Special features of Hamilton By-Pass Motorway (M74)

J. PATON, D. D. FRASER & J. B. DAVIDSON

Mr J. Paton

At its northern limit as now constructed the M74 Motorway described in the Paper reaches within 2 miles of the Glasgow city boundary or about 7 miles from the city centre. Considering the semi-urban nature of much of the area traversed, the clearance of property was remarkably low. There were only 14 inhabited dwellings affected in the total length of 14 miles. The price which had to be paid for land and buildings was minimal but not so the cost of the earthworks, as the route which had to be followed traversed the soft alluvial deposits referred to in the Paper for a cumulative length of 6½ miles.

95. With a view to assessing the advantages of the technique referred to in §§ 49 and 50, strain gauge readings have been repeated at regular intervals since the concrete deck of Raith bridge was cast.

96. After approximately one year's service recent readings indicate that the concrete compression at mid span is now of the order of 200 lb/sq. in. and over the supports approximately 40 lb/sq. in. thus confirming that the prestress induced has been sufficient to counteract the effects of creep and shrinkage.

Mr D. D. Fraser

I would like to mention the flooding problem in the Hamilton Low Parks. With a normal maximum flood of 50 000 cusecs, the whole area is inundated. Even with much smaller floods of the order of 20 000 cusecs, the extent of flooding approaches quite closely to what is shown here, and a flood of 20 000 cusecs is the type which can be met with in this area on an average of about once every year or two years. It will be seen from this that it was essential that the motorway and the interchange and the slip road had all to be built on embankments to keep the works above flood level.

98. The 10 in. composite base was found to be the most economic for this motorway and, I believe, has proved to be the most economic for motorways in Scotland generally. Bitumen bases have not so far been used to any great extent except in short lengths where speed of construction is important. As far as I know, asphalt bases have not been used at all. This is something which surprises us.

99. Similarly, concrete roads are not popular in Scotland and the length of two miles carried out on this motorway was really a trial length. The Paper records the test results for bituminous surfacing. Now that the whole motorway has been completed, I can show the final results for Stages 1 and 2 in Table 4.

100. The method of placing bituminous test results in three categories (in compliance with specification, slightly out, and really unacceptable) is well known. It will be seen that the test results on Stage 2 are rather better than they were on Stage 1. This is because a longer period was available for laying surfacing and also, I think, because we were getting to grips with the problem to a greater extent.

101. Even so, the percentage of passes falls far short of 100% compliance, but I think it is generally accepted that 100% compliance is an unreasonably high standard to ask for. Indeed, figures of 70, 20 and 10% for the above categories are suggested quite often. The average for all materials on Stage 2 was 66, 28, and 6%.

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Table 4. Bituminous test surfacing results

Bituminous test surfacing results			
Material	Category	Percentage	
		Stage 1 (one season)	Stage 2 (two seasons)
Asphalt wearing course	1	43	67
	2	39	28
	3	18	5
Asphalt base course	1	57	83
	2	20	12
	3	23	5
Dense bitumen Macadam	1	22	56
	2	43	37
	3	35	7

Mr J. B. Davidson

A survey of the performance of the reinforced concrete carriageway after two years' service can be summarized as follows:

(*a*) no cracks have been observed in the slab proper;
(*b*) many of the expansion joints show spalling of the arris on the side from which traffic approaches but this is mainly in the slow lane;
(*c*) the contraction joints are all sound but the joint sealant was obviously extruded during the hot summer of 1968 and now has been well rolled into the immediate area of the joint. Winter contraction has resulted in the sealant being torn away from one side of each joint in places and over intermittent lengths.

103. It has been noted that over some parts of the slab a random pattern of small round gravel particles, size about $\frac{3}{8}$ in., have plucked from the surface. This is of interest as it shows that the compaction of the concrete by the slip-form paver had not caused the cement and sand paste to be worked to the surface to an unacceptable degree. The subsequent brushing of the fresh concrete may have caused some aggregate particles to be susceptible to plucking out by traffic. Some of the small holes are, of course, blow holes.

104. Recent measurement of the surface irregularity index shows that Q is now of the order of 45, which is satisfactory.

105. Reference has been made to the efforts which were put into the quality control of the black top. These efforts were rewarded by steady improvement as construction progressed particularly on Stage 2 of the motorway. It is also correct to say that the riding qualities of the carriageway surface improved as well.

106. While Stage 1 has a surface irregularity index $R=112$–137, Stage 2 is better with the range $R=105$–112.

107. This compares with the best surfaces elsewhere which have an R value of about 90, with an average of about 110.

Mr A. E. Burks, Consulting Engineer

This mainly concerns the use of the slip-form paver subsequent to Hamilton. I hope that my remarks will give an idea of the sort of progress it has made and whether the

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Hamilton By-Pass and the difficulties that it showed up were really indicative of general problems with a paver.

109. Happily, the paver has not met the same difficulties elsewhere. The Hamilton By-Pass followed closely after the Cromwell By-Pass and, as the Authors have pointed out, it was the first commercial job. There were several things that the Cromwell By-Pass showed up as being rather difficult and problems which at that time had not been solved. One of the most interesting of these was the difficulty with reinforcement.

110. In § 89 of the Paper, the Authors refer to the slip-form paver as being, perhaps, not entirely suitable for the laying of reinforcement, but I do not think that this is any longer the case. In fact, I doubt whether it was the case on any other job except Hamilton, the point being that even a conventional train of machines can more easily lay without reinforcement than with it. The fact that reinforcement is present always creates some difficulties.

111. Subsequent to Hamilton, the slip-form paver laid the bar mat type of reinforcement at Tuxford and there was no special difficulty there. It laid it, incidentally, at rates of over 2000 ft/day on occasion. Two years ago at HMS *Heron*, Yeovilton Airbase, it laid mesh reinforcement in both 8 in. and 6 in. slabs where the mesh was supported on steel supports rather similar to those used with the bar mat method.

112. A 6 in. slab with steel 2 in. from the surface would, one would think, cause great difficulty. It caused some problems at first, but these were overcome and the rest of the work was satisfactory. The machine has laid a good deal of bar mat steel. Quite apart from this, in 1966, following the Cromwell job, the Civil Engineering Research Association sponsored further trials to determine whether steel could be laid satisfactorily by the sledge method, which was referred to in the Cromwell Paper.[4] This work was carried out in the summer of 1966 and is reported in CERA Report No. 8.[5] Three weights of steel were laid successfully with a simulated paver which was in longitudinal section identical to the Guntert and Zimmermann. The laying rates with this steel on one occasion reached 12 in./min.

113. The problems that were outstanding from Cromwell on this aspect were, I think, quite satisfactorily solved, including the tying of the steel with its overlaps and the tying of the joints. I look forward to this method being used on one of the new estate pavers which will soon be put into service.

114. I have seen the paver working on subsequent contracts but have never seen the same sort of mix problems as occurred at Hamilton. I wonder whether a lot of this was due to the unavoidable rather extreme richness of the mix. Certainly, it had a cohesive quality which caused drag on the steel of an order which has not been experienced elsewhere. If any more work of this sort is done in Scotland, it would certainly be worthwhile doing a fairly extensive investigation of the mix properties before the job is taken in hand.

Mr J. P. Maclaren, Clugston Construction Ltd

The area in which the work was carried out has been undergoing great improvements since the cessation of mining and is beginning to take on its past parkland appearance. In view of all the troubles that we have heard about in the construction of the motorway, one wonders why we built it there at all. However, I read from the Paper that it is probably inevitable that it should be built there.

116. In selecting special features of mention, the Paper rightly speaks about the large scale of the earthmoving that was necessary. Earthmoving is, of course, an important part of the economics of motorway construction, and it provides great imponderables of planning, financing and, eventually, contract settlement. Where the quantities are large, as they were at Hamilton, these problems are accentuated. The reason for the large quantities in this motorway is that it has to find its way down into the Clyde Valley, which is very narrow and steep sided, and once down there it

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has to be provided with embankments which will carry it over the Clyde and local roads. In Stage 1 it falls nearly 600 ft in 6 miles, and much of this fall has been taken up in the first half of its length resulting in a much deeper cutting behind the golf course at Larkhall than would have been necessary to accommodate a more uniform gradient.

117. This cutting, together with two adjacent deep cuttings where it breaks out into the Clyde Valley, were intended to provide 850 000 cu. yd of suitable material surplus to the requirements of filling that length of motorway and to provide filling for the very large embankments at the interchange where the motorway crosses the A723.

118. This particular feature was inevitably an important part in the planning of the works, as in the first place we had to penetrate along the line of the motorway to reach this surplus excavation. Therefore, the first season's work was directed towards doing this. In this initial work it was anticipated that about 400 000 cu. yd of material would become available to form embankments. This not only did not materialize, but considerable additional quantities of unsuitable material had to be removed below the formation level as described by the Authors. It caused a considerable delay in the first phase of the programme and robbed the earthworks balance of a substantial quantity of filling which had to be replaced by imported material at greatly increased cost in order to maintain the programme objectives.

119. Another matter highlighted by these large quantities arising at Hamilton is the question of the reliability of the information provided by a soils investigation and the extent to which this is implicated in the contractual position. The fact that 400 000 cu. yd of suitable filling went missing, and that additional depths had to be ordered below formation level, points to the well known inadequacy of the information at present derived from boreholes.

120. Another feature of the muck shifting is that in the initial planning out of the large golf course cutting we expected to move about 330 000 cu. yd to assist in the making of embankments at the south end. At the south end of this cutting there were additionally large quantities of rock which would be exposed early on, and these could be used for crossing a peat area. It is a sad commentary on the way we have to do things nowadays that this planning was completely frustrated by high pressure water mains crossing the line of the motorway at four points at shallow depths and in soft ground. The delayed diversion of these resulted in having to alter completely the earthmoving programme. The filling and rock no longer available from this cutting had to be provided from borrow pits and imported material, all of which had to be organized subsequent to the letting of the work. The 330 000 cu. yd which was to have gone south from the golf course cutting naturally contributed towards the 400 000 cu. yd deficiency at the north end. It also delayed the work in this cutting and we were faced towards the end of the job with drainage works and formation preparation in very solid rock. These considerations and many like them throw considerable problems on the engineer, particularly as the viability of a contract under radically altered conditions might come into question.

121. The motorway has had a considerable impact in the area. The need for filling material has levelled adjacent colliery waste heaps and the disposal of unsuitable spoil has levelled areas undulated due to mining settlement. All this has led to speculation as to whether the Authority should not prearrange these matters. Pit heaps are gambles and in Lanarkshire perhaps only 50% of a heap provides the hard, well burnt shale which is specified.

122. The question then arises of what is to be done with the unusable shale. There would seem to be a case for detailed examination of such heaps in the planning stage and for decisions to be taken as to the extent to which they can be used within the works and for the disposal or landscaping of the remainder to be included in the contract. However, the problems of land acquisition are difficult enough and one would hesitate to add the complication of tips and borrow pits.

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123. Moreover, the contractor is also motivated by commercial considerations and is in a better position to bargain against a known allowance in his pricing than a public authority which must be confined to empirical values and guided by political consideration. My feeling, and what comes out in the Lofthouse Report[6] which was published during the course of the work, is that if the contractor is appointed early he may, by using his commercial acumen, considerably assist in overcoming problems as they are exposed by his ability to negotiate with owners of mineral rights and others, and might, if given time for planning, effect economy in the final construction.

124. It seems that a great deal of emphasis is being laid upon the rigid pavement. That is, perhaps, unfair because it constitutes only 2 miles of the finished motorway. We used the slip-form paver only because the Authority insisted upon having this 2 miles of carriageway and it had to be fitted in very late into the programme. We investigated the specification of the work to enable the machine to be used, and in all this we seem to have ignored the ultimate problem of the concrete. The main aggregates in the area are deficient in $\frac{3}{4}$ in. size, and the larger aggregates were crushed and fed back to the screens. This gives rise to a very harsh mix.

125. Discussions at the Institution on the question of railway conversion to roads led us to investigate the possibility of using disused railway tracks for the distribution of both lean mix concrete and pavement quality concrete, and a mixing station was established at a railway junction. This distribution was very effectively carried out. A car could maintain a steady 70 mile/h on formations which probably never saw train speeds in excess of 20 mile/h.

126. The main factor in completing Stage 1 of the motorway on time was a large heap of steelworks waste which was adjacent to the line of the motorway. In the initial stages this material was rejected as being too high in free lime and carbon content. The samples that were taken avoided the firebrick which constituted something in excess of one tenth of the volume. The practical demonstration of the qualities of this material in the haul roads assisted towards reconsideration and eventually it was accepted as filling provided it was laid in 9 in. layers and sandwiched between either clay or burnt colliery shale. With the firebrick crushed, it was eventually accepted as Type II sub-base.

127. The Ministry of Transport specification called for 12 in. of material to be left in cuttings and 6 in. to be surcharged on embankments, these thicknesses to be removed after completion of drainage works and just prior to road base laying. Where the sub-base had not already been replaced, this specification proved quite unworkable in the heavy boulder clays and the operation, as well as proving highly weather susceptible, was subject to delay and proceeded to turn good suitable fill into unsuitable material.

128. These problems were overcome by leaving the embankments 1 ft low, excavating the cuttings 1 ft low, and cloaking the formation with this steelworks waste immediately after the bulk muck shift operation. From this, surface drainage works were executed, and I believe that the type 2 sub-base could have been omitted as well as the EO rates for the final preparation item. I understand that this blanketing of formations, not covered by the Ministry of Transport specification in Scotland, is fairly standard practice.

Mr D. J. Twigg, Donovan H. Lee and Partners

I would like to comment on the section of the Paper relating to interchanges and in particular to the development of their final form.

130. Capacity, cost benefit, geometry, staging, land use and aesthetics are those factors normally considered, but there is one other which I believe to be of fundamental importance. This is the number of potential driver decisions. It is my belief that if the number of these conflicts can be reduced, the interchange of vehicles from one route to another will be safer and more efficient. We have found that the total

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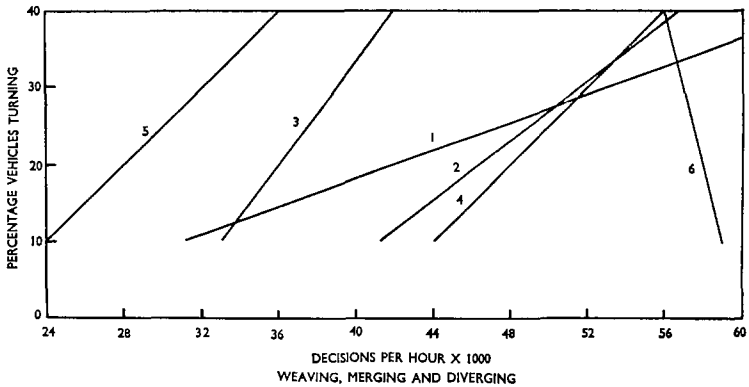

Fig. 15. Relationship of the percentage of traffic turning to the number of weaving, merging and diverging decisions

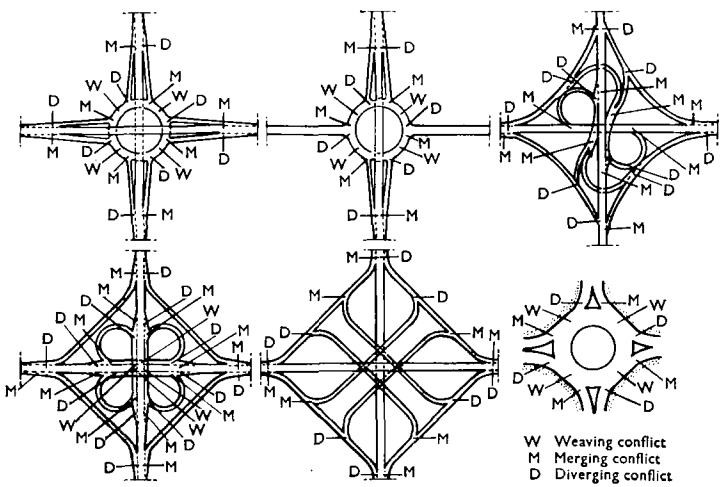

Fig. 16. Six alternative solutions

number of decisions may be reduced by the correct choice of interchange form relative to the traffic distribution requirements.

131. Fig. 15 shows the relationship of the percentage of traffic turning to the number of weaving, merging and diverging decisions required per hour assuming a feed of 3000 vehicles each way on the major route and 2000 vehicles each way on the minor route. Fig. 16 shows the six alternative solutions which were considered for this analysis.

132. These six alternative solutions for a hypothetical problem have been prepared assuming equal turning proportions from each of the four feeder roads. Although this percentage in practice will, of course, vary according to the requirements of the traffic predictions, the principle of the analysis will remain unaffected.

133. In this type of analysis it will be seen that for higher turning volumes the two and three level roundabout systems and the clover leaf fare rather badly, and the

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single level roundabout, although it improves with higher turning volumes, may be discounted for other reasons.

134. Since all these types have either been adopted or considered and rejected during the design studies, especially in connexion with the A723 interchange, I should be most interested to know whether the Authors believe that this type of analysis should be a contributory factor in the selection of interchange solutions.

Professor A. L. L. Baker, Imperial College

Most of the work seems to be in prestressed concrete and I would be interested to know whether the Authors now favour any particular kind of anchorage? I do not mean as a proprietary article, but whether they favour friction grip, button-ended or whatever. Secondly, if the prestressed beams were precast and post-tensioned, do the Authors favour any particular method of calculating the stresses around the anchorages and did they experience any difficulty with splitting or high stresses around the anchorages? If so, what did they do about it?

136. My third question concerns grouting up the cable against corrosion and to get bond. Have the Authors any particular views on this problem? Prestressed concrete has now come almost to be taken for granted, but it would be interesting to know what their views are.

137. Finally, can the Authors give a rough figure of the total cost of these bridges per sq. ft of deck? I would be interested to compare their costs with the sort of costs which we are getting in the South of England. I suspect that their costs may be a little more economical.

Mr G. Duncan, Babtie Shaw and Morton

Having been concerned with the design of the bridges which have been presented in the Paper, I think that Professor Baker has the wrong impression in saying that a lot of the bridges were prestressed. In fact, the majority are of reinforced concrete.

139. In the series of bridges involved in these contracts, there are steel, composite, prestressed, and reinforced concrete bridges, covering a large range of small span bridges. The experience gained in this work has generally indicated to us that reinforced concrete is one of the most economic and most versatile types of construction for small span bridges. I feel that prestressed concrete often catches more than its due share of attention in comparison. Reinforced concrete also has a very big advantage, which is brought out in the Paper, regarding the varying geometry of these motorway bridges, in that it is possible to take up different shapes very readily.

140. The only other aspect on which I wish to comment is the Raith bridge. The cambering operation which was done there has been the subject of discussion about whether it is worthwhile to camber when all that one is left with is a minor prestress over the supports. I think that this is well worth doing because it ensures a monolithic slab with no shrinkage cracking and, at least from an engineering angle, the bridge will be much better. The cost of cambering is really nothing because of the saving in the steel weight, and this compensates for the cost of the jacking operation.

141. If we consider a composite bridge with a concrete deck on top and steel underneath, as it necessarily has to be, this shape favours a positive bending moment and not a negative one. The cambering operation which was done at Raith bridge transforms some of the negative moment into positive moment and, therefore, it is more in keeping with the design of the bridge. Thus one not only gets the benefit of prestraining the slab, but one saves steel also.

Mr A. W. Shilston, Consulting Engineer

I should like to make some comments on the earthworks aspects of the Paper. First, is there any realistic alternative to the present measurement and valuation system inseparable from the present ICE Form of Contract? The employer's problem is how to get the least expensive stable road built in the time he has fixed. Secondly,

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the contractor has the problem of how to meet the aims of the contract, as set out in the tendering documents, and achieve and perhaps enhance his estimated profitability level, notwithstanding the almost inevitable dislocation of progress caused by the employer denying him the usual freedom conferred on a contractor to organize the works (and order his materials) in a manner most suitable and presumably economical to him.

143. The dichotomy arises since the employer, in his desire to build a road at minimum expense, reserves the right to instruct the contractor to use spoil (which the employer owns) from the cutting excavations as fill material for permanent embankment structures. The structural fill to be used in embankments is frequently allocated to the contractor on a piecemeal, hour to hour basis; any interruption in the supply of site structural fill material through the frequently unpredictable subsoil conditions will dislocate the conduct of the works which can be very costly in view of the highly mechanized character of present day road building.

144. I tend to conclude that this approach, notwithstanding compensation or damages for disrupting progress, is probably the least expensive way of building roads. It is vastly time consuming in valuation, calling for considerable intellectual resources and knowledge of both engineering and legal principles in the solution of the problems encountered.

145. Could the process be shortened by adopting alternative contract measurement and valuation procedures from those currently in use? If the objective is to achieve the least expensive road for the employer, I very much doubt it. I would be interested to hear the Authors' views on this dilemma.

146. The second point relates to the increasing use of quantity surveyors by employers in civil engineering work. It is probably a reasonable generalization that civil engineers tend to be bored with quantities. It is contended by some that the best use of resources argues the case for the employment of quantity surveyors in civil engineering work. But I cannot see how quantity surveyors trained in building could take over the valuation of civil engineering works of the character described in this Paper, on behalf of the engineer. Of course quantity surveyors could efficiently take off the quantities in the preparation of the original bill—but surely the presentation would have to be vetted by a senior engineer? They could efficiently measure up, but could they value disrupted work for which bill of quantities rates might be largely inapplicable? I cannot see that quantity surveyors would receive professional satisfaction if their role in civil engineering works were confined to that of providing partial technical services to assist the engineer. But surely the overriding principle must be that although it might be dull work to some, measurement and valuation must be firmly in the control of the engineer, when the employer's intrusion into the control of the supply of structural fill for embankments will almost inevitably yield some dislocation with its ensuing valuation problems.

147. What are the Authors' views on the use of quantity surveyors in roadworks?

Messrs J. Paton, D. D. Fraser and J. B. Davidson

Mr Twigg's comment concerning the volume of turning vehicles at the two- and three-level roundabout and clover-leaf forms of interchanges is interesting.

149. The question of vehicle conflict and driver decision should be a factor in the final choice of interchange layout. It was certainly a factor in our designs. It can only be one factor, among many, because to achieve a high degree of satisfaction in this respect involves extra cost and, as in all civil engineering problems, cost at the end of the day tends to determine the layout to a considerable extent.

150. **Mr Burks** has added his comments concerning the performance of the slip-form paver. At the end of the comparatively short run of two miles, the machine was going ahead reasonably well and it seemed that the trials and tribulations had been overcome. Since it left Hamilton it has used a similar bar mat system of reinforcement, all of which is encouraging and should be recorded. Mr Burks has men-

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tioned the mix. It is the case that the Contractors had to use a relatively rich mix to attain the usual specified strength and the quality of the aggregates which they selected was undoubtedly a factor in this situation.

151. Many of the troubles associated with the slipform paver were related to the reinforcement. It was felt that when the regulations regarding the use of reinforcement were relaxed to some extent, the machine would be able to show its paces. It is, however, good to know that even these problems with reinforcement have been largely overcome.

152. **Mr Maclaren** contributed some very useful remarks about Stage 1. One of the things not mentioned in the Paper was the more detailed programme operations of shifting the quantities of muck which were involved, because in a Paper of this nature the full details cannot be given.

153. It is the case that some of the difficulties referred to involved programme adjustments along the line of the motorway and the Contractors made a good effort in dealing with these.

154. In some parts of England research is being carried out into the use of unburnt colliery waste (most plentiful in the mining counties) for use in roadworks. It is a big problem in Lanarkshire where many of the deposits are from old coal pits which may contain some most unsuitable material. Mr Maclaren has asked whether the acquisition of colliery shale might be prearranged by the employing authority. The Authors would not favour such a course in general, particularly as Mr Maclaren has pointed out, the process of order procedures and land acquisition for the permanent works is very cumbersome and time consuming. To add to the duties of those involved would only aggravate the situation. Furthermore, contractors with their experience of hard commercial bargaining are better able to carry through these negotiations with the owners of shale deposits.

155. One of the small but interesting features of Hamilton Stage 1 was the use of old railways as haul roads. It was certainly due in part to the location of these old railways adjacent to the site, but it was of great interest at the time to see the way they could be used to carry the heavy haul traffic as haul roads.

156. Mr Maclaren also mentioned the layer of granular material which was laid on top of the earthworks at formation level. The specification which calls for a second stage excavation of earthworks above formation in cuttings and on embankments is familiar to everyone. The Contractors on both stages of the Hamilton By-Pass made considerable use of the expedient of laying a capping of granular material at formation level thus providing an all weather working surface for drainage construction and spreading of sub-base material. It will be of interest to see whether such a detail is incorporated in the new specification now being prepared.

157. Mr Maclaren posed the question of why the motorway was built there at all, having regard to the poor nature of the subsoil. The answer is quite simple. The alternative would have been to embark on a large scale demolition of property and to enclose the communities of Larkhall and Hamilton in particular, with the motorway aligned close to the fringe of these townships. From a planning point of view, it would have been a most unsatisfactory alternative.

158. We knew from the very outset, from the very first site exploration—in fact, when walking over the ground at the time of the site exploration—that the soil conditions were most unfavourable, but, after all, that was why the corridor was vacant. The land was relatively free from development and was not expensive to purchase but, as indicated in the introduction to the Paper, involved high construction costs and earthworks.

159. As to the reliability of site exploration and soil investigation, to which Mr Maclaren referred, upwards of £50 000 were spent on this. The services of one of the most experienced specialists in this field were engaged, but it must be recognized that some of the ground conditions were extremely difficult.

160. From Fig. 4 in the Paper, it will be seen that as a result of the most

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sophisticated laboratory testing of numerous samples, the value of some of the plastic clays gave shear values ranging between 250 and 450 lb/sq. ft. The adoption of a figure in that range would have meant a flattening of side slopes, and a flattening of cuttings thus increasing the cost and scale of earthmoving. As engineers, we were not satisfied that it was quite as bad as that, although we knew that the ground was far from desirable. A considerable programme of vane testing in the ground was embarked upon. The general average run of results from these mean tests came out considerably higher, as shown in Fig. 4. We finally adopted a design figure of 750 lb/sq. ft for many of these stability calculations. Earthworks formed to the appropriate slope or profile proved to be satisfactory. The extensive study which was made served to confirm that boreholes and soil tests would require to be at very close intervals to give precise results in this type of ground and to cover a wide corridor 14 miles long in this way would be a very formidable undertaking.

161. Mr Maclaren also referred to the large supply of steelworks waste which was available adjoining the northern section of Stage 1 and how, in the first instance, this material was first rejected and later accepted with the proviso that it be layered with boulder clay or other infill of known quality. This was the case and considerable investigation was required to ensure that the steelworks material was sufficiently reliable for use in high embankments supporting an expensive carriageway pavement.

162. The layering referred to was very successful and as the areas involved were extensive the procedure did not cause any significant delay to progress. Boulder clay could be placed successfully in the drier weather whereas the steelworks waste could be used during less favourable weather periods. In retrospect the layering proved to be a practical and economical solution for the circumstances pertaining.

163. **Professor Baker** referred to the bridges and suggested that most of them were prestressed concrete structures. In fact, of 42 bridges on the motorway, only three were prestressed. Two of these comprised factory-made precast units whereas bridge no. 5 at the A723 interchange, or no. 15 in the table given in Fig. 9 was of in situ construction, post-tensioned.

164. For bridge no. 5 a tapered wedge type anchorage was adopted. In the early stages some difficulty arose on stressing resulting from inaccuracy in placing coupled with the introduction of incorrect spiral reinforcement which was too light to resist the bursting forces. On investigation it was found that the supplier had provided a light form of spiral appropriate to an earlier design. When these deficiencies were rectified the stressing went ahead without difficulty.

165. Professor Baker also refers to bridge costs. In preparing the Paper the Authors endeavoured to set out the costs in considerable detail—see Fig. 9. It is of interest, now that the work has been completed, to note that the final costs are generally very close to the figures given in the Paper which refer to the tender prices. There were some variations in one or two instances but, basically, the unit costs per sq. ft of deck given in Fig. 9 are a good guide to the final cost of these bridges. In other words, the unit costs were of the order of £3–£5/sq. ft for the shorter multi span range of slabs and beam. With the single span where abutment costs have a prominent influence, the figure was of the order of £7 or as high as £8/sq. ft. For the large continuous spans, e.g. the Raith bridge with spans of 140 ft, 170 ft and 140 ft, the cost was again about £7/sq. ft.

166. Professor Baker has referred to the effectiveness of grouting for the protection of prestressing cables. The Authors consider that reliable protection can be attained without question as a result of the improvements which have been achieved in grouting techniques.

167. **Mr Shilston** has cited a hypothetical case of filling material to be used in roadway embankments being allocated to the contractor on a piecemeal, hour to hour basis. Having regard to the high capital investment in modern earthmoving plant this is obviously a most unsatisfactory state of affairs and one which is likely to lead to difficulties in settlement no matter who is involved in the process. It is certain

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that a quantity surveyor trained in the building industry where earthwork volumes are generally smaller and measured to take account of digging and transporting in small units will require a reasonable period on the measurement of roadworks to become accustomed to the scale and complexity of these larger earthmoving operations. There are, of course, many quantity surveyors trained and employed in the industry who are very familiar with the ICE Conditions of Contract and Standard Method of Measurement as applied to large scale civil engineering works. The Authors are inclined to the view, however, that a civil engineer by reason of his broader training and greater involvement with the planning, organization and control of works is better fitted to deal with the main issues which arise in measurement and final settlement of such works. As to the mode of measurement for earthworks, the current system has been developed after much experience and it is doubtful if any basic change would lead to improvement.

Corrigendum

In § 12, figures of 250 and 700 lb/sq. in. are quoted for the shear strengths of the soft clays which were encountered on the motorway. The term lb/sq. in. should be lb/sq. ft.

References

4. BURKS A. E. and MAGGS M. F. The Cromwell slip-form paver trials. *Proc. Instn civ. Engrs*, 1967, **36** (February) 225–271.
5. BURKS A. E. Slip-form paver; incorporation of fabric reinforcement. *Civil Engineering Research Association, London,* April 1967. *CERA Research Report 8.*
6. LOFTHOUSE M. A. *Efficiency in road construction.* Economic Development Council for Civil Engineering, London, HMSO, June, 1966.

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