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7969 DISCUSSION

Some features of the Aberdulais to Llandarcy section of the Neath–Abergavenny trunk road (A465)

D. H. NEW, A. L. BENJAMIN & K. S. MILES

Mr New

Limitations of space have required us to deal mainly with items of particular interest rather than the whole concept of the work. I would also like to record my long association with the other Authors.

Mr Benjamin

Had the unusual ground conditions found in the area of bridge 14 been discovered earlier there would have been only minor changes to the basic design. I would also refer to the recent accident in Australia where a slab bridge fell directly on a train after the removal of a supporting column by collision. Only one bridge needed consideration for this sort of event and the vulnerable pier has been well protected to the standard required by the Inspector of Railways.

Mr Miles

In the Specification for Road and Bridge works, 1969 (the 'Orange book'), no upper strength limit is specified for lean mix concrete, whereas in the new edition of 1976 an upper limit of 20·5 N/mm^2 is given. Using the local aggregates it would not have been possible to keep the strength down to this figure and it did not make economic sense to haul in special aggregates to achieve low strength.

Mr B. Martin: for Director, Welsh Office, Transport and Highways Group

South Wales has a marshy coastal strip with steep sided valleys basically running N–S inland. The valley bottoms are heavily congested because of development and infrastructure. Even now, major roads run mainly north or south of the valleys.

70. The Romans produced roads to service their garrisons in South Wales but for about 1000 years after the Romans there was little need for national roads. In the 16th century there was decay of the manorial system and the start of an industrial situation, so there was need for more than parish roads. An Act of 1555 required each landowner to produce a cart with necessary horses or bullocks, and two men to work 4 days on roads. Supervision was by two unpaid surveyors appointed by the parish. By the late 1600s a little more order appeared with the appointment of surveyors by the magistrates. The magistrates were allowed to levy a rate in order to pay for some of the work. By the early 1700s there was more industry and more need for longer distance travel, and the Turnpike Trusts came into being. In South Wales there were turnpikes along the coast, more or less following the present motorway line, and up the Merthyr

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Valley and across the hills to Abergavenny, Brecon, Llandovery and down to Carmarthen. But there was nothing across the tops of the valleys from Abergavenny to Neath. The Turnpike Trusts caused some upset in South Wales, where there were riots. Most of the turnpike gates were destroyed and county road boards were required to maintain the roads. The South Wales Highways Act in 1860 put things on a more businesslike footing, formally making the counties responsible, and added other roads besides the turnpike roads. The 1862 Act did the same for the UK. Further Acts consolidated matters, but the important ones were the Trunk Road Acts which transferred the responsibility for certain roads to the Ministry of Transport. The 1946 Act provided for the first time a road from Swansea diagonally across to join the road E–W from Brecon; the first Heads of the Valleys road.

71. In 1946 the Heads of the Valleys road was not regarded as a principal route. In 1952 the plan was to divert the road across the mouth of the river, and an improvement began in the highway network in the Swansea–Neath area. In 1967 a White Paper 'Wales: the Way Ahead' was published, which introduced a major improvement linking the tops of the valleys and thence the A40 and M5. The subject of the Paper concerns one of the most difficult sections.

Mr J. B. Holt, G. Maunsell & Partners

One of the conclusions is that this project has demonstrated that highway embankments can be placed over very soft ground provided that proper attention is given to design construction and contractual aspects. I am not certain that within the restricted confines of the Paper the Authors have really done themselves justice in supporting this important conclusion, and therefore I would like, if I may, to offer a few comments on this side of the work.

73. The ground in question has already been mentioned, the Saltings, the area of mud flats in the tidal portions of the River Neath. There were 10 m or so of normally consolidated clayey silt, or silted clay, providing poor grazing for cattle. It is commendable that the Authors and their clients, the Welsh Office, accepted the challenge of building a major part of this trunk road over ground of such inferior character rather than taking up better land on the flanks of the valley that could have been put to better use.

74. The road pavement had to be lifted well clear of the tide level, and this necessitated embankments the weight of which was bound to cause appreciable settlement. There were doubts as to whether a road to the required pavement standards could be built in these circumstances. Even 10 or 15 years earlier this road would not have been built over this particular route, and apart from the basic worries about eventual performance, the actual cost of instrumental control on construction procedure would probably have been prohibitive. Yet 19th century engineers successfully built a railway across this same area, on quite a high embankment, and their example was an important factor demonstrating the practicability of the proposed road construction.

75. The Author's approach was to assess the ground conditions fully, and then bring the soil mechanics aspects of the construction down to commonplace procedure. Conventional laboratory consolidation tests demonstrated that settlement of the embankments would vary between 1 and 0·5 m. The exact magnitude was not of consequence. The important thing was that the sub-sediments were of uniform composition and there appeared to be no major inclusions of widely different material which could give rise to abrupt differences in settlement potential. The laboratory tests also indicated that although settlement could continue for as long as 20 years, the bulk of it would be completed in 5 or 6 years, and it was further surmised that horizontal drainage in these estuarine sediments could accelerate the rates of consolidation appreciably.

76. Having recognized that there was going to be this appreciable settlement as the embankments were raised, it was, of course, essential to keep a check on this to ensure that it was due only to consolidation and that additional settlement did not develop by yielding of the ground as a result of shear failure.

77. There were two sets of monitoring devices. Simple settlement gauges (a plate

at the bottom of the embankment with a pole sticking up from it) enabled the level of the base of the embankment to be measured by normal surveying instruments, and secondly vertical stakes were driven into the ground near to the toe of the embankment, and aligned horizontally at a tangent to the toe of the embankment. By regular checks on the alignment of these stakes it was possible to ensure that there was no tendency towards outward yielding.

78. Apart from controlling the rates of raising the embankments, there was also provision in the specification for halting emplacement if the rate of settlement suggested that something was going wrong. This provision was invoked on at least one occasion.

79. When a job was out to tender, geotechnical experts employed by two of the tendering contractors expressed informally their concern that there was no provision for monitoring by more elaborate instrumentation. It was part of the philosophy of the design to recognize that differential settlement between pavement on embankment supported on compressible ground and on structures founded on piles would be absolutely inevitable, and that consequently there would be imperfections in the surface that would have to be remedied from time to time, continuing probably for some period after completion of construction. I understand that the riding qualities are in no way inferior to comparable trunk roads elsewhere.

80. It would be interesting to hear from the Authors whether they feel in retrospect that the control provided was adequate, and whether Mr Miles, as Resident Engineer, found it unduly onerous to implement the special provisions of the specification. Were such controls ever disruptive to the contractor's programme?

Mr A. C. E. Sandberg, Messrs Sandberg, Testing Engineers

There were three main fabricators for the bridges. In view of the Merrison recommendations one elected to introduce additional framing to the boxes to help meet the new tolerances, and another worked in the same way as he had intended, but took greater precautions and allowed for a certain amount of correction that might be necessary later on. The fabricators had to have a team of three men working jointly with an inspector, and in these early days each box took a day or more to complete. It is to be hoped that the new bridge code will reduce the amount of checking and recording that has to be done.

82. Normal material dimensions and welding checking were done, and ultrasonic checking of the diaphragm web areas, corner web areas and compression flanges, to see that no laminations were present to a significant extent. The fabricator on his part did his lamination checking before the welding occurred, so that he was not running the risk of wasting fabrication effort only to find that he had run into trouble. This made for a good team effort and avoided the cost of buying ultrasonically tested plates from the mills with the extra cost that that involves.

83. There was very little trouble with the Corten steel. Some cracking had to be repaired, and there was one piece which was replaced. There is the general question of how much protective treatment should be done on steel after blasting. In some cases on this contract, because of delays, the blasting primer broke down. I do not think enough thought is given to providing adequate protection after blasting. Everyone thinks that construction will go according to the time table, but delays are extremely frequent and should be catered for.

84. On the lean mix concrete, 24 to 1 is as lean as my firm considers one can go to get proper mixing. A leaner mix might be achieved in the laboratory, but I do not think there will be proper mixing on site. But if there are some cementatious properties in the original materials, what are the rules? Margam slag was tested for iron unsoundness and water absorption. The specification for iron unsoundness was not at all clear and it was very difficult to know whether the deposit that collected after the tests was dust coming from the interstices of the slag or part of the breaking down of the slag itself. Margam have since changed their general processing and are now producing a better product with less iron.

85. As far as the defective concrete was concerned, our only anxious moment was wondering if the cores would correlate with the cubes. Once that happened, worries then passed on!

Dr M. H. Ogle, G. Maunsell & Partners

I should like to mention further features of bridge 14, Saltings Viaduct. The contracts had been let only a few months before the Merrison requirements were introduced. Publicity given to the complexity of the Merrison rules and the extra work involved, has I think been very much to the detriment of the box girder type of construction. In fact, I think this contract has probably used far more steel box girders than any other contract.

87. In bridge 14 there are 16 identical spans carried on four identical box girders. There is no secondary bracing at all between the girders: the only connection is via the in situ reinforced concrete deck. This means that the accuracy of alignment of one girder to the other is very much less than if there is steel work between them. It also allows greater freedom for maintenance and means that only the flat surface of the box girder has to be maintained, not a profusion of secondary steel work which is so common, particularly on plate girder bridges.

88. At 4 ft square the box girders are about the minimum size that one would want to fabricate where there is internal work to be done. The minimum thickness of plate is 15 mm, and it is all mild steel. The span is 31 m and the box was made up of four plates only. They are connected together by internal diaphragms which are again made of plates with a hole in for access.

89. The box sections weighed about 16 tons, so they were quite readily handled in the shop, on the lorry and during erection on site. One feature is that there are no longitudinal stiffeners. This leads to an enormous increase in speed and ease of fabrication.

90. The torsional strength of the box is used significantly: on many box girder bridges it is not. The strength of the box is used to react against the bending moments from the slab. Particularly under concentrated loading between two boxes there is a tendency for the box to twist and for the slab to flex, and this can be quite substantial under the HV loading. For that reason the top flange oversails the webs so that any tension or uplift on the outer webs can be taken by the 'T' joint and will pull on two slabs. Any pull on the remaining stud would tend to rack the corner weld, which would be a very bad fatigue feature. The outstand has other advantages, in that it means that the top plate can be slightly thinner for the same area. It also enables a grip on the box to be achieved by any falsework, and helps to keep rust from the top of the flange from running down the webs.

91. For about 80% of its length the box is fully sealed and is not painted internally. It is only in the bolted splice compartments that any internal painting is required.

92. The box lengths were at times sufficient to make them out of single lengths of 19·7 m plate, and so the entire 1800 tons of steel were made without a single transverse weld, which again helps to keep the fabrication costs down. With a thickness of plating of about 15 mm, particularly with the internal areas sealed, good efficiency of paint coverage is achieved.

93. Bolted splices were chosen for ease of erection. For this sort of work I would recommend grip bolts as they are easy to inspect and require far less expert labour and inspection on site.

94. Attention was also paid to the simplification of geometry. This structure is super-elevated: it is on a horizontal curve and on a varying vertical curve, and to make the steelwork follow that precisely would make the fabrication geometry extremely complicated. The first simplification was to keep the box square rather than trapezoidal and to tilt it at the angle of the cross fall (1 in 30). The vertical alignment is accommodated merely be profiling the webs in plane and keeping all the internal components at 90°. The horizontal alignment is maintained by cranking the

girders and keeping the girders straight between splices. The angle was not bisected, with the result that 50% of the girder sections are of the same length and have square ends. The variations are taken out in the support sections. The result, I think, is that potentially this design should have been very cheap and quick. Erection was speedy (3 months) and fabrication lent itself to production line flows through the shops, but, as Mr Sandberg mentioned, the delays produced by the extra measurements and the worries about achieving these measurements rather negated the advantages to which I have referred.

Mr C. J. Lucas, British Rail, Western Region

I thought at first that a period of 3½ years for the construction of 7 km of road seemed a rather longish time. Having seen further details of the structures, perhaps it would not be unfair to conclude that the original contract of 2·3 years was unduly optimistic. Certainly faced with political hazards, such as three-day weeks, fuel crises and the Merrison Report, in addition to the usual set of unforeseen engineering hazards, serious delays were inevitable. I would be interested if the Authors would comment on the effect on the costs of the contract of these delays.

96. My particular interest was in the railway bridge 18. In the early stages this seemed likely to be a conventional structure from the railway viewpoint. It was decided to recommend a scheme for the thrusting of the abutments to meet British Rail's usual requirements of minimal effect of the works on main line rail operations. The aim was to take up the tracks once only for the installation of the bridge deck and to cut down on the period for which speed restriction of trains was required to a few weeks only during the jacking period.

97. The first indication of problems occurred when the sheet piling for the thrust pits proved extremely hard to drive. This was subsequently found to be due to the large boulders in the base of the embankment which tore some of the piles apart. In the bottom of the pit when it was opened up some of the piles had actually turned through 180°.

98. Due to the nature of the ground, and in particular the presence of these boulders, the thrusting of the bottom section of the abutment took rather longer than had been planned. The boulders had to be broken out in places, and where overbreak occurred packing had to be done by hand to restore the material on the outsides of the box. But the fact that the bottom units were jacked caused little disturbance of the tracks.

99. When the start was made on jacking the 4 m high top units they proved to be much more troublesome. They had not gone far when the face caved in and it became evident that the grouting of the upper 3 m of the embankment had not been particularly successful. However, as has already been explained, another occupation for another bridge became available at just the right time, and the scheme was rapidly altered to dig out the top fill over the lower units and drop the upper units into the thrust pit, jacking forward with no ground pressure from the sides and with an easy excavation from the face by machine.

100. Although the total thrusting method was not completed as intended, perhaps the lesson to be learned is that there could be advantages in thrusting the bottom foundation unit of an abutment under the railway and constructing the vertical walls in open cut, either in a separate operation or, as has been done elsewhere, by designing a deck which is a portal frame incorporating the abutment in the final roll-in operation. With the benefit of hindsight I would like to know whether the Authors have any thoughts on whether they might have adopted a different form of construction in the early stages.

101. I would like to endorse the need, underlined in the Paper, for having plant in reserve and in particular for it to be properly tested. I have found on more than one occasion that even though the number of jacks on site was double that specified, there were not enough in full working order at full working load and extension, to use satisfactorily.

102. There is one other point I would like to raise with the Authors. They seem to be slightly lukewarm towards Corten steel. I should like to know if they have recommended or adopted the use of Corten in any subsequent structures.

Mr W. A. H. Hamilton, Binnie & Partners

I am speaking in a private capacity, having had some involvement with the scheme when I was living in the area in 1970 and 1971.

104. There were other aspects of this scheme in addition to the matters covered in the Paper, where I think that both the outcome was unsatisfactory and that there are lessons to be learnt for the future. I wish to discuss one of these, the complex issue of the routing of the southern link road into Neath.

105. The Authors' scheme is really two new roads—first the A465 of the title, and second, the road between the town of Neath, the Neath interchange and Neath Abbey. This latter road is a 4 lane dual carriage road of the same capacity as the A465, and is in fact expected to carry more traffic than the more northerly section of the A465 itself. This road provides the River Neath crossing at Neath and is now, I think, the only crossing for 5 km in either direction. It is the choice and routing of what I shall refer to as the southern link which I wish to discuss.

106. The southern link was included because the previous river crossing at Bridge Street was cut by the new A465. The southern link provides four lanes across the river instead of the two previously existing at Bridge Street. It is to the doubling of river crossing capacity that the Authors seem to refer when they write of giving greater traffic facilities to Neath.

107. In two separate ways the southern link appeared to be defective in concept and represented at best a lost opportunity and at worst an environmental misfortune. The first is in its traffic carrying function: it is in the wrong place for maximum traffic benefit. The most recent traffic surveys (1967) when I was concerned with this scheme, appeared to show that the greater part of the traffic on the southern link would be coming from the Rhydding and Cadoxton area, NE and going to Neath town centre. Journey lengths are substantially increased by the substitution of the southern link for Bridge Street. More seriously, at the termination of the southern link in Neath, the four new lanes end in narrow congested streets which must be traversed both by traffic going south out of Neath to Briton Ferry and north into Neath centre. It was accepted that if the southern link ever came to carry its full traffic capacity, major road improvements would be necessary in this part of Neath, requiring much demolition of housing. More than 100 further houses would be lost.

108. The second way in which it is defective is that to build the link as it is has already required the demolition of 100 houses, the dividing of a neighbourhood and the overlooking of more houses by this road on an elevated section 5 to 10 m away. In London, when such conditions were caused by Westway, there was much concern expressed. It seems that this concern did not reach as far as Wales. Circumstances sometimes dictate that the only possible solution is unsatisfactory in some way and that this has to be accepted. It did not, in my opinion, apply in Neath, where there appeared to be a viable alternative avoiding most of the defects of the southern link and probably costing less on account of reduced demolition of property. This arrangement is now a dead duck, but it would have consisted of three elements: (*a*) a two-lane southern link on the Authors' lines, but stopping short of the main railway in Neath and the houses, and connecting one way via a new bridge over the railway to Chemical Road and the road south out of Neath, and the other way by an improved Milland Road to the centre of Neath; (*b*) a retained Bridge Street (there are no real problems here to engineers of the Authors' skill); (*c*) by the northern link, already agreed by everyone to be a necessary complement to the Authors' scheme, but I believe not built, despite a recommendation at the time of the public inquiry that it should be built simultaneously with the southern link (Fig. 8).

109. I am not describing this alternative to rake over old wounds and might-have-

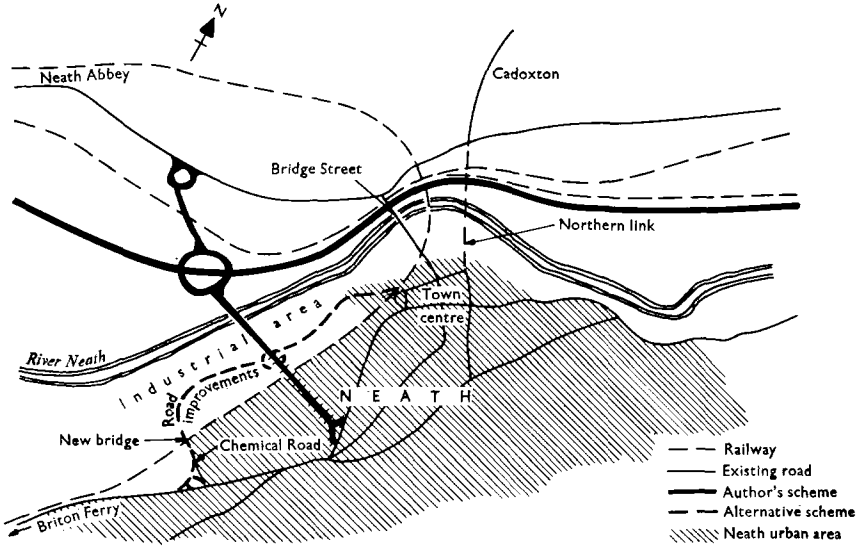

Fig. 8. Alternative scheme

beens, but to illustrate how things can fall short of the best possible in the planning of public works and hopefully to point out some lessons for the future.

110. As far as I know, this alternative scheme was never studied in detail either by the Authors' firm or their clients, the Welsh Office, or the County Planning Department. The main reason seems to have been one of the methods of finance. The alternative scheme retained the Bridge Street crossing of the Neath. With no requirement for its replacement, the Welsh Office frankly stated that they would not have been legitimately interested in the southern or any other link or improvement in Neath. As the Welsh Office seems, in fact, to have wished to increase the capacity of the Neath crossing, it was expedient to cut Bridge Street and introduce these benefits by stealth. For the county council the need to cut Bridge Street was even more imperative. In the absence of the southern link the county, short of money, would have had to find far more to provide the 4 lane river crossing capacity which was otherwise seen to be necessary. For Neath Borough, the question was more complicated. They were not the road planning authority for their area. Despite what the Paper says, the borough council members were officially opposed to the southern link scheme but were able to offer only an unworkable variant in its place. Their own officials, confronted by the real problems existing at Bridge Street, saw the southern link as providing the only likely way of actually getting the additional capacity required.

111. The only party with a real incentive to seek a better alternative was the protest group formed from the inhabitants of the affected houses. The several hundred members of this group were neither wealthy nor experienced in dealing with officialdom or protest action. Their funds were sufficient to hire counsel to represent them at the public inquiry, but not engineers. Nevertheless the germ of the alternative scheme came through their action. Regrettably it was only developed to the form I have given after the inquiry and, indeed, after the signing of the letter of intent for the Order. By that stage, naturally the authorities had little interest in any scheme which would require further statutory processes and maybe another inquiry.

112. Finally, my last point is the lessons I draw from this, which are, first, that the splitting of financial responsibility for the trunk road and for the local roads between central government on the one hand and county authority on the other was a serious fault of the system. Where such close interdependence as applied in Neath is seen in a scheme, the promoting authority should be given the financial ability to deal directly with all the affected roads or to provide funds for this. The area of responsibility should not depend on arbitrary questions of cutting this road or that.

113. Second, if an agency such as the Welsh Office determines to improve existing roads as a by-product of a new road scheme, it should do so openly and wholeheartedly. If there are at present statutory limitations on this, these should be changed.

114. Third, and most important, individuals and groups affected by new schemes should be brought into the decision-making process early on. They should be given advice on how to protect their interests, and should be given financial support to enable them to seek heavyweight independent technical advice. It is not sufficient to assume that local government can properly represent them. This is not simply a matter of justice, but a matter of finding the best solutions. I have no doubt that a threat to one's property, one's home and one's interests can be a most powerful spur to original thought and thorough examination of the true issues, and that roads such as the M4, at any rate in England, were greatly improved because of the presence of active, informed and comparatively wealthy protest groups.

115. I would like to ask the Authors first, whether, with the scheme complete, my foreboding for the Neath environment looks to be as serious as I have suggested; second, if they could comment on the desirability of divided responsibilities for roads at Neath; third, whether they would agree on the need to give more support rather than less to affected parties in road schemes?

Mr D. A. Brown, retired; formerly Sir M. MacDonald & Partners

My remarks will be very brief and are not intended to be any sort of criticism of a very interesting paper.

117. I would like to comment on the malfunction of the jacks used at bridge 18 during the rolling-in operation. I would draw attention to a case with which my firm was concerned in 1962. This was a continuous girder bridge about 58 m long, which was to carry a double track main line over a motorway. The construction of the motorway had not then started. The bridge was erected on trestling beside its final position. During discussions with British Railways on the rolling-in operation, the risks of lowering heavy loads on jacks (in this case about 1400 tons) were discussed in detail. It was therefore decided that when the bridge span was rolled in and on its correct alignment the span should be raised to its final level instead of being lowered.

118. As rail traffic was expected to pass over the bridge within 2 hours of its rolling-in, the usual sand and cement grout under the bearing plates was plainly not suitable. After laboratory testing it was decided to use an epoxy resin mixed with pea gravel in place of sand–cement grout. This special material developed double the 28 day strength of high grade concrete within 1 hour. The cost of this special material was about ten times that of the traditional sand–cement mixture, but having regard to the elimination of lowering jacks under load, I think all concerned with the job agreed that the extra cost was well justified.

Mr A. M. Muir Wood, Sir Wm Halcrow and Partners

Could Mr Benjamin confirm that the tests referred to were 100 mm penetration tests: these would require adjustment to provide figures to a standard penetration, bearing in mind that he was using a cone.

120. The term 'anticlastic' was used. I have never heard it in this context before. I believe the bearing was shaped from two surfaces of rotation at right angles to each other, which would give a bent trough element, i.e. part of a toroid: 'anticlastic' surely

has a very specific meaning and should not be applied to the shape of a surface unless it is in fact made by bending and hence causing the curvature in the anticlastic direction to the bending.

121. As far as the embankment is concerned, either Mr Holt knows a great deal more than he told us about the ground, or else he was very lucky to get away with his elementary monitoring system. If the ground had been in the least bit brittle (in the geotechnical sense) the slip could well have taken place before there was time for anybody to measure the pegs, apart from the inevitable risk of their being displaced by the contractor. I would have expected piezometers to give a much better advance warning of incipient instability. The observational method is surely what was called for, bearing in mind that the critical conditions would be during the time of construction.

122. I recall a bank where an arch had fallen down and I had to find out why it had happened. There had been excellent advice from an academic during its construction, but unfortunately he thought that it took a whole season to build a bank of that particular height, whereas it was built in 7 weeks, and in consequence collapsed because of the pore pressure build-up that took place in that time.

123. I would like much more information on the scheme of thrust boring for the abutments. As far as I can make out, the bottom section of the abutment was below the base of the bank. There has been so much repetition of problems in thrust boring through banks that I am surprised to find people apparently rediscovering the same problems. If this was an old bank, it was probably made by end tipping and in consequence the material would be very loose, particularly near the bottom. Once this is disturbed, subsidence supervenes. Possibly the grouting was intended to prevent this, but nevertheless, looking at the aspect ratio of the unit that was being thrust on top, I cannot think how one would get away with this without the possibility either of the face coming in or else pulling the surface along, in the absence of jacks to support the face in front of a shield. Rather than the several intermediate jacking stations used by the Authors, it would surely have been far better to have employed an ordinary tunnelling system embracing a segmental lining within a shield. This would then give a much better way of controlling the ground and face, without excessive drag.

124. Did the lean base possibly have stress raisers in it, due to the way in which it is compacted? Perhaps this is a reason why one does not get the degree of trouble that one would otherwise expect to get with a base course of comparable strength to that described by the Authors.

Mr Martin

With reference to the instrumentation described by Mr Holt, the same simple measures had been used on other contracts for major road works in South Wales with good results. The system is advocated in association with control of the rate of placement of embankments for use in similar soft ground conditions by the Welsh Office and the Department of Transport.

Mr T. E. Clarkson, Cementation Projects Ltd

My company was involved in bridge 18 and the jacking in of the abutments. Cementation Projects Ltd has been involved in jacking in bridge abutments and other structures for about 12 years. I would take issue to some extent with Mr Muir Wood on some of the comments about the feasibility of the proposals that were put forward at Neath, although I would also admit that it does not always work out as planned.

127. The reason for the top box being 4 m high was that it is essentially a three-tier abutment, similar to those installed at Wandsworth under the main lines out of Waterloo some years previously. In an attempt to minimize costs, by speeding up the jacking operation, and disruptions in rail track by virtue of speed restrictions an attempt was made to combine the upper and middle tiers as one composite box. In the event, primarily because of the failure of the grouting in that particular embankment, it proved not to be successful, but double tier boxes have been used on a number of other structures where the ground conditions have been somewhat more favourable.

128. Since this job in 1971 techniques to install large boxes have been developed which can in effect provide a tunnel underneath a railway or a road, rather than just putting in abutments and then installing a deck by conventional methods. It will be interesting to hear from the Authors whether such a solution might have been acceptable.

129. A scheme is going forward shortly in which it is proposed to construct a large concrete box to one side of the track, and in the same period of occupation as is traditionally used for putting in the deck to jack the whole structure into place in a single weekend occupation. The track should be open again within 48 or 50 h.

130. As a further development in recent jobs the box has been constructed in situ alongside the railway track. The advantage of this sort of construction is that it produces a relatively long structure rather than a series of prefabricated units. This gives more stability and certainly it is easier to maintain alignment and level. In South Africa such a structure has been jacked underneath eight tracks of the main railway into Durban with a series of cantilever steel joints projecting ahead of the shield. The tracks were supported on these cantilevers by small roller units. It would be interesting to know whether, had the state of the art been so advanced, something similar might have been more suitable at Neath.

Mr A. C. G. Hayward, Mott, Hay and Anderson

Thrust boring of bridge abutments under railway tracks (§ 12), is expensive and appears here to have led to difficulties. Currently my firm is using the method under four tracks with overhead wiring, as almost the only possible method. The Authors had two tracks only. Could not the bridge supports have consisted of precast bedcourse units as shown being erected in Fig 3, resting on piles (or portal legs) driven clear of the tracks? The only disturbance to the tracks would then be possessions for bedcourse installation, apart from deck rolling-in. A longer bridge (possibly having three spans with portals forming intermediate supports) would be necessary, but would eliminate under-track foundations. Can the Authors comment on costs and why thrust boring was done?

132. The steel box girder bridges must have cost considerably more in the end due to Merrison stiffening and checking being applied part-way through the contract—always a bad time for making revisions. The final costs would be misleading in a current assessment of the economy of such bridges. Now that the dust has settled a little on the Merrison work, perhaps the time is approaching to review the place of steel box girders in the bridge scene. The present apparent reluctance to design steel box girders might arise from past fears, from expensive design, expensive construction, or lack of suitable designers. The Authors' comments would be welcome.

133. The Paper describes a number of difficulties and how these were overcome (e.g. § 11, embankments; § 14 thrust bored abutments; § 21, bridge rolling-in; § 23, Merrison; § 36, deck strengthening). This information is extremely valuable to those facing such difficulties in the future. Most contracts have their problems, both man-made and 'natural hazard'. Do the Authors consider themselves particularly 'accident-prone' here. Would they make any particular changes in design or specification if starting again? The conclusions (§ 57) might give the impression that they would.

Mr U. A. Potter, Project Manager, Kier Ltd

It is to be regretted by all civil engineers that the new roadworks obliterated some of the few remaining traces of the famous Neath Abbey Ironworks where Benjamin Baker served his apprenticeship before going on to greater glory at the Forth Railway Bridge and where the railway lines for the Stockton and Darlington Railway were manufactured.

135. The joint venture contractors (Kier Ltd and Sydney Green Ltd) found a number of interesting features and problems in the work, some of the highlights being as follows.

136. The very soft ground conditions prevailing over three-quarters of the site with part of the area being regularly flooded on spring tides meant that access for construction

of the structures could only be obtained after the initial rockfill for the earthworks had reached these locations. Unexpected problems in this connection combined with unscheduled services revealed during the site clearance work meant that 4 months after the starting date no structural work was being carried out at the locations anticipated in the contract programme. It should also be noted that ten of the bridges are over canals and a further eight are railway bridges with traffic having to be maintained through both types at all times. This necessitated the negotiation and construction of five temporary canal bridges, one temporary river bridge, three manned level crossing and eight accesses, all outside the area provided for the works.

137. Troubles encountered in sheet piling the thrust pits through boulders and gravel at bridge 18 meant that the designed 'toe in' of the piles could not be achieved, clutches and ends of the piles were extensively damaged and fully justified the designer's decision not to have the abutments constructed within sheet piled trenches.

138. Apart from the problems which the Merrison Report raised in the fabrication and erection of the box girders, problems of at least comparable magnitude were raised in the deck concreting operations. The four principal box girder bridges all had a concrete deck of composite design and in each case the only feasible construction method was to suspend the falsework from the erected boxes. The design therefore had to be analysed to confirm stability at every intermediate stage, between the bare boxes and the completed structure involving a large amount of additional work by independent consultants retained by the contractor (Ove Arup and Partners).

139. In the end reasonably straightforward schemes were devised, the most interesting of which was for the 570 m long Saltings Viaduct. At this structure the noteworthy features were that the boxes could move longitudinally up to 200 mm, and because they have no cross-bracing to stabilize them prior to concrete deck construction, they could rotate in the anticlastic bearings. The bridge is curved in plan and elevation and the boxes have a superimposed camber between supports as well as superelevation. The deck also has a large (4 m) eccentric overhang on the inside of the curve, tending to rotate the adjacent box progressively as shuttering is stripped.

140. The shutter scheme was therefore built up around five $600 \times 300 \times 149$ kg/m UBs per 31 m span with welded lugs to hold the boxes laterally, and a system of high tensile bars and balancing beams was used to try to transfer loads into the boxes to minimize the tendency to rotate. Inconclusive calculations were made to establish the best arrangement for transmitting these loads but the empirical method finally adopted proved satisfactory in practice.

141. The designer had allowed a 100 mm overhang on the top flange which the contractor was allowed to drill for bolt holes to obtain positive fixings between the falsework and the boxes. This proved to be of invaluable assistance in devising a sensible shuttering scheme.

142. The cantilever falsework supported by the UB cross members had to be preset by varying amounts up to 100 mm maximum to overcome deflexions such as:

(*a*) progressive deflexions of the falsework under load;
(*b*) progressive longitudinal deflexions of the box beams under load;
(*c*) deflexions caused by rotation of the outer boxes because of the unbalanced effect of the cantilever as controlled by the deck slab;
(*d*) deflexion of the unsupported completed cantilever.

The cantilever overhang was propped for several days prior to removal of falsework to prevent rotation of the outer box. These struts were pin ended to allow longitudinal movement.

143. Because of the ground conditions and the configuration of bridge 15 and the weight of the box girders it was considered necessary to erect 20 and 35 t Scotch derricks on piled foundations for the construction of this bridge over the tidal Neath River. One of these derricks straddled the Neath Canal with one leg piled around a

high voltage cable. It had to be erected by a mobile crane standing on a temporary bridge (also on pile foundations) over the canal.

144. The only practicable method for the erection of the boxes for bridges 3 and 4 was by the use of 125 t mobile cranes standing on the existing bridge (no. 29 on Fig. 1). Extensive investigations had to be made into the stability and strength of this structure in deciding where to position the cranes. In addition the carriageways on this existing bridge had to be widened, involving the removal of steel and concrete placed during its construction about 20 years before. We were pleased to note that it was all in excellent condition and as good as new.

145. Although the Contractor was responsible for the setting out of the various service diversions to lines and levels provided by the Engineer, there was in fact no assurance that these directions would be worked to, and at all times the statutory undertakers exhibited a healthy spirit of independence.

146. We are not convinced that problems with service diversions are overcome by having one engineer dealing solely with the SUs in the early stages of the job. In practice some of the SU diversions are so critical and negotiations have to proceed at such a level that both the resident engineer and project manager have to give their personal attention and considerable amounts of time to these matters.

147. Five of the bridges were of composite universal beam and concrete construction, involving a total of 14 spans. They were noteworthy for the fact that, as with the box girders, there was no cross bracing. This left the contractor with the fairly considerable problem of providing temporary bracing to ensure lateral stability during shuttering and concreting operations, especially as skews of as much as 27° were involved.

Mr A. G. Simpson, Mott, Hay and Anderson

This is a valuable paper and thanks are due to the Authors for highlighting the problems rather than the successes of the project.

149. The Authors refer (§§ 21 and 62) to malfunctioning of hydraulic jacks. This is not uncommon and can in many cases be due to inaccurate setting-up of the jack, whereby the top and bottom bearing plates are not parallel. This of course gives rise to bending and subsequent jamming of the piston in the body of the jack. Under site conditions where there are time restrictions and operations take place in adverse conditions of weather, cleanliness and lighting, there is often a good case for using jacks at no more than half their rated capacity (even after testing). For conditions where lowering only is to be carried out, there may still be a case for the use of sand jacks.

150. The problem of the understrength concrete in the deck of bridge 15 has been solved in an ingenious manner. The Authors do not mention the concrete strength required in the original design. The fact that the span/depth ratio of this bridge is 27 whereas the other composite steel box girder bridges mentioned in Appendix 1 have ratios of 17, and 18 and 21, suggests that a fairly high strength may have been called for. Were the construction depth restrictions such that no additional material could be tolerated in order to avoid modification of the surfacing specification?

151. The choice of expansion joints is interesting. All joints on the short and medium length bridges are of types which are normally installed after completion of the wearing course. This ensures that the best possible riding quality is obtained. The Maurer-Sohne joint is not of this type and hence demands work of a high quality from the surfacing gang if a 'bow wave' is not to occur on each side of the joint. Hence the converse of the statement in § 52 becomes true, i.e. it is important that the surfacing is laid accurately to the joint (once it is fixed) almost irrespective of the theoretical road profile.

Messrs New, Benjamin and Miles

The Authors thank the contributors to the discussion for their valuable queries and comments and have the following observations to make.

153. **Mr Martin**, on behalf of the Director, Welsh Office, Transport and Highways Group, gave a most interesting historical account of the background of Welsh roads over the last 500 years or so, a helpful addition to the Paper, since it is not possible to work in the Neath area without being conscious of strong associations with a stirring and interesting past.

154. We appreciate the further detailed information on the ground problems in the Saltings area from **Mr Holt** who afforded such valuable advice in the planning stages and throughout the contract. His very practical approach to the problems did a great deal to ease the burden of supervision on site. The measuring devices were unsophisticated and there was no evidence to show that they had a disruptive effect on the Contractor's programme. Only minor problems occurred in the maintenance of the protective barriers which were occasionally disturbed by the activities of the earthworks sub-contractor. Some damaged lengths of settlement poles had to be replaced, but this was not an onerous task.

155. **Mr Sandberg**, whose site laboratory afforded efficient quality control throughout, has given details of some of his most specialized investigations. We must agree with him that the specification for iron unsoundness was not at all clear, but even so, the wide variation in density of the slag could, on its own, have led to difficulties.

156. **Dr Ogle** made a valuable contribution by giving so many details of the Saltings Viaduct (bridge 14) and box girder construction. The Authors consider that any reconsideration of design for bridges on the general lines of bridges 3, 4, 14 and 15 would show steel box girder construction to be economically sound, a point queried by **Mr Hayward**. Particularly, there are considerable advantages when constructing over railways and rivers.

157. With regard to bridge 18, on which **Mr Lucas**'s further observations were most useful, faced with a similar problem, with hindsight the Authors would certainly again thrust the bottom unit, and feel there is considerable merit in using the general system, even if some of it has to be in open cut. However it will be appreciated that engineering problems never seem to exactly repeat themselves. It is agreed that such factors as the 3 day week, the fuel crises and the Merrison Report, together with the normal sort of engineering hazards and variation of price, did lead to an increased cost from £7 million to about £12 million and an extension of time of 66 weeks. The Authors are not in a position to detail this increase in cost and break it down into its components.

158. There was no intention to appear 'lukewarm' as regards Corten steel which must always have some advantage in like circumstances. The Authors have recommended its use on several occasions since, but so far have not had any further opportunity for its adoption.

159. Replying to **Mr Hamilton**, the Authors would not propose to enter into any political discussion regarding the scheme or the aid that should be given to parties who may feel that they have grievances. However since the matter of planning has been raised they feel that there would be some merit in setting down a few historical facts.

160. The old trunk road A465 passed through heavily built-up areas of Neath Rural District and Neath Borough but ran clear of Neath town centre. The main access to Neath from this road was at Bridge Street, now closed. Inadequate carriageway widths, pedestrian crossings and similar problems on roads in the northern part of the town centre gave rise to severe overloading of the carriageways, with the result that for quite long periods during each day there was backing up of traffic from the town centre onto Bridge Street and beyond on the trunk road itself. The main road system in the southern half of the town of Neath had reasonable traffic carrying capacity by reason of the fact that traffic management measures had been taken. The exception was at Stockham's Corner where five roads converged at a very inadequate roundabout. It had long been accepted by those concerned that an improvement was required at Stockham's Corner and that this would involve demolition of property.

161. The public inquiry was held in March 1970. The particular alternative suggested by Mr Hamilton in October 1970 would not have connected adequately to the

existing road system, and would not have reduced the amount of traffic passing through Stockham's Corner which would still have needed to be improved. The demolition and disturbance involved in constructing a scheme based on Mr Hamilton's proposals would have been not less than that involved in the Secretary of State's scheme.

162. The design of the new trunk road and its associated side road changes, which included the southern link road, was seen early in the planning stage to affect the road system in Neath with particular areas, Stockham's Corner, Milland Road and some short sections of road in Neath town centre, needing improvement to raise them to the standard of the remainder of the one way system. Neath Borough Council put forward and accepted grant on schemes to improve the latter in the years 1969–72. Glamorgan County Council, as the Highway Authority, put forward a staged design for an improvement of Stockham's Corner roundabout, which would fit in with the layout of the southern link road. Feasible designs were agreed with the County Council and Neath Borough Council for a northern link road and link roads joining the southern link road to Milland Road. In order to complete the picture to the inspector and members of the public and councils involved at the public inquiry, the general arrangement of Stockham's Corner improvement (the various stages), the northern link and the Milland link were indicated on the order plans and described in the statements made at the public inquiry. Glamorgan County Council, as the Highway Authority, indicated at the public inquiry that if the Secretary of State's scheme was constructed as proposed with a southern link road they would undertake the construction of a northern link road to ameliorate any inconvenience which traffic to the NW dormitory suburbs might experience from the closure of Bridge Street.

163. The making of the orders for the new trunk road and associated side roads was made public on 30 October, 1970. In December 1970 the Welsh Office was advised by the Parliamentary Commissioner for Administration that the Windsor Road Link Protest Association, the association represented by Mr Hamilton, had complained to the local Member of Parliament about various factors concerning the making of orders for the new trunk road and more particularly the southern link road. The Parliamentary Commissioner for Administration reported in March 1971. The conclusion of his report reads '. . . As a result of my investigation I am satisfied that the Inspector gave due consideration to all the evidence presented at the Inquiry and that the Welsh Office considered the Report in its fullest detail. I have also seen evidence that the implications of the proposals were drawn specifically to the attention of the Secretary of State. Having found no evidence of maladministration I do not question the merits of the decision given in this case.'

164. As regards the expression of concern over Westway, also a job within the Authors' ambit, they would suggest that if the Westway scheme is considered with land use and potential land use in mind, it will be found to be an outstanding example of the roadmaker's art, giving general improvement to the area. This is particularly so where the road passes over railway land and is closely integrated with Paddington maintenance depot.

165. **Mr Brown** observes that he considers that there is some merit in jacking up the bridge rather than lowering it by jacking. However, the same loads would appear to have to be applied by jacks in either case and there seems to be little difference in the severity of the jacking operations.

166. **Mr Muir Wood** refers to the collapse of a bank which had been built in 7 weeks. For Neath a rate of placing was laid down for filling the embankments across the flood plain and a 13 week suspension period allowed in the contract, as a precaution against the type of collapse he suggests.

167. The Authors do not consider that any more luck came into the Neath situation than is usual for major earthworks jobs. The embankments are not particularly high, and sideslopes of 1 in 3 were adopted over the soft areas. The laboratory tests over the stress range involved showed no signs of 'brittle' behaviour in either the silty clay or clayey silt. Piezometers were installed beneath a short length of embankment where

the height rose to 15 m at Aberdulais, and the readings from half of these suggested that they were not working properly. This is not typical of our experience but it strengthened our belief that in the less critical areas simple monitoring devices were the most appropriate approach.

168. The lower thrust bored units were founded on well-consolidated ground under a very old railway embankment and are showing no signs of settlement. The grouting was intended to stabilize the ground in the region of the upper thrust unit, not under the main foundation.

169. There were no crack inducers built into the lean base and it can only be assumed that a satisfactory pattern of cracking came about in spite of the high strength attained by the lean concrete.

170. Mr Martin has indicated that the general simple methods used for instrumentation and control of the rate of placing have been also satisfactorily used on other Welsh contracts.

171. **Mr Clarkson**'s comments on the development of jacking operations are of much interest. He does not indicate the size of the 'large concrete box' it is proposed to jack in under a weekend occupation and we shall look forward to reading about this in the technical press. The box required for bridge 18 would have had to be 'very substantial', and would undoubtedly have involved alignment problems for the road.

172. **Mr Hayward**'s suggestion for bridge 18 is interesting, but the Authors cannot think that it would have been economic, quite apart from the fact that the close proximity of bridges over the canal and Vale of Neath line would have restricted any extension in length of the bridge. Dr Ogle has drawn attention to the advantages of steel box girder construction and the Authors certainly feel that it will continue to be competitive in conditions comparable to those encountered on bridges 3, 4, 14 and 15.

173. The Authors do not consider that they have had more problems than average on this or any other of their jobs. The points made at the end of the Paper are general points applicable to any comparable work.

174. **Mr Potter** has given a valuable contribution based on his intimate knowledge of the work, particularly in respect of bridges 14 and 15, and supports the case for thrusting the abutments of bridge 18. It is appreciated that both the resident engineer and the project manager may well have to give a great deal of personal attention to service diversions in the early stages of any job, but there is still a good case to ease their burden by having an engineer delegated to the details of this particular responsibility.

175. Replying to **Mr Simpson**, the Authors agree that sand jacks are a positive and reliable method of lowering heavy loads, but they would not have been appropriate for the jacking of bridge 18. This required lifting the bridge deck off the rolling-in carriages and lowering it on to the bearings.

176. The specified 28 day cube strength of the concrete in the deck slab of bridge 15 was 40 N/mm^2. The construction depth restrictions were to avoid any increase in the deadload of the bridge and to maintain the specified road profile. The surfacing specification was modified locally to allow the omission of the DBM basecourse and its replacement by structural concrete, thereby maintaining the original design load and road profile. The deadload could not have been increased and the Merrison requirements still been complied with. The only alternative would have been to remove the deck and recast, certainly not the most desirable of operations.