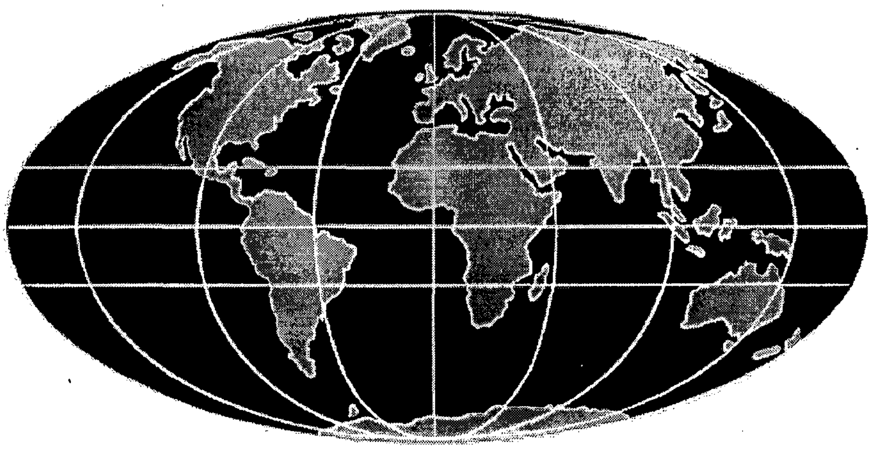
TRANSPORT RESEARCH LABORATORY

DFID Department For International Development

TITLE: Concrete roads in developing countries

by: J D Parry



Transport Research Laboratory
Crowthorne
Berkshire RG45 6AU
United Kingdom

PA1150/85

PA1150/85 PARRY, J D (1985). **Concrete roads in developing countries.** *Highways and Transportation, 32 (8), 13-17.*

Concrete Roads in Developing Countries

J.D. Parry, MIMechE., MIHT.

INTRODUCTION

OVER the past 30 years many thousands of kilometres of bitumen road have been built in developing countries. This ever enlarging and ageing network represents an increasing burden on the road authorities responsible for maintaining it. In many of these countries the time has come when there are no longer sufficient resources in terms of equipment, money or organisation, to prevent major deterioration over much of the network, with a consequent loss of both amenity and investment.

In the past, bituminous surfaced roads have been cheaper to build than concrete ones, but the rapid rise in oil prices during the last decade greatly reduced this cost differential. Additionally, the normal maintenance operations on the two types of road are different in character, and experience from the industrialised countries suggests that concrete roads require substantially less maintenance than bituminous surface roads. In view of the difficulty that many develping countries are experiencing in maintaining their road networks, the prospect of roads that are comparatively maintenance-free is very attractive.

This paper is based on a study that was carried out by the Overseas Unit of the TRRL for the British Overseas Development Administration, and is based mainly on information from the Phillippines, the Caribbean and the USA, together with reports and manuals written in Australia and the UK.

COSTS

IT has been very difficult to obtain cost information which is relevant to developing countries in the tropics. What has been obtained has tended to concentrate on construction costs. Little quantitative information appears to be available on lifetime maintenance costs, and nothing at all has been found on differences in road user costs on the alternative types of construction.

Further difficulties in comparing costs have been highlighted by Hodgkinson [1], who states that the picture is complicated by the selection of design lives, discount rates (which can be made to show that either concrete or flexible pavements cost less), the stage construction of some flexible pavements by the progressive application of overlays, and the definition of acceptable or desirable levels of serviceability of the pavement at some time in the future.

From the evidence that has been collected, there appears to be no outstanding differences in the cost of the two methods of road construction. Initial costs tend to favour bituminous materials in most cases but, in the long term, concrete roads appear to be cheaper. The trend is in favour of concrete because of the increase in the price of bitumen, which could possibly continue after the recent respite. The comparison of costs will also vary according to the type of road to be built, the type of funds available to pay for it, and the available machinery and labour.

Table 1 gives examples of the prices of road surfacing materials in five areas

TABLE 1. COMPARISON OF TYPICAL MATERIAL COSTS US DOLLARS 1983

	Iowa USA	Australia	Philippines	Caribbean Islands	UK
Asphaltic concrete 100 mm/m²	10	12	11	15	13
Mass OPC concrete m³	80-100	65	70	100-130	56
OPC concrete laid 225 mm/m²	15	15	10-17.5		15
125 mm/m²				20-25	

THE AUTHOR

On leaving school Mr Parry took a student apprenticeship in mechanical engineering and studied at Reading College of Technology. He became a member of the Institution of Mechanical Engineers in 1972. Most of his career, apart from three years as engineer to a refugee team in North Africa, has been spent at the TRRL. He was responsible for the instrumentation of guardrail development and mini roundabout experiments, and carried out trials in the use of radio communication for bus route control.

In 1979 he joined the Overseas Unit at TRRL and has reported on the design of modular timber bridges, low technology road maintenance and the application of concrete road technology in developing countries.

THE PAPER

This paper discusses the suitability of portland cement concrete pavements for developing countries. The comparative costs of construction and maintenance of bituminous and concrete roads are considered and design, construction and maintenance aspects are compared at different levels of technology. The conclusion is drawn that concrete roads may be viable in many countries that until now have used only bituminous surfaces. The recommendation is made that the concrete alternative should be investigated and costed for all road projects in developing countries.

of the world. These prices are of the materials used in these places and do not represent the costs of identical specifications. For example, in Iowa the concrete is of high strength with an extremely low slump whereas, in the Caribbean, the concrete is as-mixed on site in small machines, or the local premix. Quantities are relatively small in the Caribbean and the material is often used on very narrow roads and on steep inclines, so the unit cost is high.

Although both cement and bitumen are imported to the smaller Caribbean islands, there are many developing countries with their own cement industries. Many of these countries find it difficult to raise foreign exchange to import bitumen for road construction and maintenance. Concrete roads may be built in these countries, using semi-manual methods as in the Philippines, which require almost no foreign exchange from the road building Ministry. Cement factories, however, use imported equipment and often burn imported fuel, so the foreign exchange costs to the country may still be significant.

In the Philippines, there is no significant difference in the costs of constructing bituminous and concrete roads. Forty per cent of the paved roads in the country are of concrete and represent about 13,000 kilometres. In practice, roads constructed by the government tend to be of concrete; while those sponsored by outside agencies are more usually of flexible construction.

The costs of rebuilding the Baths Road in Virgin Gorda in the Caribbean were estimated for both a flexible (crushed stone base with double surface dressing) and rigid pavement. This showed that there was little difference in capital outlay between concrete and bitumen. However, it was concluded by the author that concrete was preferable because it is more durable and produces a far better long-term road base. It is maintenance-free for a much longer period than bitumen, given similar quality control. Table 2 summarises the cost estimates.

TABLE 2 - CONSTRUCTION COST IN $ PER SQUARE METRE, VIRGIN GORDA.

	1980	1981
flexible pavement	19.6	25.7
rigid pavement	18.0	27.0

In the UK, it is usual for bills of quantities to be prepared using both rigid and flexible materials for most major construction contracts. Ten or more years ago, these cost comparisons would have shown the rigid pavement to be more costly to construct by up to 20 per cent. Now either material may be cheaper depending on local conditions. Of five motorway contracts let by the Department of Transport in 1982, two were cheaper using bituminous construction and two were cheaper using concrete. The remaining contract was similarly priced using either material.

Further Investigations Required to Compare Overall Costs

The most effective tool available to date for comparing the costs of alternative pavement designs and maintenance strategies in developing countries is the computer model RTIM2 [2]. Unfortunately there is not enough data available yet to apply this model to concrete pavements.

The Overseas Unit, TRRL is currently monitoring maintenance and construction projects in Zimbabwe and Thailand in order to obtain more precise data on the most economic maintenance intervention levels for gravel and bitumen surfaced roads, to further improve the relationships in the model. Trial sections of concrete pavement were constructed this year and existing pavements are already being monitored. The purpose of this work is to obtain the following information, so that RTIM2 may also be used to predict the costs and benefits of proposed concrete pavements of different designs.

Construction costs: (in non-financial terms)

Materials quantities for each layer of the pavement.
Plant costs for each layer of the pavement.
Labour costs for each layer of the pavement.
Foreign exchange component of each.

Deterioration:

Cumulative traffic and cracking relationships.
Cumulative traffic and joint sealing relationships.

Road user costs:

Tyre and spare parts consumption related to roughness; the effects of stepping and potholing may also have to be measured.

Road maintenance costs:

Routine maintenance costs are expected to be similar to those for flexible pavements.

Recurrent maintenance should be minimal after the correction of early faults, but the cost of repairing them may be significant. Faults will include spalling due to poor laying or inappropriate materials, and the premature deterioration of joint seals.

Periodic maintenance and upgrading costs are not difficult to measure in terms of plant hours and materials, but the pavement life between these activities is much more difficult to predict as it is affected by climate, sub-base, quality of the concrete materials and workmanship during slab laying, and the number of heavy axle loads carried.

It is possible to make predictions now but more data is required to refine these relationships, particularly those relating to more lightly trafficked roads.

DESIGN AND SPECIFICATION

DESIGNS in current use vary greatly from country to country, both in terms of dimensions and materials. These two aspects of design are of course interrelated, and are in turn influenced by construction resources and methods, which also differ greatly from region to region. It is therefore not surprising that designs developed in different places vary considerably, and may be appropriate only in the region in which they evolved. To illustrate this, examples from three very different areas are discussed.

The Philippines

All major projects are designed and drawn by consultants or engineers at the Ministry of Public Works and Highways, Bureau of Design. They use AASHTO [3] and British manuals [4] as references in addition to their own publications [5].

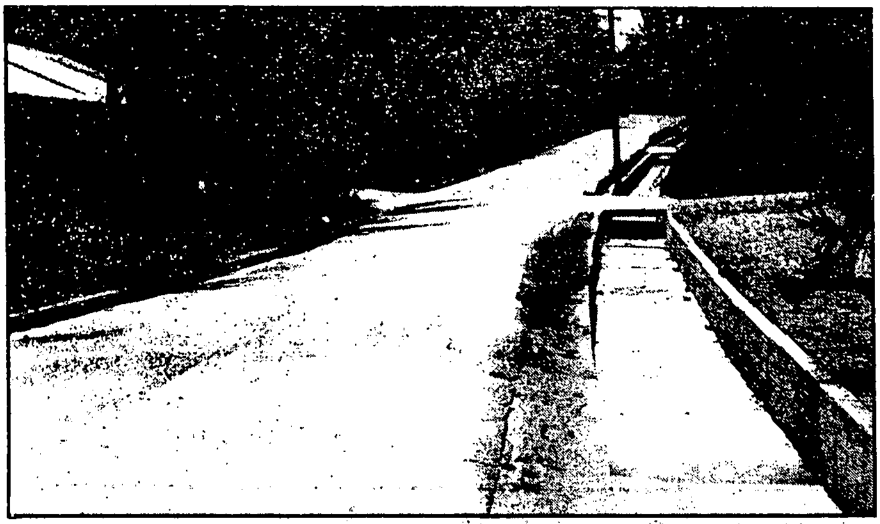
Typically, a dual carriageway road, designed to carry more than 5000 vehicles per day with 15 per cent HGVs would be built on a shaped subgrade with 180mm of sub-base, 150mm of crushed gravel base, sometimes cement-treated, and finally 230mm unreinforced concrete. The three layer design of sub-base, base and concrete slab is used except for reconstruction in which case the slab is cast onto the existing base, so long as it is judged to be strong enough.

Contraction joints are sawn at 4.5m intervals and sealed usually with 60-70 pen bitumen. In recent years, these joints have been set at an angle of 80° to the centre-line so that both wheels on an axle do not impact the slab at the same time. No expansion joints are used, except on fixed structures. Dowels are not usually employed on transverse joints, but may be used at the end of the day's construction run. Tie bars are set at 750mm spacing. On large projects, where two lanes are cast together, a 50mm plastic strip is set by the paver to induce a crack between the lanes.

The Caribbean

Designs and methods of construction vary from island to island in the Caribbean according to tradition, available materials and topography. Standards of construction and maintenance are generally poor but the traffic is usually very light. Here comment is confined to four of the smaller islands.

ANTIGUA. The general policy here has been to lay concrete pavements in low areas subject to flooding. There are several roads with 90 to 100mm concrete slabs that were built 20 and 30 years ago. These are cracked in places and due for upgrading, but the ride is acceptable at the low speeds dictated by the width and geometry.



■ **Figure 1. General view of a concrete road and ditch in the West Indies.**

MONTSERRAT. The Montserrat terrain is very hilly and some erosion results from severe flooding of the roads. Concrete is used where asphalt would fail quickly on the steeper gradients. Crushed beach rock, beach sand and river gravel are used in concrete laid to a nominal depth of 125mm with wood-filled joints 10 to 13m apart. Concrete is mixed in a two-bag mixer or smaller, as no readymix is available. The heaviest loads on Montserrat roads are twin axle gravel lorries weighing up to 30 tonnes.

ST. KITTS. Here, concrete is used for roads only where asphalt would fail. This is on the steep slopes and hairpin bends, and those roads which act as drains during heavy storms. These are mostly 200mm thick. Nominal 20mm stone and that passing the 6mm sieve is used for concrete of 1:3:6 proportions by volume, the remainder being kept for surface dressing. Wood filled joints are used at variable distances.

TORTOLA. Concrete is used for paving steep gradients. It is laid nominally 125mm thick and carries axles up to 9 tonnes. One-bag mixers are used to make concrete at 1:2:4 proportions with crushed rock and beach sand. The bays are 3m wide by 7m long and are laid alternately with staggered wooden joints or they have 50mm x 25mm wooden crack inducers set in the surface. The concrete tends to polish on the very steep gradients and hairpin bends. It is then overlaid with a premixed material made of bitumen emulsion and as-dug sand of 8mm maximum size. It is laid without a tack coat in thicknesses from 12mm upwards and appears to be remarkably successful. Tortola has about 30 kilometres of concrete road.

CONSTRUCTION

CRUSHING cores from remote construction sites often reveals that the concrete strength is well below specification. This is the result of poor control of materials or procedures and is a waste of resources.

At this stage strict quality control is very important, but often difficult to achieve. Poor communications, long hauls to remote sites, lack of resources for maintenance of equipment and not enough trained engineers for site supervision can all lead to a finished product of low variable quality.

Materials

The final responsibility for the quality of materials and the correct batching lies with the site engineer. This is particularly important for concrete construction, as a check must be made for segregation, and frequent slump tests carried out. Should there be an investigation some time after construction because of early failure, it is very difficult to be sure of a diagnosis and remedial measures unless all the materials, including the water, are sampled regularly and the analyses recorded.

TABLE 3 SUMMARY OF PRACTICES ON THE FOUR CARIBBEAN ISLANDS

	Antigua	Montserrat	St. Kitts	Tortola
Proportions by volume	**1:3:6 or premix concrete**	**1:2½:5**	**1:3:6**	**1:2:4**
Aggregates	crushed rock	crushed beach rock river gravel beach sand	river sand crushed rock	beach sand crushed rock
Thickness mm	60-150	125	150-200	125
Slab length m	12	10-13	5	7
Joints	wood	wood	wood	wood

Methods and Equipment

The choice of method of laying the pavement should be largely influenced by the ability of the machine operators and labourers. Because the life of the pavement is affected significantly by the quality of the workmanship, it is important to match the method and equipment to the skill and diligence of the laying team. The hand laying procedure observed in the Philippines was successful because the labourers were both willing and skilful. More mechanisation might be justified where the labour is either more costly or less reliable. In broad terms, the laying of concrete by a paving machine is at the same technological level as laying a bituminous overlay or carrying out surface dressing. Whereas both these bituminous treatments may be done by labour intensive methods, the results rarely compare well with the mechanised results. However, concrete pavements of good quality can be laid by hand using only very basic equipment.

In both developing and industrialised countries, there is a larger pool of labour familiar with concrete than with bitumen. This is not to suggest that workers may be taken from a building site and set to lay pavements without some instruction, but good results have been obtained with the help of a trained overseer.

Site Management

Cleanliness and good timing are as important when laying concrete, as they are when surfacing with premixed asphalt or when surface dressing.

The critical aspects of site management of concrete paving are:-

(a) THE SUB-BASE. The supervisor should ensure that it is evenly compacted and thoroughly soaked but with no excess water, or covered with heavy grade polythene.

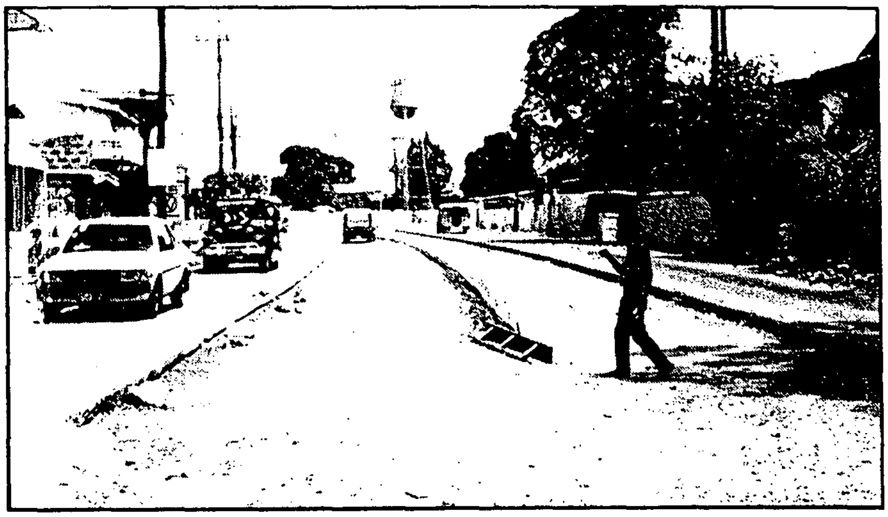
This condition is very rarely fulfilled at remote sites.

(b) FORMWORK. The forms, whether timber or steel, must be in first rate condition and must be firmly laid on compacted sub-base. The rejection of damaged forms should have the full support of the chief engineer.

(c) INSPECTION OF THE RAW MATERIAL. When the fresh concrete is spread between the forms, all the team should work quickly to conclude the laying. However, samples must be taken and a slump test carried out first. Should the concrete be sub-standard in any way it must be rejected. This is a most unpopular decision to take as the premix supplier, the contract manager, the laying team and the Ministry administrators are all inconvenienced and some of them lose money as a result. It always retards the progress of the work and can provoke interference by the media and politicians, who may be under pressure from the local inhabitants or the suppliers. It is important that rejection of substandard material should have the support of the whole of the administration.

(d) TIMING. It is particularly important in hot climates to carry out the laying without delay. This means that all items of equipment, fuel and personnel must be ready before the material arrives. Once approved, the concrete must be spread, struck off, compacted, small areas made good and the surface textured as quickly as is consistent with good work.

When there is a break in supply, the supervisor must judge whether to install a transverse joint or continue laying when the next batch of material arrives. If joints are to be sawn, at least every fourth joint should be cut as soon as is possible without tearing the concrete, and the intermediate ones by the end of the following day.



■ **Figure 2. Road widening and rehabilitation in Manilia.**

MAINTENANCE

AS a lower maintenance requirement is often an important reason for deciding to build a road in concrete, it is worth examining the types of maintenance appropriate to concrete pavements, and the likely effects of neglected maintenance.

Routine maintenance

The only work required in this category is the cleaning of ditches and culverts. The result of neglecting this work will depend largely on the sub-base material. Concrete pavements exist in the Philippines and the Caribbean that have been subjected to flooding every year for several decades. Roads like these, built on stable sub-bases, will not suffer if the side drains are neglected, but the surrounding country may be damaged by erosion due to lack of control of the runoff. However, when the sub-base contains a significant amount of fine material, it is important to keep out the water and it is then necessary to maintain good side drains well below the level of the sub-base.

Periodic maintenance

The frequency of periodic works depends mostly on the intensity of the traffic, but also partly on the severity of the rainfall.

Resealing of joints and crack sealing

These are important on the weaker sub-bases to prevent the ingress of water. Many major concrete roads in the Philippines contain cracks several hundred metres long progressing through many slabs, but the pavements are not considered to have failed. These cracks are sealed with hot bitumen or a rubber compound to keep out the rain and the pavements remain stable. New cracks should be sealed as soon as they open sufficiently to allow the sealant to enter. Depending on climate and traffic, resealing may be required every five to 15 years. Failure to carry out this type of maintenance leads to deterioration in the form of further cracking and rocking slabs, with possible pumping out of the fines from the sub-base.

Hole repairs

Hole patching in concrete is similar to hole patching of flexible roads. The hole is excavated, sound material is placed in the sub-base and compacted, and the surface is finished with concrete at least as thick and strong as the existing slab. Alternatively a bitumen mixture may be used. If it is suspected that an adjacent slab is rocking, a flexible patch of bituminous premix will last longer, but should be expected to fail again and so require frequent inspection, until the rocking is cured permanently.

Stabilising rocking slabs

When a concrete slab rocks under the action of traffic, it acts as a pump, ejecting fine material with the water that has entered by the joints which must have failed. With the loss of material from the sub-base the rocking becomes worse. The problem is to stop the movement and then seal the joints.

Having ensured that poor drainage will not lead to further failure, the slab may be treated in two ways. The loss of sub-base may be made good by injecting cement slurry or bitumen through holes drilled near the joints. This requires several items of equipment, which may not be readily available, and well-trained operators. The simpler solution is to break out the old slab, make good the sub-base with granular material and cast a new slab, which may be keyed to the adjacent ones with dowels and tie-bars.

Shoulder maintenance

This is less critical for concrete roads than for flexible roads because the pavement edge is less susceptible to damage. However, a pronounced step down from the pavement presents a hazard to traffic and a possible channel for water, so shoulders should be maintained to the same standard as for flexible roads. Eroded shoulders may be treated with a bituminous fillet sloping from the level of the pavement at 20° or 30° down to the level of the shoulder.

Retexturing

This may be required when the surface becomes polished. Grooving, milling and scabbling are all relatively expensive remedies and require an investment in machinery. Short, steep sections, such as on the hairpin bends on Tortola could be treated by sawing shallow grooves across the road. They are, in fact, overlaid with a thin premix as described earlier.

By the time a major road becomes polished, it may well be expedient to carry out other repairs or strengthening. In the Philippines, severely eroded or polished concrete is often overlaid with asphalt. Cracks and joints from the underlying concrete pavement reflect through the overlay after a period of time depending on the thickness, the traffic intensity and the flexibility of the overlay. Concrete overlays had been tried, but it was difficult to align the joints closely with those in the old pavement.

Rehabilitation

When concrete slabs become broken to the extent that an overlay is not the solution, or surrounding levels preclude an increase in pavement thickness, the pavement must be removed and relaid. A good example of this is a recent project in the Philippines. The Manila South concrete road sustained virtually all the traffic load south of the city from around 1950 to 1970, when a bypass was built From 1970 to date it has carried only part of the traffic, but is now busy enough to warrant upgrading from one to two lanes in each direction. To do this a new lane was laid either side of the old road, which was then broken up and relaid. Reclaimed material such as this may be used as coarse aggregate or sub-base material if crushing facilities exist, or may be broken and compacted *in situ* if adjacent levels are not critical.

DISCUSSION AND RECOMMENDATIONS

CONCRETE roads are used successfully in several developing countries, although the designs and construction methods differ considerably. Costs of concrete and bituminous construction are difficult to compare and also vary from region to region. In general, concrete roads range from being similarly priced to being 30 per cent more expensive. Maintenance costs for the two types of construction are even more difficult to compare than the construction costs, but a concensus suggests that the maintenance requirement for concrete roads is lower in terms of cost, materials and manpower by up to 70 per cent for the first 20 years.

There are two approaches to the costs of maintenance. In the developed world it is assumed that the required maintenance operations will be carried out more or less as needed, despite any economic difficulties, such as those experienced in the UK in recent years.

When projecting the long term cost of a road to be built in a developing country, the same assumptions are often made. Should these maintenance or upgrading operations not be carried out on time, the road may fail or require expensive rehabilitation much earlier than projected. Many developing countries do not have the ability in terms of funds, equipment or personnel to maintain their existing road network, and so cannot reasonably be expected to maintain more new roads in the way that planners would wish. In the medium and long term under these circumstances, roads designed to require minimum maintenance may last several times longer than traditionally designed roads, and thus would cost far less over the design life. Concrete roads that are not heavily-trafficked require very little skilled maintenance for 10 or 20 years.

A further advantage of concrete roads is that they can be built by labour-intensive methods using skills and technology learned in the building trade. This is advantageous for both the mobility and the availability of skilled labour, and also to a limited extent for equipment. The introduction of concrete technology in the road building sector can also do much to develop local skills and offers scope for the fostering of local contracting industries.

From the evidence available, concrete should be considered as an alternative form of construction, particularly in those developing countries with indigenous cement manufacturing capability. Some countries are net importers of cement and some produce only sufficient supplies for their building trade, but world-wide there is surplus capacity, particularly in south-east Asia. Even where the initial cost of construction is higher than for a comparable bituminous surfaced road, the reduced maintenance requirement over the design life and may make this type of construction more economic in the long term. This should be considered particularly in those countries experiencing difficulties maintaining their road network to an economic standard.

Bilateral and multilateral aid donors should encourage the building of concrete roads, where they can be shown to be economic. They should ensure that feasibility studies include the concrete option, taking into account the maintenance performance of the receiving agency.

REFERENCES

(1) **Hodgkinson, R.J.** Concrete roads for Queensland. Cement and Concrete Association of Australia. 1980.

(2) **Parsley, L.L. and Robinson, R.** The TRRL Road Investment Model for developing countries (RTIM2). Department of the Environment, Department of Transport, TRRL Report LR 1057. Crowthorne, 1982 (TRRL)

(3) **AASHTO.** Interim guide for design of pavement structures. Washington, 1972 (American Association of State Highway and Transportation Officials).

(4) **Road Research Laboratory.** A guide to the structural design of pavements for new roads. Department of the Environment, Road Note No. 29. London 1970. (HM Stationery Office).

(5) **Bureau of Public Highways.** Standard specifications for highways and bridges. Manila, 1972. (Department of Public Works and Communications, Republic of the Philippines).