The reconstruction of Federal Highway 2, Kuala Lumpur

N. J. DALLARD

Mr Dallard

Whereas, as reported in the Paper, 20% of the total traffic in 1971 was motor cycles, the flow count of motor cycles in October 1977 gave 26%, pedal cycle flow being only 1.6% of the motor cycle flow. The total traffic flow predictions given in the Paper seem to have been justified by the count of 110 000 passenger car units per day in October 1977 in the dual four-lane length, which is about 100 000 vehicles/day.

Mr A. N. Brant, Department of Transport, Midland Road Construction Unit

Is the design engineer in Malaysia allowed to exercise his own discretion as to the standards and parameters he uses? Did Freeman Fox & Partners or the Malaysian Government set the parameters for trends in population, employment, vehicle ownership and propensity to travel? Is there a Malaysian version of COBA for economic evaluation? Generally speaking, UK standards were adopted for design speeds, speed flow relationships, geometry, pavement and bridge design. Whose decision was this?

83. It seems to me that Scheme D in Table 1 would have allowed considerably greater flexibility of operation in traffic terms. In Germany and the USA, and now in the UK, it is being found that maintenance operations inevitable with the passage of time can often justify a higher initial standard of road, designed to provide free flow (even though restricted speeds are necessary) during surfacing and reconstruction programmes. I take it that such future maintenance operations were not an essential part of your design or economic evaluation. I wonder whether in recommending such schemes as A, B, C and D in future you would pay more attention to such factors.

84. You mention utilities (§ 50) but you do not say whether the new road actually contains the usual collection of public utilities which are allowed to be placed in all-purpose roads in the UK. Presumably this Federal Highway in Malaysia is equivalent to a UK motorway and not an all-purpose road. You do talk, however, about cycle tracks and cycle segregation. What about pedestrians? Apart from the ox cart shown in one of your slides, presumably no allowance has been made for these or for non-mechanically propelled vehicles which normally seem to abound in Malaysia. Perhaps with 100 000 vehicles/day they would not get much of a chance!

85. I know from my own experience in connection with your work on the M5 from Gloucester to Exeter that Freeman Fox & Partners pay great attention to aesthetics, particularly with regard to structures, and continue to win awards for that element of their work. But you do not pay a great deal of attention to that in your Paper, although you show a photograph of the ribbed concrete. How much attention was paid to environmental matters in your design?

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86. Earthworks are referred to in terms of soil survey and design criteria rather than what happened in practice. You do not appear to have undertaken any advance earthworks over the alluvial silt or slime. According to § 64, settlement (as usual) was quicker than anticipated at the time of design. Perhaps advance earthworks would not, therefore, have been of benefit.

87. Did you determine the jagged form of the karstic limestone by excavation of the material above it (§ 20) or did you simply extend your 36 in. dia. tube until the engineer lowered down it (§ 46) was satisfied?

88. Work began in September 1973 and ended in August 1977. With an extension of eleven months, that makes it a three-year contract period. Would you have proposed a contract period of three years if it had been in the UK? Was the considerable rainfall the main factor in the contract period? Would you have eliminated the need for the extension of time by rearrangement of the public utilities in advance of the main contract as we tend to do in the UK?

Mr B. G. Combridge, Institution of Highway Engineers

I had the privilege and pleasure of visiting Malaysia ten years ago on holiday, and it is obvious comparing what I saw then with what the Author has shown us today that he will go down in history as the maker of modern Malaysia! Great changes have been taking place but, reading his description of the Federal Highway 2 which he was going to replace, I tried to compare the situation with that in Greater London, picturing this 8 km dual two-lane carriageway and the hardship for the commuters of the nearby town daily doing their 10 min stint to Kuala Lumpur at speeds of 30–40 mile/h! Such a road today would be the envy of commuters rash enough to try to get into London by car! It is odd that such a road can be deemed superfluous and scrappable; the Author and his firm must be thankful that they found a gullible client like the World Bank willing to finance such terrible destruction!

90. The typically English but indefensible standard of 1:36 crossfall has been adopted (Fig. 4), even on a three-lane carriageway, and I am trying to square that with the tropical rainfall common in the Far East. Ten years ago in building London's first motorway—the southern approach to Blackwall Tunnel—we decided to steepen the crossfall to reduce splash on the 33 ft wide carriageways and the wider slip road areas, but that was only for London drizzle. We steepened it to 1:33, convenient for calculation. Nobody notices, but the runoff is better and the splash is less. But what about this in Malaysian tropical rainfall?

91. The cycleways are splendid when thought of as motor cycle ways as well as pedal cycle ways. There seems to be enough saving on road in the new carriageway in traffic capacity to make it worthwhile building these great separated cycleways.

92. From Fig. 1 there seem to be nearly 2 miles of road across alluvium about 50 ft deep, obviously a significant problem, and I am not surprised that the specification called for surcharging over that section of road. I am surprised and alarmed to learn that it was found not necessary because the settlement was too fast. Would not this make surcharging even more necessary? Would the Author enlighten us on the rate of settlement, and say if it stopped?

Mr D. J. Pain, Messrs Sandberg

I was seconded to Freeman Fox & Partners for three months in 1972 to supervise the site investigation for the reconstruction of Federal Highway 2, and was on site during construction as Materials Engineer in charge of quality control and testing of materials from September 1973 to June 1977.

94. Figure 11 demonstrates the great variability of the limestone surface mentioned in § 46. Piles 3 ft dia. were bored down until they hit the limestone. A rock socket was then bored in the limestone, and although an engineer was lowered down on one or

Fig. 11. Level of top of limestone at bridge 3: (a) west abutment; (b) east abutment

two occasions, it was not done very often. A diamond drill hole was drilled 8 ft from the bottom of the pile to locate cavities, and where they were located the bored pile was extended until there was sound rock below it.

95. Another interesting feature of the job was the wet mix macadam that was used. This was basically a 2 in. down crusher-run granite to which was added about 20% of $\frac{3}{16}$ in. down granite dust in order to improve the gap which one always gets in a crusher-run grading. Water was added to the wet mix from a water supply over the centre of the gyratory crusher which was used to crush oversize material. This is a neat way of adding the water, and getting the moisture content right. A moisture content of about 6% was needed at the quarry to get the 5% required on site. The necessary moisture content was determined by the vibrating hammer test to find the optimum, but in practice the optimum for the plant used was a little lower than that shown by the vibrating hammer test. There was a method specification, so density tests in the material were unnecessary, but some tests were done and, as a matter of interest, I had compaction tests done in the laboratory on materials which were in the centre of the specification and on the fine and coarse limits. Fig. 12 shows that there are significant differences.

96. For the asphaltic concrete, the 'voids in mix' in the base course were specified as 5-7%; they were 3-5% for the wearing course. We had difficulty in achieving the higher voids because of the nature of the aggregates.

97. To enable a satisfactory degree of control to be exercised over the filler content it was specified that 60% of the material passing the 75 μ sieve in the asphaltic concrete wearing course should be added filler. Because of the dusty nature of the local aggregates it was found impossible to achieve this figure without having too much filler in the mix. Shell's advice was sought, and they advised the addition of at least 2% limestone filler to avoid the risk of the bitumen stripping from the acidic granite aggregate. Stripping was known to have occurred at Senai Airport in Johore where only granite dust had been used as filler. On a subsequent job in Malaysia an adhesion agent,

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Fig. 12. BS heavy compaction curves for wet mix macadam samples artificially made up to the centre and fine and coarse limits of the specified grading: 5 layers, 61 blows, CBR mould, maximum dry density 141 lb/cu. ft, optimum moisture content 6.4% dry weight

0.2% by weight, had to be used to counter stripping of granite aggregate from surface dressing.

98. In Malaysia, although they nominally obey the UK Highway Code, many drivers overtake on the inside, and when we started construction we were very nervous about how the hard shoulders would be used. I should like to ask the Author whether or not he now thinks the provision of hard shoulders was a wise course.

Mr D. N. Holt, Freeman Fox & Partners

I should like to comment on the use of mine tailings because on any project if such waste materials can be used it is always much in the public interest, and a source of satisfaction to both the client and the contractor. In the case of Federal Highway 2 mine waste material was used in two ways. In the first place more than 350 000 cu. yd was used as fill for embankment construction. The average gradings of the material are given in § 63. In the BS compaction test the optimum density for the material was 115–122 lb/cu. ft, and the optimum moisture content was 10–13%, which gave a CBR value of about 10.

100. The second way in which the tin tailings were used was in the granular sub-base. In this case a CBR value of 30 was required. The tailings alone were not suitable, but it was found that a blend of tailings with crusher-run limestone rock, and later granite rock, was acceptable, and had the following advantages. It helped the supply situation; it introduced flexibility by enabling the two components to be mixed in varying proportions which could be altered to keep the grading correct; and it enabled the specification to be met which neither of the components individually could have done without a great deal of selection, sorting and regrading. Compaction in the case of the granular sub-base was done by a vibrating roller to a method specification.

101. At the same time as they were involved in the Federal Highway 2 project, Mr Dallard and some of his design team were involved in the design of the Camborne and Scorrier Bypass, also in a tin mining area with similar interesting problems. In Cornwall there is also a great deal of mine waste lying around, particularly the vast amounts of material around St Austell which derive from the open-cast china clay pits. In the

case of the Camborne and Scorrier Bypass the waste was blended with quarry scalplings and used as cement-bound granular base.

102. Now that he is involved in another Federal Highway project in Malaysia, I should like to ask the Author if there is any feedback of experience from Federal Highway 2 he would apply in the new project; or if he were starting Federal Highway 2 again, if there is anything he would do differently.

Mr J. D. Harris, Harris & Sutherland

It was a joy on this job that decisions were made promptly and at no time was there delay caused by arguing the finer points on any piece of paper.

104. In Malaysia, as formwork is cheap but concrete is expensive, it was cheaper for a number of the taller retaining walls to be built as counterfort walls.

105. The box beams going up to 55 ft were pre-tensioned: there was a local firm (albeit Australian), Humes, who had pioneered prestressed concrete in South East Asia, and the beams could be carried from their works to the site. The box beams were chosen because they gave a smooth soffit, they were shallow, and the method produced a deck, once the beams were placed, that trucks could be driven over as distinct from traffic. The confusion when doubling up on a highway is considerable, so this was an advantage.

106. The beams were transversely prestressed, as we wanted to make sure that the deck was waterproof on its own, without any waterproofing being added. The spans were continuous over the piers with in situ concrete and a few reinforcing bars. This had two advantages. When the rains come they come fast and heavy but not for long. We therefore did not get dribbling down the piers. We could end up with bridges that looked as if they were continuous. In that area a green mould grows on concrete, which makes it look charming, but over joints there is more mould. We have hopefully avoided that, and have made the spans continuous for live loads via the in situ joints.

107. For the I beam bridges, the I beams (which were about 65 ft) were designed to be the same weight as the box beams so that the same crane would cover both jobs. We used a Cement and Concrete Association section, the same shape along the sides but slightly wider, because the I beams were post-tensioned, not pre-tensioned. The main contractor made the I beams, and did not have pre-tension beds.

108. As to piling, reinforced concrete piles were used for the shorter lengths where we knew where the bottom was. If we felt we would hit something deeper, we had steel piles.

Dr S. K. Hammerton, Halcrow Fox & Associates

The problems faced in traffic forecasting and economic analysis of projects in developing countries are obviously very different from those in the UK. One of the first is the different length of time available for doing the job. The feasibility study of seven months was quite long in comparison with current practice but one has to work quickly. (There are longer projects in which I am still involved and on which we have been working for eleven years without doing much other than diverting a few drains, gas pipes and so on.) The clients recognize that all they want to do is to get the job assessed and get it done. They are not persuaded easily to indulge in detailed work and detailed studies. Malaysia is a country with a well proven growth rate. Its average over the past ten years is 8%/year or more; during international trade recessions the Malaysian economy has kept on growing, and the road is located in an important corridor where there is a great deal of industrial development. It is on the way to the airport and the port, and everything there is booming.

110. One sees annual growth rates of traffic of 11–12%, and those who come from the West and are used to a rate of 2–3% think surely this cannot be so. Purchase of new cars is increasing at about 16%/year and motor cycles at 22%/year. Then one starts wondering why the traffic is only going up by 11%/year. Malaysians have commented that expatriate consultants say that the growth rate will be less than expected. Kuala Lumpur is not as jammed up as London, but it has astounded people who have

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worked there how the growth of traffic has taken off. We were fortunate to have had people working on the feasibility study who were outspoken enough to establish and to believe that these rates would exist, and fortunately they have been justified.

111. The forecasting was not so good with regard to goods trucks. There are two factors, the growth rate slightly higher than expected and the effect of overloading of vehicles. Although lorries are only supposed to take 16 tons, frequently they can take 25 tons, 35 tons or even 40 tons. Studies of axle loadings have shown that thicker pavements should be considered for increase of pavement life and reduction of the need for frequent repair.

112. The Malaysians are already going through with plans to construct a parallel expressway to the north of the Federal Highway. Basically this is developing as a primary road network. Everything else is fairly minor. There is not a secondary network to act as a feeder to the primary network.

113. Safety is a problem which is not perhaps as bad in Malaysia as it is in other countries, but the people accept high accident rates, and it is a fact of life and of driving.

114. Although we generally adopt a pragmatic approach, because of the time limitations, does the Author feel that engineers should try and persuade the clients who are already very astute that perhaps it would be in their own interests to spend a little more time on the feasibility study, really looking at things such as growth rates, maintenance and the wider implications?

A speaker

As far as asphaltic concrete is concerned, I should like the Author to say something about softening in tropical countries. Even rolled asphalt would have caused some problems. As the road is now open to traffic, can the Author say whether there has been any cracking or stripping? Stripping is also due to high temperature, and I should like to know what penetration could have been used.

116. For transverse stressing, particularly in a country such as Malaysia, the units should be precision-built. Internal stiffener diaphragms have to be inserted, and Fig. 4 shows that there is a camber. The transverse stressing has to be done in two stages. The beams cannot be stepped to take the camber, so they have to go on a slope, and there are bearing problems. Having jacks on the end and traffic working underneath (Fig. 5) is not simple and it is expensive. So many engineers have dispensed with that because of the problems with torque and twist and lack of fit on beams. I should like to know why transverse stress was used here.

Mr Harris

As we wanted continuity over the piers we had to squeeze the whole lot together, which is all that prestressing does. We continued this across the spans. The reason that it is not done in the UK any longer is that labour is so expensive that it ceases to be worthwhile economically. In Malaysia it is still an economical way of getting a monolithic deck.

Mr J. N. Bulman, Overseas Unit, Transport and Road Research Laboratory

Were any problems encountered in using tin tailings either for fill or for sub-base? I understand that many of these spoil heaps vary greatly in their consistency, often containing lenses of highly plastic material. If incorporated in the construction, such material would of course be deleterious. Were such lenses encountered? If so, how were they dealt with? Was the material washed at the loading point or were the plastic zones avoided simply by careful selection of non-plastic material?

Mr K. G. Bassi, Ontario Ministry of Transportation and Communications

It is interesting to note the use of cast-in-place post-tensioned decks with round voids for bridges 14 and 24. Were the decks of these bridges transversely prestressed? If not, have any longitudinal cracks developed over the voids?

120. The Ontario Ministry of Transportation and Communications started constructing cast-in-place post-tensioned decks with round voids in 1964 and has utilized this type of construction on a large number of continuous bridges with individual spans of 30–45 m. The early bridges with round voids were only post-tensioned in the longitudinal direction. The transverse moments were provided for by mild steel reinforcement. These bridges developed longitudinal cracks over the voids after about three months and at first it was felt that the amount of transverse reinforcement provided was insufficient. The amount of transverse mild steel reinforcement was increased considerably in subsequent bridges but the cracks still developed after about three months. The Ministry then sponsored extensive research work^{15–18} on post-tensioned decks with round voids in order to eliminate these cracks. As a result of this research, it is now the Ministry's practice to provide transverse prestressing at the tops of cast-in-place post-tensioned decks with round voids. As a rough guide an effective transverse prestress of about 4.50 MPa in the concrete above the voids has been found to be satisfactory for bridges where

- (a) the individual spans exceed $1\frac{1}{2}$ times the deck width;
- (b) the skew angle is less than 25° ;
- (c) the length of the solid slab at the end of the deck is at least equal to the distance from the outermost anchorage to the edge of the deck, but is not less than $\frac{1}{3}$ of the span length.

The ends of these decks are provided with transverse prestressing at the top and the bottom in order to resist the in-plane transverse stresses due to the effects of longitudinal post-tensioning.

121. The Ontario highway bridge design code¹⁹ also limits the average effective prestress in the longitudinal direction to $0.16f'_c$, where f'_c is the specified strength of standard concrete cylinders at 28 days. This limit is based on tests¹⁹ on compression members with round voids parallel to the main axis. The tests indicate that concrete members with round voids subjected to a sustained axial stress in excess of $0.16f'_c$ can develop transverse tensile stresses over the voids which can exceed the flexural tensile stress at cracking.

Mr Dallard

The client expected the consulting engineer to produce the results stipulated in the written terms of reference. This meant that we, the consulting engineer, had to take the initiative in regard to stating the standards and parameters mentioned by **Mr Brant** and then to obtain the approval of the client. Economic evaluation was carried out to produce end-products stipulated by the client and the World Bank, the method of evaluation being left to us. There was no Malaysian version of COBA. The decision generally to use UK standards was the client's, the suggestion to use them having been made by us in the proposal we submitted before our selection.

123. The rates of return for schemes considered take into account *inter alia* maintenance costs and traffic forecasts; and Scheme C is shown to produce a better return than Scheme D. As Scheme D was estimated to cost 38% more than Scheme C, there was good reason for selecting the latter scheme. The need to take account of future maintenance operations is very important.

124. Within the right-of-way, utilities are located within margins outside the carriageways. Two foot-bridges were built where it was known that many pedestrians would cross. Pedestrians are also able to cross the main highway on footpaths on the other overbridges. The only non-mechanically propelled vehicles seen on the highway nowadays are pedal cycles which are safely catered for on the cycle tracks, the ox cart referred to by **Mr Brant** being rare in the area and an object of interest only during construction when it was used by a small, but nonetheless specialist, masonry sub-contractor, a type of artisan still to be found in Malaysia but, regretfully, hardly so in the UK.

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125. It was a requirement of the client that we should study and report on environmental effect, and this we did. We concluded that the new highway, with traffic moving more freely than on the old road which was narrower and not grade-separated, would not cause the environmental conditions to deteriorate. Careful thought was of course given to the appearance of structures, and omission of mention of this in the Paper was because we always take it for granted and prefer to let others judge the result.

126. In the design phase we did not consider advance earthworks to be necessary and we were correct. At Kelang interchange the 20 ft high embankment settled about 0.5 ft and was steady when paving was laid. We were not able during the soils investigation to determine the exact shape of the surface of the karstic limestone although the limestone was proved during the investigation. During construction an engineer inspected the surface of the limestone from within the pile liner tube after the tube was brought to a halt by the rock.

127. The contract period in the UK would probably have been what it was in Malaysia less the period the Korean contractor needed in which to send to Malaysia, by sea, earthmoving plant and vehicles. Neither rainfall nor rearrangement of utilities contributed to the extension of time; difficulty in obtaining land in a few squatter areas was the main reason. Advance work on a trunk electricity cable was in fact carried out before construction started.

128. **Mr Combridge's** picture of the old road not requiring improvement is not borne out by the description of it given in the Paper or by the danger and frustration experienced by those who drove on it. The traffic forecasts (Table 2) and the benefits and rates of return (Table 6) were sufficient to satisfy the World Bank—which allocates and controls the funds with which it is entrusted with great care—that the improvement was worthwhile. On the old road, only at the eastern and western ends was the range of speeds mentioned by **Mr Combridge** possible; in central Petaling Jaya traffic congestion was intense (§ 7).

129. Rainfall also is intense at times and whether the crossfall of the carriageway is 1:36 or 1:33 makes no difference to driving conditions in a monsoon downpour when traffic stops, drivers not being able to see clearly through their windscreens. The value of crossfall selected is a compromise which gets the water to the edge of the carriageway and does not send a driver there by undue lateral force: neither condition can be perfectly satisfied. In regard to settlement on alluvium, the type of alluvium on this job was very quick draining: the record for the 20 ft embankment at Kelang interchange shows that each time placement of fill stopped settlement continued for only one week.

130. **Mr Pain's** valuable contribution to the job as materials and testing engineer is much appreciated. I am certain that provision of hard shoulders to accommodate broken-down vehicles in the conditions of such high traffic intensity that prevail was correct. I also think that an 8 ft wide shoulder, instead of 10 ft as in UK, is sufficient.

131. I would add to what **Mr Harris** says about transverse stressing of the box beam decks that the cables were 10 ft apart and the 4 in. gap between adjacent beams was filled with concrete vibrated with a 12 in. poker. The minimum thickness of asphaltic concrete surfacing on the decks was $3\frac{1}{2}$ in.

132. In reply to **Mr Holt's** enquiry whether we would do anything differently next time, we would not use precast concrete channel slabs for side roads, we would have joints in retaining walls not farther apart than 30 ft and we would recommend cycle tracks being 2 ft wider.

133. **Dr Hammerton's** remarks about the Malaysian traffic growth rate of 11–12%, as against 2–3% in the West, support my reply to **Mr Combridge** on the need for the road improvement. I have no doubt that clients of consulting engineers are mostly in too much of a hurry to get jobs built; this is due to political and administrative pressures applied by people who do not understand engineering and the need for more time

during the study period when the fundamental decisions which affect form, safety, appearance and ultimate cost are made.

134. In reply to the next speaker, apart from a few minor blemishes the pavement has behaved well, there being no cracking or stripping. The reason for using 80/100 penetration bitumen in the asphaltic concrete is given in § 39. For a highway such as this one, where temperatures are high all the year round, an even more viscous binder, of penetration value 30/40, is desirable.

135. The question on transverse stressing from the point of view of continuity over the piers is dealt with by **Mr Harris**. To minimize depth of construction was important because of limited vertical space. In addition, speed of construction was vital because of the requirement to maintain the heavy traffic flows within the right-of-way. Once box beams were landed on their rubber bearings, access for construction vehicles was soon available, which would not have been the case with inverted T beams. Another advantage of the box beam arrangement was elimination of the need for temporary propping, and so plant working below (Fig. 5) was unrestricted. The profile of the transverse tendons is simple, allowing good grouting conditions. The transverse tendons will never be subjected to corrosive salt and freezing water as in cold climates.

136. I am glad to acknowledge the work done in Malaysia by **Mr Bulman** and other staff of the UK Transport and Road Research Laboratory. This work was referred to and made use of by us in the study and design phases. The problem of clay lenses in tin tailings was encountered but overcome by careful selection of new sources when, as a result of screening, more than 3½% passed the No. 200 sieve. This was the limit set for concreting sand, reduction in the strength of concrete being shown to occur above this value of silt content. The coarse residue of the screening was used for filter material. For embankment fill we relied on selection. Washing tin tailings was tried once but was abandoned because the nature of the material was such that the process tended to concentrate the silt rather than disperse it.

137. In reply to **Mr Bassi's** interesting contribution, the decks of bridges 14 and 24 were not transversely prestressed, and no longitudinal cracks over the voids have appeared. We have been responsible for other bridges of this type, without transverse prestressing, which have not cracked, transverse moments being satisfactorily catered for with reinforcing steel. Two layers were placed above the voids, one layer below, the steel being normal to the bridge centre-line. Many factors could contribute to the kind of cracking in Ontario which Mr Bassi has described. Among these, the relative thickness of concrete above and below the voids, and concrete shrinkage in a locality subject to a wide ambient temperature range (which is not the case in Malaysia) are but two. Deformed (high bond) bars are superior to plain mild steel in restricting shrinkage cracking. Undoubtedly it is an advantage to be able to avoid transverse prestressing in bridges of this type, but particular factors in Ontario appear to preclude this.

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