then be regarded as a straightforward foundation and, if the stress was distributed over the whole ground area, the maximum bending moment was $W/8$. The effect of the support given by the second slab could be taken as reducing that to $W/10$.

If the slab was so large that the spread of stress did not reach the edge of the slab, then it behaved as a built-in beam, the unstressed periphery holding down the rest of the slab. The value for the bending moment in one slab was then $W/16$ and, including the two slabs, the lowest bending moment was $W/20$. The range of bending moment was therefore from $W/10$ to $W/20$.

Both the nature of the ground and the size of the slab influenced the bending moment. It had been stated that on the old runway at Belfast the existing bay size was 40 ft \times 20 ft, and that the new slabs were of the same size. A previous speaker had implied that they were only 20 ft \times 20 ft. Which was right? For the larger size the average pressure on the ground for a 72,000-lb. load was only 90 lb/sq. ft, and even on sleech could not spread over the full 40 ft \times 20 ft, but would probably only be drawing on the inner 15 ft, so that the slab would behave as a built-in beam and the bending moment would be $W/20$; for an 8-in. double slab the stress in the slab would come to 340 lb/sq. ft. In his view, there had never been any reason to consider having two new slabs on top of the existing one.

On the extension portion the slab size had been reduced to 15 ft \times 15 ft, and the average pressure from the 72,000-lb. load was 350 lb/sq. ft. In the sleech area, therefore, it would have to be assumed that the whole slab was loaded, and the bending moment in the slab would be $W/10$, which gave a stress of 680 lb/sq. in.

Had any plate loading tests been made on the slabs in the extension area? He thought it had been a mistake to reduce the bay size to 15 ft \times 15 ft. If it had been 20 ft \times 20 ft, the ground pressure would have been only 180 lb/sq. ft, and he thought the bending moment then would have had some intermediate value between $W/10$ and $W/20$, possibly $W/15$, and for a 72,000-lb. wheel load the stress in the concrete would have been 500 lb/sq. in.

From the work which he had done and from the work described in the

Paper, Mr Little was quite convinced that a slab could be safely designed on that basis. It was a very simple basis, but he believed that it was reliable so far as static load was concerned. All that had been dealt with in the discussion had been the effect of applying a single load through a jack onto a slab. What was unknown was the effect of continued application of loads. Were those twin slabs going to rock against each other? Was the ground going to sink? Was the bottom slab going to project into the middle of the top slab and cause the top slab to break its back? He did not think that the answers were known because none of the runways yet had really had extensive repetitions of loading.

He felt, however, that the twin slab, of the right size, was the answer on indifferent and bad soils. Could the Authors give more information about the separating medium that had been adopted? He believed it had been Sisalcraft, but felt that such a thin separating medium did require the bottom slab to be of such a fine finish that perhaps something like a roofing felt, which was a little thicker, would be better.

Mr G. L. Hargreaves (Superintending Civil Engineer in charge of the Chatham Works District, Civil Engineer-in-Chief's Department, Admiralty) said that he could claim to have some acquaintance with sleet, since he had been the engineer responsible for building the repair yard. As had already been said in the discussion, sleet was fairly common, particularly at the sites of naval and other establishments built on tidal estuaries.

As the Authors had stated, the sleet dried rapidly in the upper few inches, and cracked, crazed, and laminated, becoming quite a different material. A foot or so down, it was like jelly, but when dried out to lose quite a small percentage of its weight it became almost an ash-like material, capable of sustaining a considerable load.

Mr Hargreaves had had an opportunity of carrying out on a small scale some experiments to find out whether it was practicable to turn the sleet, by loss of water, into something useful as a structural material. From them he had concluded that if the sleet was excavated, spread thinly over an area, and allowed to lose its water by evaporation, it could, in the course of a few weeks, be converted into a usable material. He mentioned that because during the experiments he had noticed that, even in wet weather, the sleet lost water by evaporation more rapidly than it gained it from precipitation.

Although possibly not applicable at Belfast, he suggested that it was possible to use sleet as a road or runway foundation by first excavating a shallow layer, spreading, air-drying, and re-laying it on top of a water-proof membrane to prevent re-absorption of water by capillary action. The surface would, of course, have to be sealed.

Mr C. E. Loveridge asked if there was any danger of the embankments sliding outwards on the sleet.

Mr J. M. Fisher noted that on p. 554 the Authors had stated that the specification called for concrete having a minimum strength of 4,000 lb/sq. in. at 28 days, and that, assuming very good control with weigh-batching and moisture determination on aggregates, the mix was required to be designed to give a strength of 5,300 lb/sq. in. at 28 days. On p. 557, where the Authors gave an analysis of the results of the tests, it was stated that the average strength was 7,000 lb/sq. in. at 28 days and that no result fell below 5,300 lb/sq. in. That indicated either that the Authors had based their mix design calculations on too meagre evidence of the probable strengths which would be attained on site, or that the batching of the concrete always resulted in a mix a good deal richer than intended. A check on cement consumption, related to the output of concrete, would have revealed such an error.

The cubes indicated that the concrete had a consistent density of 160 lb/cu. ft. That seemed to be high, even allowing for the fact that basalt had been used as the coarse aggregate. Basalt, generally speaking, had a specific gravity of about 2.7 to 2.75 and using the upper figure, the bulk density of the concrete, assuming no air voids in the concrete, would be about 155-156 lb/cu. ft. Had all the aggregate been of the same specific gravity then the bulk density would be about 158 lb/cu. ft. How had the Authors managed to compact the concrete to such a density?

The figure of 7 min quoted by the Authors as the average time required to cut through an 8-in. slab of unhardened concrete with the vibrating joint-cutter indicated an inordinately slow rate of cutting for such a machine. It had been found on other works that, provided the frequency of vibration was at the specified figure, joints could be properly cut in less than half that time. Such a slow rate of progress would suggest that the machine was not functioning correctly or that the concrete had stiffened very considerably when the joints were cut.

Sir Arthur Whitaker (Partner in the firm of Livesey and Henderson, Consulting Engineers, London) said that he wished to refer to one or two points that Mr Greenaway had made when introducing the Paper. The Chairman had remarked that the job was one that called for the power to assume responsibility, and for a spirit of adventure in civil engineering. He thought that Mr Greenaway had implied rather that at Belfast the responsibility had been extended a little farther than was perhaps normal. Having been Civil Engineer-in-Chief at the Admiralty at the time, Sir Arthur wished to say that an individual was always given as much responsibility as he would take. There were many people who would not take responsibility, and who hesitated to do so mainly because they were afraid of repercussions, but he thought it would generally be found that if a person was willing to assume responsibility, he would be allowed to take it. The fact that Mr Greenaway had delegated a lot of responsibility merely confirmed that the staff at the site had been well chosen.

He wished to say a few words about sleet. He did not altogether agree with Mr Little that the sleet was the same at Belfast as elsewhere, for in his younger days Sir Arthur had had early acquaintance with the equivalent of sleet at Rosyth, and he could say that the worst of the Rosyth sleet was only the average of that at Belfast. At Rosyth after a while they had been able to build on it with quite heavy buildings.

Mr Greenaway had also said that the runway had not subsided at all during the year or so since its completion. Personally, he would have expected the sleet to have dried out. Apparently it had not done so because that would have caused a certain amount of settlement. The question that arose, therefore, was whether the sleet could be expected always to remain in a sort of semi-fluid condition. If so, the problem became one of confining the sleet in its position and putting on it such loads as it could bear. In the Paper the Authors had shown how the use of hessian had been quite successful in confining the sleet.

It might be asked why such a site had been chosen for an airport. He noted from the Paper that when the Air Ministry had taken over the airport there had been only one east-west runway and only a portion of it was in concrete, the remainder being cinders. Undoubtedly the aircraft of that time had put a light load on the airfield. The Admiralty, of course, were vitally interested in having an aerodrome sited alongside deep water where a carrier could come alongside; that had led them into the adventure of paying the cost of providing a big runway on such a site. There was, moreover, the Short and Harland factory, and he would like, on that point, to ask the Authors what had been the experience in the flying-off of aircraft straight from the factory. He understood that they came straight out of the factory without any trials whatever and were flown off.

He believed that the prevailing wind was from the Belfast end of the runway to the sea end. Did the aircraft limit their taking off to flying to the west, or was there ever any experience of flying eastwards on that particular runway? There was quite a difference, of course, because one started from the narrow runway and worked out on to the big aerodrome.

On the question of labour, it was a fact that there had not been much skilled labour available, but the unskilled labour had been of rather a higher grade than was usual. Whether that had been because of a scarcity of jobs in Northern Ireland he did not know, but when he had visited the site about 2 years previously the labour had been quite good.

* * **Mr W. T. Shaddock** observed that the reference made by the Authors to the establishment and maintenance of good relations between management and labour was to be welcomed, since information on that aspect of the civil engineer's professional activities was rarely given in Papers describing the execution of engineering works. The quality of such

* * This contribution was submitted in writing after the closure of the oral discussion.—SEC.

relations might well have a considerable influence not only upon the achievement of satisfactory standards of work but also upon the cost of construction and the time taken to complete the work. Any one of those factors might, on occasion, assume more than ordinary importance.

With regard to the periodical broadsheet would the Authors furnish some additional details on such points, for example, as :—

- (1) Responsibility for preparing the text. Did that fall upon a civil engineer? Was there any collaboration with laymen?
- (2) Frequency of issue and method of distribution. Was it issued with the men's pay or was some other method adopted?
- (3) Cost of production.
- (4) Reaction of recipients. Was there any indication, in the way of criticism or questions, of enhanced interest in the common purpose?

Mr Shaddock would be interested to see some extracts from the bulletin reproduced in the Proceedings as examples of what was considered to be a suitable form for presentation to the specialized class of reader.

Mr Greenaway, in reply to Mr Raitt's remarks about the war-time plant, said that its maintenance had been a major problem, particularly in the early stages of the work.

Mr Hargreaves had drawn attention to the large increase in the strength of the sleet with a reduction in moisture content and the Chairman had referred to sand-piling. Mr Greenaway thought that, provided the moisture content of the sleet was not too high, there was the possibility of using the sand-piling technique but it would have been limited to quite a small area of the original reclamation.

Mr Loveridge had inquired about the stability of the side embankments. The base of those embankments was about 60 ft and Mr Greenaway thought there was sufficient weight in them to justify the absence of qualms about their stability.

Mr Fisher had taken the Authors to task regarding the design of the concrete mix. He could rest assured that a considerable amount of preliminary work had been done, taking account of the aggregates available, and that during the work checks had been made on aggregate/cement consumption. For airfield pavements a 7 : 1 mix was not a rich mix and as the Authors had mentioned in the Paper they had been deliberately cautious, since, until cores had been taken they did not know the relation between the in-situ concrete strength and the test-cube strengths.

The joint cutter was not a British machine and that might account for the difference in operating times.

Sir Arthur Whitaker had referred to the delegation of responsibility. In his introductory remarks, Mr Greenaway had not been thinking about the Admiralty work. Earlier in his life he had come across another direct labour job which seemed to be completely frustrated because nobody could

make any decisions. In the case of the Belfast runway, he thought they had had all the authority they needed to get on with the job; in fact, he could recall only two occasions of reference back to headquarters: one was on the question of omitting the third slab and the other was in connexion with shifting the longitudinal drains under the runway to the outside. There had been the authority necessary to get on with the job, and that in turn had been delegated down at all levels.

With regard to settlement, he still thought that, with a reduction of moisture content which must come, there was bound to be ultimately some settlement on the site. He thought that the presence of the side embankments had possibly retarded the movement of the pore water, which had resulted in no settlement appearing to date.

With regard to the flying-off of aircraft, unfortunately neither of the Authors had been to Belfast since the completion of the job, but he believed that they flew off in both directions.

Mr Callagin, commenting on Mr Raitt's remark about the supply of labour, said that out of 260 men only about ten were trained when taken on, and all the rest had been trained on the job. He thought that Sir Arthur Whitaker was correct in saying that the Irish labour had been good. It was so for purely manual operations, but had needed a lot of training for that particular work.

Mr Raitt's figure of 5*d* as the cost per cu. yd at the quarries was a good average. The figure had varied on spot costings from 4*d* to 8*d*, depending entirely on traffic jams in the city of Belfast. That had applied to many of the costs; all the quarries were about 9 miles away and it had been necessary to pass right through the centre of Belfast with everything that went to the site.

In reply to Mr Little, the slab had been 20 ft \times 20 ft and not 40 ft \times 20 ft. Plate loading tests had been taken on the 15-ft \times 15-ft slabs, but some research would be necessary to find out the results of those tests.

The separating medium had been sisalcraft. The blade of the finishing machine had left a very smooth finish, and they had then drawn a soft brush across it to give a fine hair-finish to the job. In addition to sisalcraft, bitumen emulsion had been used and had helped to make a better separating medium.

With regard to concrete quality, referred to by Mr Fisher, the specific gravity of the basalt in the area was higher than 2.7—it was about 2.9—and the resultant concrete averaged between 158 and 160 lb/cu. ft, the highest result being 166 lb/cu. ft, as measured by Queen's University. The strength had come out at more than the Authors had expected. They had aimed at 5,333, whereas they had achieved 7,200 lb/sq. in. They had always been trying to get a cheaper mix, but they had never been very sure that one could take a concrete cube and say that that was what was being obtained in the slab. They had been patiently waiting for a core cutter

for the concrete, but they had not got it until very late in the job—otherwise, they might have been able to economize on the mixture rather more than they had done.

With regard to Mr Shaddock's observations, the Authors had written the broadsheets themselves and were more or less finding their way with them. The first had been produced about 6 months after the work had started, and 4 or 5 more had been issued thereafter at about 2-monthly intervals. The production costs had been negligible; about 200 copies had been duplicated and given to the chargemen for distribution. It was difficult to assess the value of such publications, but all the evidence from the site and from the men's Trades Union representatives indicated that they were welcomed and received with great interest. Quite a number of references had been made to them by the men and one or two suggestions for better working methods had been received. With regard to the works, the Authors felt the broadsheets had contributed to unity of purpose, and assisted with output and the quality of the work. On any future large works they would certainly be in favour of issuing broadsheets regularly right from the beginning of the job.

The most difficult task at all times was to present the broadsheets in such a form that they were easily readable and could be understood by all concerned. Instead of reproducing extracts from the various broadsheets the Authors felt it would be more helpful if they set out briefly the principles they had followed.

The first bulletin had aimed at putting the men "in the know" regarding the nature and scope of the work, high-lighting the salient features and giving perspective by simple factual information, i.e., building up the ground on which the men could just stand by filling so that it would support a 50-ton aircraft; to do it half a million tons of filling would be brought to the site. A brief outline of the construction programme had also been included. Subsequent issues dealt with the position at the time and explained how any unusual impending operations would be carried out and what was expected of the various gangs. Progress on various sections of the work would be given competitively and target dates announced. The Authors had had no hesitation in drawing attention to any shortcomings with regard to quality of work and likewise had given commendation when due.

The closing date for Correspondence on the foregoing Paper has now passed without the receipt of any communication.—SEC.