STRATEGIES FOR PROMOTING THE USE OF CONCRETE PAVEMENTS IN TANZANIA: TECHNICAL AND INSTITUTIONAL CONSIDERATIONS

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ABSTRACT

High-type roads in Tanzania have been predominantly of asphaltic concrete construction. This ever enlarging and ageing asphaltic road network represents increasing resource requirements on the road agency in the form of maintenance. Limited resources coupled with the ever sky-rocketing costs of petroleum products and the competing demands of social economic developments, presupposes the need to look for alternative road construction technology that is more cost-effective and resource optimising. Experience gained from developed and some developing countries where concrete pavements have been widely used suggests the potential of this type of pavement in many developing countries. This paper discusses the technical aspects of design and construction- and maintenance-related aspects of concrete pavements. The discussion extends further to highlight issues pertaining to the performance of concrete pavements and strategies for promoting the use of concrete pavements in Tanzania. Conclusions and recommendations are made with suggestions on how to start implementing the proposed strategies.

Key words: *Cement Concrete Pavement, High-Type Pavements, Pavement Construction Technology.*

INTRODUCTION

The use of concrete pavements ranges from sidewalks that support foot traffic to runways that support heavier aircraft. Concrete pavements in Europe, Canada and USA are designed for 30 years or more years before rehabilitation or replacement, and require little if any maintenance intervention over the service life (Hall et al., 2007). Generally, concrete pavements may be designed for a life of 20, 40 and even 50 years. Each concrete pavement consists of a number of important features; designers can therefore select options for these features to produce a unique design that is tailored to specific project requirements.

Data from some countries which have widely used cement concrete pavements show that when concrete and asphalt pavements are both designed for the same conditions, concrete will usually, but not always, have a somewhat higher initial cost. However, on a life-cycle cost basis, existing literature shows longer service life and low maintenance costs for concrete pavements with lower present worth expenditure and annual cost for cement concrete pavements (Parry, 1985; Packard, 1994; Smith et al., 2001; Mfinanga, 2002). It is further suggested that when different pavement types are to be compared, it is essential to use realistic and equitable designs which are based on sound design procedures (Packard, 1994).

Hall et al. (2007) observed that jointed plain concretes make up some 25 percent of the German high-volume motorway network while about 66 percent (about 4,000 one-directional km) of Austria high-volume motorways are concrete pavements. Motorways make up just over 1 percent of the Belgian road network. Concrete pavements make up 40 percent of these motorways. Concrete pavements are used more on lower-volume roads in Belgium than in most of the other countries in Europe, even rural roads, 60 percent of which are concrete.

In Tanzania, concrete pavements have mostly been used on containers yards at Dar es Salaam Port and on an experimental scale for surfacing roads in hilly areas (e.g. at the 7.64 km Kitonga Gorge Section) that are most prone to heavy rains and vehicle traffic. In such hilly areas asphalt had quickly failed through deformation because of the higher stresses as a result of heavy vehicle traffic action and low speeds. Other areas of use have been on parking lots and petrol stations to avoid the fuel action.

Road transport accounts for over 70% of freight movement in the country and besides handling most of the domestic traffic, Dar es Salaam is a key transit port taking traffic for Zambia, Malawi, Rwanda, Burundi and Democratic Republic of Congo. In 1993/94 road freight transport was estimated at 3,750 million tonne-km. Interregional road freight accounts for about 75% of the total freight transportation demand which tend to use high capacity trucks. A high proportion of this movement is between regional centres and Dar es Salaam (Hine et al., 1997). In terms of traffic loads, these trucks have a significant impact on pavement performance. These heavy loads combined with warm and wet climatic regions result in very demanding requirements for road pavements in these climatic regions. Additionally, fiscal requirements demand improved roads and reduced user delays associated with construction.

Generally, concrete pavements have not been extensively used in most developing countries. There are technical and institutional challenges that impede a more widespread use of concrete pavements. The purpose of this study was therefore to identify both the technical and institutional requirements used by other countries to construct and operate concrete pavements, which would be appropriate for Tanzania.

TECHNICAL CONSIDERATIONS

Generally, a number of pavement types are available through modern pavement technology with such terms rigid pavement, flexible pavement, composite pavement, and full-depth asphalt pavement, among others. Each of these terms has been developed for some particular reason and each has a useful connotation. However, it is recommended to categorise pavements according to their reaction to loads (Beg et al., 1998). Thus, pavements are normally termed as rigid or flexible. This classical categorisation is, in some cases, an over-simplification. However, the terms rigid and flexible provide a good description of how the pavements react to loads and the environment. The essential difference between the two types of pavements, flexible and rigid, is the manner in which they distribute the load over the subgrade. Usually materials for rigid and flexible pavements are cement concrete and asphaltic concrete, respectively.

Pavement Design and Selection Considerations

Traditionally, the main focus of pavement design is to recommend a suitable pavement structure that will meet functional and structural performance criteria through the service life of the pavement. The design philosophy now involves not only a pavement design strategy that seeks to identify the best initial structural section, but also the best combination of materials, construction technologies, and maintenance and rehabilitation strategies. Therefore the basic objective of pavement design is to provide structural alternatives that are feasible both technically and economically. This is achieved by specifying pavement layer thickness with proper types of materials based on the traffic and environmental conditions and the life cycle costs analysis (Beg et al., 1998). As a result a number of feasible strategies for different combinations of pavement materials and performance periods for a particular set of pavement design data can be obtained.

A number of procedures are available for design of asphalt and cement concrete pavements. In addition to the environmental and design traffic consideration, pavement and materials design for asphalt concrete pavement structures relies on the asphalt layer(s), base and subbase layers to transfer the applied load over the subgrade. Consequently, each layer is important to the structural integrity of the pavement. Bases and subbases must be tested to ensure the materials meet the gradation requirements and other properties. The subgrade type and strength are also an important factor to determining the required thickness of the layers in the pavement structure. Generally, the thickness of the flexible pavement layers is determined according to the applied traffic loads and subgrade soil conditions.

Concrete pavements do not require the base or subbase for structural support and subgrade strength is not a critical element in the thickness design. Subgrade has minor impact on the overall thickness in terms of structural design but is a consideration for drainage. However, proper design and construction of rigid pavements are related to uniform support. The applied load is transferred across the rigid structure so that only a small bearing stress is applied to the underlying foundation. Bases or subbases provide a working platform during construction. A permeable subbase is often used under a rigid pavement for drainage purposes and can be either stabilised or unstabilised. If a rigid pavement is being constructed over a poor subgrade material, it is generally desirable to use subgrade stabilisation in expansive soils or install subdrains to eliminate or reduce subgrade moisture levels.

The key design parameters required by any cement concrete pavement design procedure are design traffic, foundation support, subbase material properties, environment, concrete material properties, performance criteria, and design reliability (Hall, 2002). The design of cement concrete pavements also includes many other elements other than thickness design. Such elements include joint design, load transfer design, steel reinforcement design and the selection and specification of other design-related features of concrete pavements.

The concept of generating alternative pavement design has evolved from merely specifying an initial structural section. However, it now involves a pavement design strategy that seeks to identify not only the best initial structural section, but also the best combination of materials, construction policies, and maintenance and overlay polices (Haas et al., 1994). Thus, several feasible pavement design alternatives for combinations of layer materials and performance periods for a particular set of project design data (e.g., traffic, soil condition, and climatic data) can be obtained.

The pavement type selection process is based on the comparison of feasible alternatives pavement designs for a roadway project. This involves comparison of adequate structural design and maintenance and rehabilitation (M&R) policies for different pavement types (Beg et al., 1998).

Generally, the task of selecting a specific pavement type to be constructed for a given project is a complex undertaking that requires consideration of many technical, economic, and miscellaneous factors. In practice, while several pavement types are often technically feasible for a given road construction project, one is often selected over the others based on decisions that involve no systematic evaluation. A range of pavement materials, such as asphalt concrete, Portland cement concrete, stabilised materials, and granular materials, can be used to build pavements. If good technical information is available on several pavement types, then a proper economic analysis will often provide the suitable solution. It is necessary for such information to include not only construction and maintenance/rehabilitation costs, but also road user costs associated with pavement strategies (Beg et al., 1998).

In real-world decision-making environment, there typically exist several miscellaneous factors, that at times they become critical as a result of prevailing project conditions, which affect pavement type selection decision. These factors include historical practice, constructability, recyclability, maintainability, adjacent existing pavements, availability of local materials, and local experience (Beg et al., 1998).

On the other hand, pavement construction issues that have profound influence on the selection of the type of pavement include (MacDonald, 2005):

- Limitations of pavement thickness as a result of the consideration of the impact of utilities below the pavement and overhead clearances.
- Consideration of the effects of geometric and structural capacity of detours, bypasses, and alternate routes on rerouted traffic.
- Effects of underground pipes and services on performance.
- Anticipated future improvements and upgrades.
- Consideration of the impact of grades, curvature, and unique loadings on pavement performance.
- Consideration of critical construction features.

Basic Components and Types of Cement Concrete Pavements

Concrete pavements have a number of features. As a result of the versatility and the range of features not all concrete pavements are similar. The basic features of cement concrete pavements include foundation support (subgrade), subbase, concrete materials, slab thickness, transverse joints, dowel bars, longitudinal joints, tiebars, surface smoothness and texture, subsurface drainage provisions, lateral edge support, joint spacing, and joint sealant material with related construction details and requirements.

Therefore a variety of options is available for each of concrete pavement features. For instance, subbases under concrete highways are typically constructed of dense graded granular material, lean concrete, open-graded (drainable) granular material, cement or asphalt stabilised material, both dense and open-graded. Choices for paved shoulders include asphalt, partial-depth concrete, and full-depth concrete. Gravel shoulders are also used when standards permit.

Concrete pavements have been categorised into three common types: Jointed Plain Concrete Pavements (JPCP), Jointed Reinforced Concrete Pavements (JRCP), and Continuously Reinforced Concrete Pavements (CRCP) (Hall, 2002). Prestressed concrete pavements (PCP) have also been used to a lesser extent. The one item that distinguishes each type is the jointing system used to control crack development.

For various reasons concrete shrinks, contracts and expands and that these actions induce cracks. It is equally important to know that this natural cracking can be easily controlled by the appropriate use of joints and/or reinforcing steel within the pavement.

Commonly used joint spacings that perform well are 4.6 m for plain pavements, not more than 6.6 m for plain-dowelled pavements, and not more than about 13.0 m for reinforced pavements. Joint spacing greater than these have been used but sometimes greater spacing causes pavement distress at joints and intermediate cracks between joints.

Pavement Design Alternatives and Construction in Tanzania

The 1999 Tanzania Pavement and Materials Design Manual (PMDM) (MoW, 1999) provides guide to material selection and design of asphalt concrete pavements. As illustrated in Figure 1, the manual provides several options for generating asphaltic pavement design alternatives which can bear traffic loads of up to 50 million equivalent standard axle loads. It does not cover cement concrete pavements. The design for asphalt pavements relies on the asphalt layer(s), base and subbase layers to transfer the applied load over the subgrade.

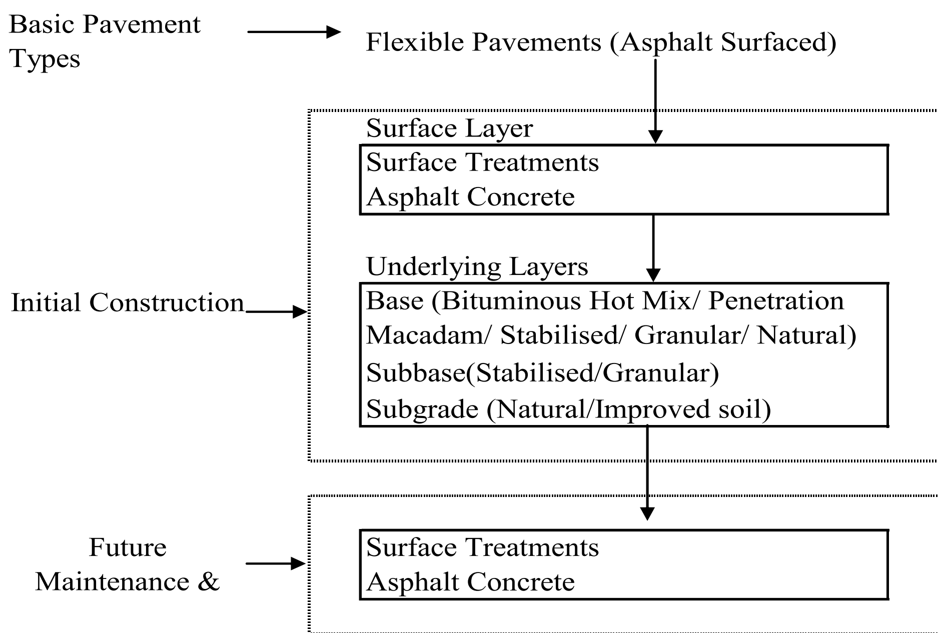

Figure 1: Candidate Pavement Alternatives Covered by the PMDM

The subgrade type and strength are also an important factor to determining the required thickness of the layers in the pavement structure. The thickness of the flexible pavement layers is determined according to the applied traffic loads and subgrade soil conditions.

Concrete pavement design and construction has not been extensively applied in Tanzania. They have mostly been used on an experimental scale for surfacing roads in hilly areas, e.g. Kitonga Gorge Section, which are most prone to heavy traffic and rains. Kitonga Gorge Section of 7.64 km length on TANZAM Highway, Iringa region was rehabilitated from seriously damaged bituminous concrete pavement to cement concrete pavement. The properties of materials used to rehabilitate the section are shown in Table 1 whereas the details of surfacing and base course layers are presented in Table 2.

Table 1: The physical properties of materials used on Kitonga Gorge Section

Material	Source	Properties
Cement	Twiga Cement Co. Ltd.	Specific gravity 3.06
Water	Iringa	Well water
Fine aggregate	Mahenge quarry	Specific gravity 2.64, finness modulus 3.03, water absorption 0.90
Course aggregate	Mahenge quarry	5 mm ~ 13 mm Specific gravity 2.66 Water absorption 0.90 13 mm ~ 20 mm

admixture	Pozzolith Co. Ltd.	Specific gravity 2.69 Water absorption 1.36 AE- water reducer (retarder type) POZZOLITH 300R

Table 2: Pavement details of Kitonga Gorge Section

Feature	Material	Thickness
Surfacing layer	Cement concrete of 45kgf/cm2 after 7 days	250 mm, slab length 5 m
Base course	CRS	150 mm

The TANZAM Highway road is the most important trunk road in Tanzania linking neighbour landlocked countries such as Zambia, Malawi and Democratic Republic of Congo as an international corridor to these countries. The topographical character of the rehabilitated section is weathered rocky terrain that is on average approximately 6.5% of continuously inclined road with short radius bend. The two lanes road experienced serious deep rutting, maximum 15 cm deep was measured with lateral material displacement, and many cracks due to the lack of proper periodical maintenance and increasing number of heavy duty trucks, total weight of some truck was measured approximately 50 tonnes per unit.

Other places which have used concrete pavements in Tanzania include Ubungo bus stand, containers yard at Dar es Salaam Port, and Wazo Hill. The construction of concrete pavements in such areas focused mainly in solving the problems associated with the action of fuels, ruts, and other surface defects such as shoving, corrugations, and ravelling.

Potential Role and Sustainability of Cement Concrete Pavement Technology

Any pavement, independent of its type and applied materials, is subjected to certain traffic loads and environmental factors. These factors create various deterioration modes under in-service conditions. Deterioration modes and the pavement's susceptibility to various deteriorating factors depend on the type of pavement and materials applied. Table 3 presents typical pavement deterioration modes for asphalt concrete and Portland cement concrete pavements.

Table 3: Typical pavement deterioration modes

Asphalt Concrete	Portland Cement Concrete
Surface Deterioration	
Decrease in friction	Decrease in friction
Rutting	Cracking
Cracking	Curling and warping
Ravelling (stripping)	Roughness
Roughness	
Corrugations	
Shoving	
Structural Deterioration	
Base and subbase rutting	Cracking
Fatigue cracking	Pumping
Reflective cracking	Faulting

Referring to Table 3, heavy traffic loads can create ruts in asphalt pavements, while stopping and starting motion can create a distortion on the surface. Turning at corners or intersections on asphalt can also cause the flexible asphalt pavement to shove out its original position. The rigid surface of concrete, however, prevents these types of deformation from occurring in concrete roads.

Other technical benefits that may be accrued by the use of concrete pavements include:

- Better night visibility
- Reduced splash and spray
- Quite and comfortable ride
- Stands up to heavy loads
- Reduced lighting requirements

On the other hand, the potential for depletion of the useable sources for natural aggregates and the environmental-unfriendliness of carbon dioxide emissions from cement manufacturing poses great challenge to the sustainability of cement concrete pavement technology. Thus, the use of recycled materials generated from transport, industrial, municipal and mining processes in transportation facilities is vital to the advancement and sustainability of cement concrete pavement technology. One of the alternatives that address this issue is the utilisation of other cementatious materials like fly ash in concrete. In addition to improving concrete properties, the replacement of Portland cement by such materials will reduce the amount of Portland cement needed and also reduce energy consumption and the rate of global warming in general.

Experience gained from developed countries evidences some case studies and projects that demonstrated practical uses of supplementary cementatious materials for various types of bridges and cement concrete pavements in wide ranging environmental conditions. In all these cases the successful utilisation of supplementary cementations materials required proper mixture proportioning, testing, placement and curing (Hall, 2002).

Cement Concrete Pavement Performance

Cost and performance criteria are usually interrelated; cement concrete pavement features which improve performance often increase construction cost. However, some features cost relatively little to construct, but significantly increase pavement performance whereas other features may significantly increase construction costs with very little improved performance. Thus a happy balance is needed between these two criteria when selecting concrete pavement design features. Changing a concrete pavement design feature is expected to have an effect on the pavement's performance.

Properly designed and constructed concrete pavements can last up to 50 years, requiring little maintenance during their lives while offering valuable qualities such as better riding surface, skid resistance, night-time visibility and durability. The design and construction of cement concrete pavement for highways involves not only thickness design but also the selection, specification and construction of a number of concrete pavement features.

Many highway agencies in developed countries select the best combination of features based on experience, preference, perceived performance, percent constructability, and estimated cost. The effects of various features on concrete pavement performance have been studied extensively in developed countries. Some of the earliest test roads included varying such design features as slab thickness, transverse joint spacing, reinforcement (amount and presence), subbase type and other features and observing performance variations under known traffic loads. Smith et al. (2001) observed that the cement concrete pavement after five years of service has a superior profile ride index, riding comfort index, and friction numbers compared to those of the asphaltic pavement. Little difference was noted between roadside noise levels and the surface distresses.

They keep records of the service lives of pavements by tracking the performance of pavements throughout their life. Information from observations of in-service pavements is used to develop performance curves which are useful for predicting the remaining pavement life for life-cycle cost analysis (Packard, 1994). In addition to performance curves, performance models are also developed to allow comparisons of the effects of pavement design features on pavement performance. Many of these models are based on performance observations of in-service pavements or test-roads.

Because the life of concrete pavement is affected significantly by the quality of workmanship, it is important to match the construction method and equipment to the skill and diligence of the laying team. Parry (1985) observed that more equipment-based method of construction might be justified where the labour is either more costly or less reliable as concrete pavements of good quality can be laid by hand using only very basic equipment.

On the other hand, the performance of concrete pavements is normally adversely affected by the neglect of maintenance requirements. Concrete pavements that are not heavily-trafficked require very little skilled maintenance for 10 or 20 years (Parry, 1985). It is the low maintenance requirement that is often a decisive reason for building concrete roads. Generally, maintenance of concrete pavement includes the following works:

- Cleaning of ditches and culverts: the result of neglecting this work mainly depend on the type of subbase material

- Periodic maintenance works depending on the intensity of traffic and on the severity of the rainfall
- Resealing of joints and crack sealing to prevent water ingress and further cracking
- Hole patching
- Retexturing polished surface
- Removing and replacing broken slabs

Economic Viability of Cement Concrete Pavements

In general life-cycle cost of an asset is the total cost of operating that asset over its life, including the initial costs of providing the asset and the costs of using the asset over its life (PIARC, 2000a). The costs are incurred by the agency responsible for the asset, the people using the asset and others influenced by the existence of the asset. The most obvious costs for a road are costs for planning, design, construction, maintenance, reparation and rehabilitation of the road. Other costs are those for the road user such as vehicle operating costs, accident costs, and the environment.

The AASHTO Guide for Design of Pavement Structures suggests two categories of costs to be considered in the life-cycle cost analysis of alternative pavement strategies with different design features; agency costs and user costs. Agency costs include initial construction costs, future construction or rehabilitation costs, maintenance costs recurring throughout the design period, salvage or residual value at the end of the design period, engineering and administrative costs, and traffic control costs. User costs include travel time, vehicle operation, accidents, discomfort, time delay and extra vehicle operating costs during resurfacing or major maintenance (AASHTO, 1994). In practice, however, life-cycle cost analysis is limited to the construction and maintenance costs of the road over a specified period of time (PIARC, 2000b). One of the reasons for this is that little information exists to enable comparative analysis of differences in road user costs on the alternative types of construction. Thus, what is commonly available has tended to concentrate on construction and maintenance costs.

Comparative analysis of cost-effectiveness of concrete pavements versus flexible pavements 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 strategy for some flexible pavements, and the definition of acceptable or desirable levels of serviceability of the pavement at some time in the future (Parry, 1985). In addition comparison of costs will also vary depending on the type of road to be built, the type of funds available to pay for it, and the available machinery and labour.

Packard (2005) noted that in California, the USA, maintenance costs vary considerably depending on the pavement facility, age and condition of pavement, agency policy, availability of funds, and many other factors. For instance, if the pavement is a major roadway, the comparative cost between asphalt and concrete (average annual maintenance costs for the service life of pavement) may be about two or three to one. For lower road classifications, road agencies often spend very little on concrete maintenance so the ratio of costs rises to much higher values, perhaps as high as eight to one. On the other hand, cost information provided by Mfinanga (2002) showed that the costs for maintaining asphalt concrete pavements was five times more than the costs for maintaining concrete pavement, as shown in Table 4. In Canada, Smith et al. (2001) observed that the costs for maintaining asphaltic pavements were twelve (12) times more than the costs for maintaining concrete pavements.

Table 4: Cost Comparison of Concrete and Asphalt Pavement

Item	Concrete Pavement ($)	Asphalt Pavement ($)
Initial cost	195,000	180,000
Joint repair and panel replacement	21,500	-
Grinding at 25 years	29,000	-
First resurfacing at 15 years (mill and recycle 100 mm)	-	96,000
Second resurfacing at 25 years (mill and recycle 150 mm)	-	143,000
Crack sealing (4 times)	-	12,000
Total cost – 35 years	245,000	431,000

Source: Mfinanga (2002)

Other economic benefits that may be accrued by the use of concrete pavements include:

- Reduced maintenance delays.

- Provides fuel savings for heavy vehicles as more energy and therefore more fuel is required to drive on deflected flexible pavements.
- Uses less non-renewable resources.

INSTITUTIONAL CONSIDERATIONS

Concrete road building is firmly established in Chile largely because of the initiative of local cement manufacturers in promoting the training of engineers and workmen in concrete technology (Millard, 1993). Hall et al. (2007) observed that most European Union countries and Canadian provinces have adopted innovative financing methodologies such as public-private partnership (PPP) and alternative bids as a way of sharing risk with private entities. Subsequently, contractors are accepting more responsibility for design, construction, and long-term maintenance of roadways. Under such systems, contractors are more likely to choose concrete pavements because its longer life and lower maintenance requirements reduce future risks. Another aspect of contracting practice observed by Hall et al. was the awarding of contracts based on best value rather than low bid.

On the other hand, Hall et al. (2007) noted that most construction training of contractors occur on the job and some training is provided by the cement industry groups. Training is the contractor's responsibility and not a requirement. Good communications between contractors and highway agency, valuing academic and industry input are some of the most important aspects noted to have contributed to good industry relations.

SPECIAL ADVANTAGES OF CONCRETE PAVEMENTS FOR TANZANIA

Some of the factors which are likely to place cement concrete construction in Tanzania on a competitive edge include the availability of several indigenous cement manufacturing industries as opposed to the use of bitumen which relies on importation. Besides higher initial cost of concrete pavements, the reduced maintenance requirement over the design life may make this type of pavements more economical in the long term.

Another factor is the availability of equipment and human resource with intensive skills and knowledge learned in the building construction industry. This should not be misrepresented as to suggest that workers may be taken from a building site and set to lay pavements without some clear instructions from a trained supervisor. The hand laying procedure observed in Philippines was successful because the labourers were willing and skilful (Parry, 1985). Although the long term objective would be to use the more efficient equipment-based construction, such hand laying procedure evidences that cement concrete pavements of good quality can be laid using only very basic equipment. Other potential technical advantages of concrete pavements in tropical countries like Tanzania include (Mfinanga, 2002):

- In tropical climates where there is little variation in diurnal (being near the equator) and annual temperatures it may not be necessary to provide thermal reinforcement in the concrete slab.
- Unlike asphaltic pavements, concrete stiffness is not affected by temperature changes. Concrete pavement design methods evolved from experience in temperate regions are likely to be applicable in tropical countries.
- Concrete pavements are ideal in Tanzania where there is a problem of heavy vehicle overloading.
- One of the influences on the structural performance of concrete pavements is the strength of concrete and its coefficient of thermal expansion. Concrete made with limestone, which is widely found in tropical countries; tend to have low coefficients of thermal expansion. The use of limestone, however, should be limited to lightly traffic roads in wet climate because limestone is likely to be polished under heavy traffic.
- Maintenance costs of concrete pavements are relatively less than those of asphaltic pavements. This is an important advantage for a developing country like Tanzania where many asphaltic pavements are failing prematurely for lack of routine and periodic maintenance.

STRATEGIES FOR APPLICATION OF CONCRETE PAVEMENTS TECHNOLOGY IN TANZANIA

The discussion in the previous sections has highlighted a number of issues which deserve special attention for successful and sustainable application of cement concrete pavement construction in Tanzania. It has been pointed out that design of concrete pavements is not just a matter of considering key design inputs which influence thickness design but also the selection, specification and constructability of features of concrete pavements. Concrete pavements, however, have not been extensively used in most developing countries and where they have been used designs varied greatly from country to country, both in terms of dimensions and materials as a result of construction resources and methods (Parry, 1985). As a result, specific designs and specifications may be appropriate only in the region in which they evolved depending on the tradition, available materials and topography. Moreover, it has been noted that cement concrete road building is firmly established in some countries largely because of the initiative of local stakeholders. Thus, strategies for appropriate application of cement concrete pavement technology should embrace both technical and institutional considerations as elaborated in the following subsections.

Technical considerations

- Given the gap in technology and research, in this particular technology, there is a danger of taking for granted existing practices from elsewhere in the design, specification and construction of concrete pavement roads. There is therefore a need, as a starting point, to provide guidance on these issues before adopting the practices. This can be enhanced by identifying concrete pavement designs and materials selection information, documenting the best practices in a simple, straightforward format that will meet specified performance criteria such as those which allow rapid repair and reconstruction, low initial costs, etc.
- The responsible road agencies should take the initiative to keep track and keep records of the performance of pavements throughout their life. Such information is useful for updating documented best practices and for enhancing design procedures and life-cycle cost analysis.
- The current pavement and materials design manual may be enhanced to cover cement concrete pavement design methods and life-cycle cost analysis.

Institutional Considerations

- Local cement manufacturers should take initiatives to tap the potential market of cement concrete pavement construction in Tanzania.
- Road agencies and the cement manufacturers need also to take a leading role to enhance research and development on the utilisation of locally available cementations materials that may supplement Portland cement. These will order to reduce cement volumes needed in concrete pavement construction and ultimately reduce the amount of energy consumption and environmental pollution.
- The government and responsible road agency should encourage and champion the building of concrete roads on pilot scale basis.
- The responsible ministries and road agencies should see to it that consultants do consider concrete pavements as an alternative during feasibility studies.

CONCLUSION AND RECOMMENDATIONS

The discussion has indicated a number of issues which deserve special attention for successful and sustainable application of cement concrete pavement construction. A wide range of technical aspects of concrete pavement design have been covered. It has been pointed out that the design of concrete pavements is not just a matter of considering key design inputs which influence thickness design but also the selection, specification and constructability of features of concrete pavements. It also has been indicated that concrete roads have been used successful in some developing countries and there is great potential for their use in a country like Tanzania.

Taking into account the special advantages of concrete pavement for Tanzania, strategies have been suggested for appropriate adoption of concrete pavement technology. The suggested strategies can be summarised as:

- The Government should encourage the responsible road agencies and aid donors to demand the investigation of technical and financial feasibility of using concrete pavements as an alternative on major contracts.
- Following successful experience from other parts of the world; the responsible Government ministry, road agencies and cement manufacturers should take a leading role in promoting concrete pavement use, research and documentation of best practices in concrete pavement technology.

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