Paving Roads in Laos:
An Alternative Porous Pavement and Its Social Impacts on Rural Communities

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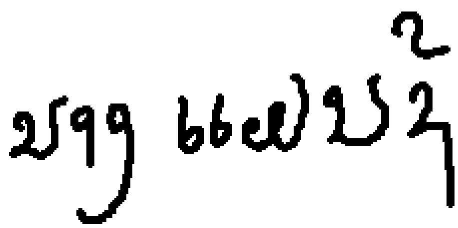

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ABSTRACT

Throughout the past decade of rapid development, Laos has been placing great emphasis on its road infrastructure as an important engine of the development by increasing annual road expenditure. However, the road infrastructure remains under-developed and mostly unpaved; road maintenance poorly funded and issues such as the serious drainage problems during the rainy seasons have not yet been tackled. Thus, porous pavement is proposed as a comparably-priced, durable and well-drained all-weather road paving alternative to conventional paving. A preliminary feasibility study of its use in Laos is conducted based on the initial assessment of the physical conditions, design considerations, economics, its use phase and its limitations. The findings, based on pure literature, show that though porous pavement outperforms conventional pavement in various technical aspects—in particular its superb drainage properties, it is deemed not feasible as an alternative. The dominant reason is that it is these exact drainage properties which would be compromised with the heavy sediment clogging from the flooding of the Mekong River. Furthermore, in midst of proposing an alternative technology based on technical and economic aspects, the social impacts of the development of roads in the specific context of rural communities are also considered and integrated for a more comprehensive and just analytical proposal.

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1. INTRODUCTION

I was first made aware of the severity of the flooding problems in Laos during a panel with professors and government officials, held on Day 1 of the SIGUS Workshop in the University of Laos. A panelist mentioned that there was a major flood in 1966 where two-thirds of the Vientiane city went underwater because a dyke collapsed. The flood water became stagnant and had to be drained to main canals. In fact, much of the national roads are not passable during rainy seasons[1]. This exemplifies the severity of the flooding and draining problems which the road infrastructure in Laos struggles with. In addition, the development and maintenance of the road infrastructure faces cost constraints due to insufficient road funds. Hence, porous pavement becomes an attractive proposed alternative because 1) due to its draining properties, it cuts down on impervious surfaces and thus lessening flooding effects; 2) since porous pavement becomes a combined road-and-drainage infrastructure, it becomes economically competitive in light of insufficient road funds; 3) it increases road safety conditions; 4) it is more integrative to the environment; and 5) Laos has advantages at laying out groundwork for physical infrastructure because it is at a very young stage of development. It should be noted that it is not the objective of the paper to advocate for increased paving of roads based on reasons such as maintenance and comfort levels, but to assess the feasibility of an alternative to conventional paving of roads which are already intended to be paved.

Firstly, the paper examines the current road infrastructure in Laos and what porous pavement entails to analyze its feasibility—using physical conditions, design considerations, economics, use phase and other limitations of porous pavement as criteria. In addition to examining the technical and economical realms of paving roads in Laos, the social impacts of paving roads—particularly in rural communities, are also assessed for a more integrated and comprehensive analytical proposal.

[1] Ref 1, p8.

2. THE ROAD INFRASTRUCTURE IN LAOS

This section looks at the current transportation infrastructure, the road conditions, types of roads and the funding for the road sector in Laos.

2.1 The Roads in Laos

Transport in Laos is dominantly road-based, while the other forms of transportation are by river or by flight. The road network transports 90% of freight and 85% of passenger traffic[2]. Currently, there are approximately 26,000 km of roads in Laos with an extremely low estimated national road network of about 0.06 km/square kilometer[3]. More than half of all district centers have no year-round road access and almost 1/6th of them are inaccessible by road at any time[4]. 18% of the total roads are all-weather routes[5] and approximately 20% of the total road network is paved[6], while the rest have gravel or earth surfaces.

2.2 Types of Roads

According to the Road Law, the roads are classified in six categories: (i) national; (ii) provincial; (iii) district; (iv) urban; (v) rural and (vi) special. The majority of the roads are local roads (38%), followed by provincial roads (35%) and national roads (24%)[7]. In addition, there is generally low level of traffic on national and provincial roads through Lao PDR. A map of the roads in Laos can be seen in Fig 1.

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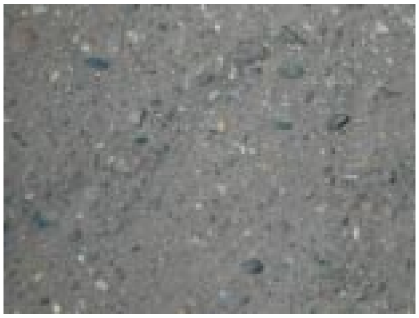
[22] Ref 3. Pg 8.
[3] Ibid. Pg 8.
[4] Ibid. Pg 8.
[5] Ref 5. Pg 1
[6] Ref 4. Pg 5.
[7] Ref 3. Pg 8.

Fig 1: Roads for rural development projects in Laos

Source: http://www.adb.org/Documents/Environment/LAO/lao_roads_rural_dev.pdf

According to Professor Boudadam of the National University of Laos, the roads are mainly of two types of paving: asphalt (or asphaltic concrete) and concrete. There are many ways in which asphalt can be treated and the most common type used in Laos is the double bituminous surface treatment (DBST).

Asphalt paving: Concrete paving:



Source: Manshi Low (Vientiane, 2004)

2.3 Development of the Road Sector

The development of the road sector encompasses (i) the development objectives and (ii) the funding for the road sector. The current development objective of the road system, according to the Prime Minister Sisavat Keobounphanh, is to create an integrated national and regional road system to ensure food security and reduce poverty. Subsequently, the government aims to provide roads to remote communities through cost efficient investment in infrastructure[8]. However, this remains to be fulfilled due to funding. The national road condition development can be seen in Fig 2.

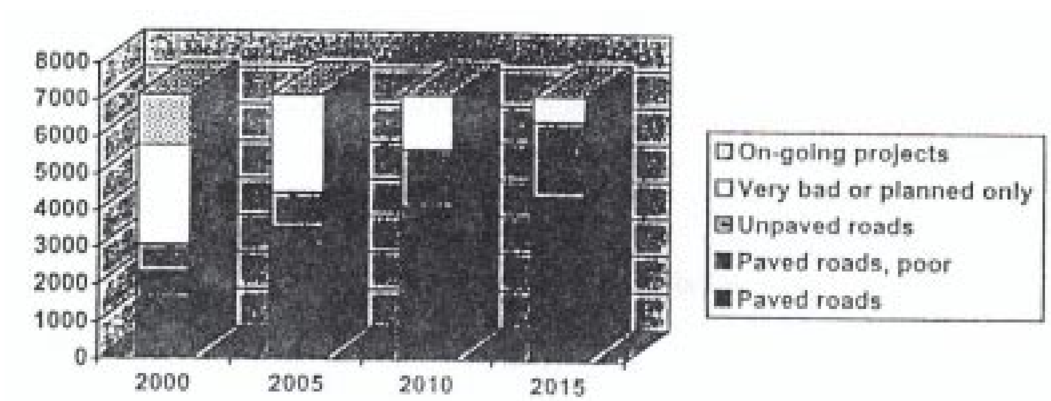


Fig 2: National road condition development. Length of road, km.
Source: World Bank (Ref 5, Section 5.4)

In addition, the roads in Laos are financed through the government's tax revenue and predominantly through external aid. Generally, the annual road sector expenditures for construction and maintenance have been increasing. In the 1990s, the government allocated about 50% of the Public Investment Program to the road sector, chiefly to upgrade national roads

[8] Ref 5. Pg 1.

and spent approximately US$600 million on the rehabilitation of national and provincial networks. An estimated 80% of the rehabilitation expenditure was funded by bilateral and multilateral donors and as a result, 3,000 km of roads improved[9]. More specifically, from FY 1994/95 to FY 1998/99, the annual average increase of 43% in total sector spending was mainly due to increased external funding since local funding actually fell[10]. Nevertheless, the road funds were still insufficient to maintain and to extend the existing network[11], which is plagued by drainage problems during the rainy seasons and unexpected, rapid deterioration due to frequent landslides, defective pavement design and inadequate maintenance[12].

The following diagram, Fig 3 shows the government's priorities of road expenditure in three overlaying levels in decreasing order: 1) routine maintenance to preserving existing connections; 2) periodic maintenance as related to volume of traffic and 3) investing in upgrading existing connections or creating new connections.

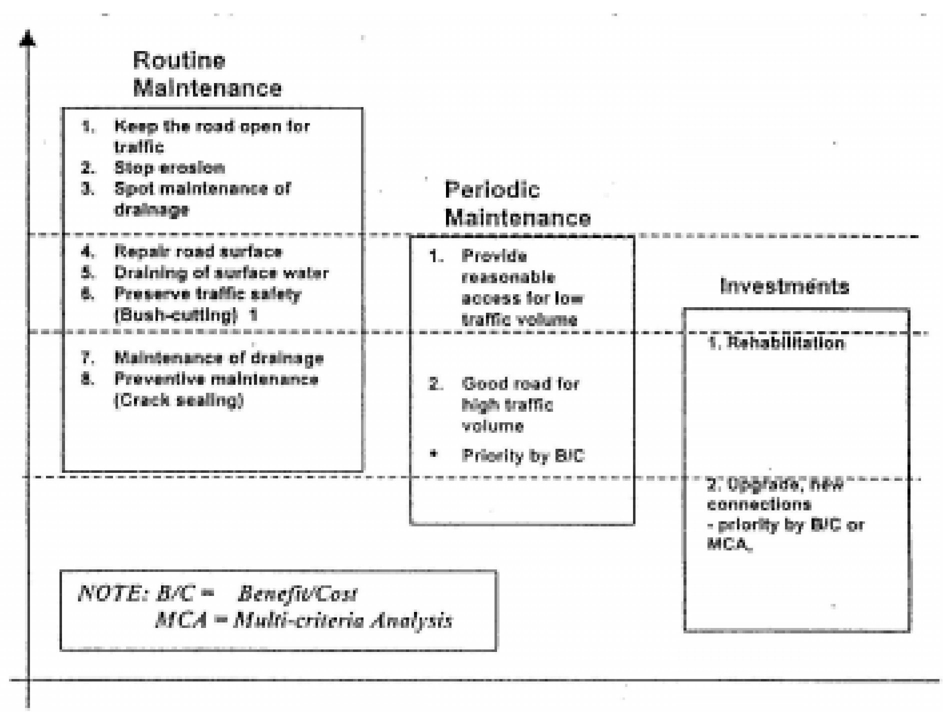


Fig 3: Approach to Maintenance and Development Priorities

Source: World Bank (Ref 5, Section 5.1)

[9] Ref 4, p4.

[10] Ref 1, p10.

[11] Ref 4, p5.

[12] Ref 4, p5.

3. POROUS PAVEMENT AS AN ALTERNATIVE TO CONVENTIONAL PAVED ROADS

3.1 What is Porous Pavement?

Firstly, there are two types of porous pavement—(i) "open graded friction course" (OGFC) for high traffic volume areas which require high skid resistance, and (ii) "open graded base mixes" also known as "asphalt treated permeable material (ATPM)" for freely draining base courses, typically used in parking lots and water-saturated areas. Since the emphasis of this paper is on roads, only OGFC porous pavement would be examined. The water flow through each type of pavement could be seen from Fig 4 and Fig 5:

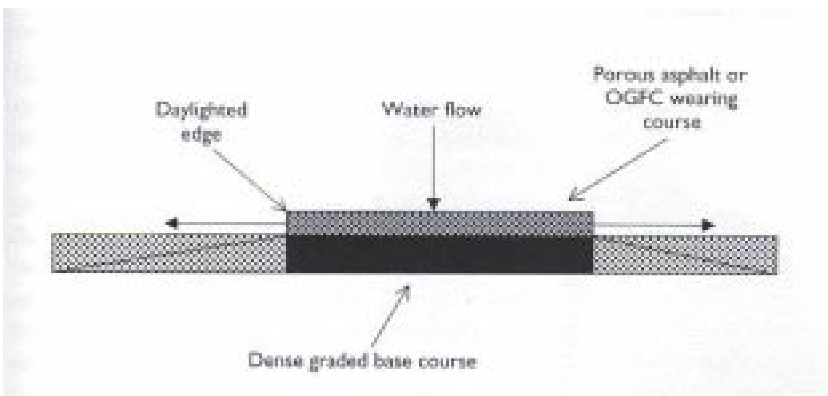


Fig 4: Water flow through porous OGFC asphalt.
(Source: Lavin, p271)

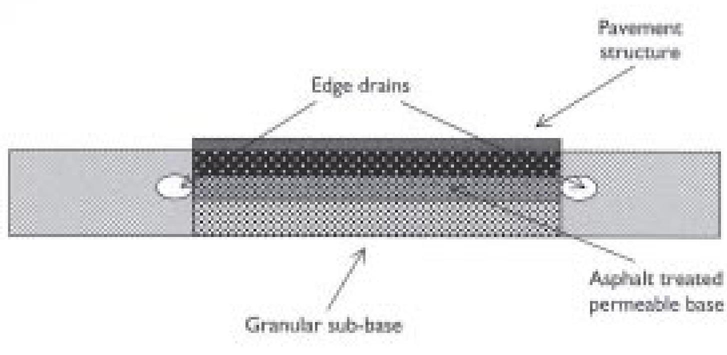


Fig 5: Water flow through porous asphalt treated base (ATPB).
(Source: Lavin, p278)

In general, porous pavement could be paved with asphalt, concrete, ceramic or plastic. Asphalt porous pavement is the most common and consists of larger-sized aggregate or mineral materials such as sand and stone, held together by a special blend of asphalt, e.g. asphalt with fiber-modifiers and polymer-modifiers added. This forms an open structure of porosity of 15% or more and can be built over a dense base course. Rain could then percolate through the pervious top course or layer to the dense graded base course and then travel laterally to the daylighted edges of the porous asphalt wearing course. Due to the recent technological advances, porous pavement is gaining popularity again in the North America, as exemplified in Georgia, Florida and Alabama, the states which now require all interstate projects to use porous pavements. In addition, ten other states, including frost-belt states such as Michigan and Vermont are currently studying its use[13].

Fig 6: Daylighted edges. (Source: Lavin, p272)

OGFC differs from conventional dense graded mixtures because the asphalt mix of OGFC itself is modified with the additions of polymer modifiers and/or spun mineral or cellulose fibers. These modifiers and/or fibers stiffen and add flexibility to the asphalt binder by forming a mat to prevent

[13] Source 13.

newly laid liquid asphalt from draining to the bottom of the course before it cools and solidifies. Secondly, the OGFC has a different grading than conventional asphalt. It contains no fine material but single-sized, generally large aggregate pieces, which create a high percentage of air voids in the mixture. In addition, the lack of fine material gives the pavement surface a negative texture, i.e. planar running surface containing surface voids, which provides good skid resistance and reduces noise levels and spray. Thirdly, the asphalt is paved differently for each type. For porous pavement, a thicker and more viscous layer of asphalt is laid over the larger-sized aggregates while conventional pavements consists of a thin layer of asphalt compacted to keep the mix glued together. Lastly, porous pavements are often built at a higher elevation than the shoulder so that water could drain onto the shoulder and into the roadside ditches.

3.2 Why is Porous Pavement a Good Alternative?

Porous pavement is a good alternative due to three factors:

(i) comparable, if not more superior pavement performance;

(ii) water-retention benefits, including reduced runoff to combined (wastewater and stormwater) sewers, reduced flooding and recharging water table, wells and other water bodies;

and (iii) other benefits.

(i) Comparable/superior porous pavement performance

	Conventional Asphalt Pavement	Porous Asphalt Pavement
Void volume and permeability	2-3%	17-22% e.g. a 50-mm thick course with 20% air voids could absorb 10 mm of rain if it all fell instanteously. (On average, pores can handle 0.1 to 1.0 cm^3/sec of rain.)
Sliding friction		Lower when dry but higher when wet
Noise level		3-5 decibels reduction
Water spray		Significantly less
Hydroplaning		Reduced
Visibility – when wet	Black and hard to see traffic markings	Increased visibility: no film of water; remains gray and traffic markings visible
Headlight glare		Reduced; due to lack of water and negative texture
Road safety		Greater
Durability	10 years.	Increased rut and stripping resistance; similar design life performance if properly designed (8 years or more).

From Ref 6, 7, 8, 9 and 12

The following figure, Fig 7 depicts the visual comparison in the reduction of spray between of the OGFC pavements and the conventional pavements.

Fig 7: Comparison of spraying generated by a tanker traveling on conventional asphalt (on left) vs. traveling on porous asphalt (on right).
(Source: Fabb, p195 & 196)

(ii) Water-retention Benefits

Porous pavement works by retaining precipitation through its void (40% by volume) in the base and then allowing it to percolate through the soils according to the absorption capacity of the soil. This reduces surface runoff and thus the peak demands on the storm sewer, thereby reducing the size and number of sewer pipes. In addition, it allows water to infiltrate and recharge the groundwater table.

(iii) Other Benefits

In addition, there are many other advantages, such as:

a) Since curbs, gutters or drains are no longer required for runoff; porous pavement is more aesthetic and follows a more natural pattern of the site.
b) Porous pavement can provide water for roadside vegetation, unlike conventional pavement.
c) No puddles are formed on porous pavement.
d) With reduced tire noise, driving is made more pleasant and less tiring.

3.3 Feasibility Studies

After understanding what porous pavement is and why it might be a good alternative, its feasibility in Laos can be investigated. These feasibilities studies are categorized into 1) physical conditions, 2) design considerations, 3) economics, 4) use phase and 5) limitations of porous pavement. Again, it should be emphasized that this is a preliminary assessment and should not be taken into considerations without a professional consulting engineering team and an actual economic cost-benefit analysis.

3.3.1 Physical Conditions

This section assesses the feasibility of porous pavements with regards to the physical conditions in Laos, mainly (a) the soil conditions, (b) climate and (c) water table.

(i) Soil Conditions

Soil assessment and permeability testing should be conducted in the actual feasibility studies. It is found through literature, that the soils in Lao PDR are generally poor, with most of the northern part consisting of shallow lateritic soils[14]. For OGFC pavements, the soils underneath should not be permeable, loose, sandy, clayey or collapse when in contact with water. Since lateritic soils could be either permeable or impermeable, it cannot be concluded through literature review, if the OGFC pavements are compatible with the soil types in Laos.

(ii) Hydrology

Laos has a tropical monsoon climate. The rainy seasons fall under May to October ranging from 1100-1500 mm[15], followed by a dry season from November through February

[14] Ref 1. Pg 21.

[15] Ref 11.

and a hot dry season in March and April. The rainfall varies regionally—the Vientiane averages 1,700 millimeters of rain annually and Louang Phrabang about 1,360 millimeters[16]. Depending on the average intensity of a rain (i.e. the amount of rain for a unit time), the porous pavements could be designed to absorb the rains almost instantaneously by varying its thickness and its void ratio. Like the earlier-mentioned example, a 50-mm thick asphalt course with 20% air voids could absorb 10 mm/sec of rain.

(iii) Groundwater Table Level

The porous pavement should not be built over shallow aquifers or high groundwater table level because the runoff that percolates through the porous pavement is likely to contain toxic chemicals, due to the asphalt of the pavement, vehicular traffic and/or road use. Using a rough approximation that the groundwater table level is similar to the water table of the Mekong River, the groundwater table level is estimated to fluctuate seasonally from 1.7 m to 5.0 m when the Mekong River floods, and is considered very high during flooding seasons[17]. In this case, porous pavement is deemed as not suitable, unless the roads are built at a higher elevation than the flood level or if more flood control is used.

3.3.1 Design Considerations

(i) Road Design Standards

Laos uses the Road Design Manual of the MCTPC with appropriate modifications corresponding to the American Association of State Highway and Transportation Officials (AASHTO) design standards. There are already existing AASHTO guidelines for open graded friction courses, including design mixes specifications for asphalt cement (AASHTO M 226) and mineral filler (AASHTO M17), and for testing physical properties e.g. as retained strength and maximum specific gravity[18]. Therefore, designing porous pavements in Laos would not present too many difficulties due to available design guidelines in a familiar and recognized set of design standards, AASHTO.

[16] Ref 4. Pg. 21.
[17] Ref 14 & 15.
[18] Ref 9.

(iii) Design Expertise

Additional expertise is needed in designing and constructing porous pavements. Porous pavements could form “fat spots” when the liquid asphalt is not stiff enough and drains down, encouraging the top layer of aggregates to unravel. Therefore, care must be taken to make sure that the temperatures of mix asphalt must be high enough and aggregates are heated dry enough to prevent asphalt from “sticking” onto them. The asphalt mix must also be properly designed to ensure durability and sound structural integrity.

3.3.3 Economics

A comprehensive cost-benefit analysis is to be performed for the actual feasibility study. Based on literature, porous asphalt generally costs more than conventional dense graded asphalt, at times 30-40% more expensive[19]. This could be explained in part by the additional modifiers which have to be specially manufactured for the OGFC asphalt mix, and extra design and aggregate-handling work for OGFC. With the existing annual road expenditures which have been inadequate, porous pavements might prove to be too costly.

However, if one realizes that the top priority of the annual road expenditures of Laos is on maintenance, including the minimization of erosion and maintenance of drainage, porous pavement might prove to be cheaper overall. This is because porous pavement can also act as a solution in reducing maintenance expenditures by minimizing runoff, hence erosion and helps with the drainage, thereby “killing two birds with one stone.” As a side note, it is not too surprising to find that the top priority of annual road expenditures is maintenance because it gives the highest returns from the experience of project economics[20]. The breakdown of the goal expenditure for routine maintenance is as follows[21]:

- Paved road: US $694/km
- Unpaved road: US $645/km
- Local roads (average for paved and unpaved): US$500/km

It would be interesting to perform a cost-benefit analysis on the net routine maintenance cost of porous paved roads and to compare that with paved roads and unpaved roads.

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[19] Ref 13.

[20] Ref 5.

In addition to road maintenance expenditure, OGFC can be integrated as part of the drainage maintenance in the future, requiring less stormwater pipes and inlets and detention basins and hence cutting initial costs of road projects. Moreover, the improved quality of the roads using OGFC, especially during the rainy seasons, would translate to more intangible savings in time and money, conveniences in traveling and transporting of goods and reduced accidents.

In addition, the materials used in porous pavement are similar to conventional pavement and are locally available and need not be imported, therefore keeping cost of materials low. There are a currently a few quarries along the main road between Buddha Park and Vientiane, which supply aggregates and crushed aggregates. An example of a quarry is shown:

Source: Manshi Low, Laos. (Jan 2004).

[21] Ref 5, Section 5.2.

On the flip side, the upkeeping the porosity of the OGFC would require specialized equipment, which might offset the cost savings and increase the maintenance expenditure in terms of road surface maintenance and preventive maintenance. The issue of porosity would be described in more details in the next section.

Lastly, even if porous pavement are in fact costlier than conventional pavement, its high cost has not curbed its widespread use in European countries, e.g. Austria, France, Netherlands, Italy, Spain, Sweden and Switzerland, thereby implying that the benefits of porous pavement do frequently outweigh its costs (Fabb, 1998.)

3.3.4 Use Phase

In this feasibility study, (i) traffic volumes and (ii) the upkeep of porosity during the use phase would be examined to determine if porous pavement is worth constructing in Laos and if it is easy enough to maintain in the long run.

(i) Traffic Volumes

To use porous pavement as highways, the technical benefits of porous pavements are only noticeable for high volume roads, and hence they should not be used for low volume roads with average annual daily traffic (AADT) of less than 1000[22]. Only areas around Vientiane and Savannakhet have AADT greater than 1000. The traffic levels on the national network are generally below 1000 ADT and on most sections, below 500 AADT. Therefore, the technical benefits of porous pavements (e.g. reduction in noise level, reduced hydroplaning and spraying) would only be realized in a few years when the AADT increases to 1000. Nevertheless, the drainage effects could be realized rather instantaneously.

[22] Ref 10.

(ii) Upkeep of Porosity

This is a very important issue which provides porous pavement its key competitive advantage over conventional pavement. Porous pavement could lose porosity due to:

1) Waterborne soil, which has been draining in the pavement, is not washed off but is grounded into the pavement by traffic;
2) Soil, either dropped from dump trucks or tracked in by tires, is grounded into by traffic; or
3) Pores collapsing when many vehicles brake at the same spot. The area of loss of porosity will be a few square feet under each wheel.

A solution is to use self-propelling machines, which have been developed in Europe, to force pressurized water into the roads and vacuum the fines and water at a single pass. Nevertheless, it is extremely difficult to clean pores plugged under pressure. For this reason, the predicted life for porous asphalt is 8 – 10 years. Therefore, a porous pavement should have minimal soil deposited on it as much as possible and dirt should be washed off or vacuumed off regularly to prevent tracking in of dirt by traffic. Interestingly, even well-clogged porous asphalt generates less spray and still reduces noise as compared with a conventional asphalt pavement (Fabb, 1998.)

In the case of Laos, the criteria of not building porous pavement in areas where there is high sediment and sand transported by stormwater or wind, would be hard to fulfill. This is because Laos is situated in the lower Mekong basin and frequently experiences flooding from May to September when the amount of water in the upper Mekong increases[23]. Therefore, porous pavement is not recommended for use in Laos; unless the roads are kept flood-free either by being constructed at a higher elevation than the flood plain or tightening flood-control.

3.3.5 Other Limitations of Porous Pavement

(i) Structural Strength of Porous Pavement

[23] Ref 16 , p1.

Since porous asphalt does not have the structural strength as dense grade mixtures, porous pavements need to be complemented with additional thickness by dense graded lower layers[24]. In the case where the roads can be at an elevation higher than the flood plain level, this might be feasible. Otherwise, this might incur greater cost and time delays in the construction of the OGFC pavement.

(ii) Lag Time in Water Absorption

There is a lag time for the pores to absorb water after a long dry spell. This is because the pores have to be "pre-soaked" for a short time to allow the surface tension of asphalt to exceed the interfacial tension of asphalt. This would allow capillary forces to draw water into the pores. Therefore, if the rains in Laos come in sudden downpour during the first part of the rain, the OFGC pavement would not be able to absorb the rain as quickly as possible and the technical benefits of OFGC would not be realized immediately.

(ii) Low Reflectance

While the low reflectance reduces glare, it also reduces overall luminance. Thus, artificial lighting has to be increased when necessary. This would be challenging in the case of Laos since the street lighting infrastructure is not yet fully developed.

3.3.6 Preliminary Findings

Even though, the advantages of porous asphalt usually outweigh the disadvantages for high-speed and/or well-populated areas and in climates with heavy rainfall, it is found that porous pavement is not recommended for use in Laos mainly because of the sediment clogging of the pavements during the flooding of the Mekong River. The sediment clogging would negate the technical benefits of the characteristic porosity of OGFC pavements (e.g. flooding, reduced noise, splay and hydroplaning.) It is pertinent to note that the feasibility of porous pavements is based on soil conditions, groundwater table, and hydrology, which are all local conditions and have to be assessed site-by-site within Laos and it would not be prudent to make a gross generalization because it is site-specific.

[24] Ref 7, p270.

4. SOCIAL IMPACTS OF PAVING ROADS IN RURAL COMMUNITIES

Engineers, architects, planners and policy makers usually make decisions on the construction of infrastructure based on the perspectives of outsiders. In an attempt to break down the more ignorant perspective as an outsider, the social impacts of paving roads in the more vulnerable communities, in particular rural communities are examined and integrated into the proposal. Firstly, the obvious social impacts are examined, followed by the more subtle social impacts.

(i) The Obvious Social Impacts

One of the most obvious impacts is that a new road inadvertently changes both the physical and the cultural landscapes while the villagers start to adapt their daily life activities to the new road. The most direct impact is the increase of accessibility of the rural poor to high schools, dispensaries, pharmacies and hospitals, information and technology, markets and shops, government services and employment centers[25]. Gradually, the rural community would undergo a more conflicting and dynamic change towards urbanization with the rustic qualities of the village being replaced by urbanization trace by trace[26]. The demographics of the village are likely to shift and motorbike ownership would increase in synchronization of the new-found accessibility[27]. On the flip side, building roads, especially larger-volume ones is likely to cause resettlement of a partial or an entire village. Unfortunately, the resettled has few advocates and resources to secure satisfactory compensation/resettlement packages. Till today, the issue of resettlement/eviction still has not been adequately addressed by the Lao government and the poor and the rural remain the most vulnerable due to the lack of institutionalized policies to secure their post-resettlement/eviction housing.

(ii) The Subtle Social Impacts

In reality, the design of a road in a rural community is an extremely sensitive matter because it is basically a controlled space which could be designed to go through the village or to it, dividing and

[25] Ref 3. p9.
[26] Ref 19, p255.
[27] Ref 19.

segregating it[28]. A paved road can be conceptualized as a change of nature, which also hints of a change in the course of human history. In particular, a straight paved road sends a message of how humans could subdue nature through technology, as opposed to a curvy road contour-fitted by nature which implies that humans subdue themselves to the will of nature instead[29]. On the other hand, paving roads in rural communities could also increase its vulnerability to insidious influences and diseases. An example, among the most extreme, is the little-known HIV epidemic at Udomxai (northern Laos). The HIV virus is rapidly propagated by the increasing influx of foreign workers who travel to Laos to build dams and roads and buy sex from young hill tribe prostitutes during stops along the roads. The problem is further compounded by the fact that many of the tribal villagers have already undergone tremendous upheaval due to the eradication of opium-growing and slash-and-burn agriculture and hence lost their original subsistence living and left with little or no other means of living.

[28] Ref 19, p250.
[29] Ref 21, p225.

5. CONCLUSIONS

Needless to say, there are many other comparable or even lower-cost alternatives to road paving other than porous pavement, e.g. trunk earth which has been successfully used in Africa. In addition, from the experience of the World Bank officials working in the field, the initial questions of whether a road should be paved at all or whether the entire or part of the road should be paved should frequently be asked in the planning of the road infrastructure in developing countries. In proposing alternative technologies, in this case, porous pavement, not only the technical and economic aspects should be analyzed but also the social aspects of the road development itself. This is important because this integrated approach would produce a more comprehensive and just analytical proposal. In conclusion, the findings, which are based on pure literature, show that though porous pavement outperforms conventional pavement in various technical aspects—in particular its superb drainage properties, it is deemed not feasible as an alternative. This is dominantly because its drainage properties would be compromised with the heavy sediment clogging from the flooding of the Mekong River. Its use would hence be recommended if the porous pavement is built at an elevation above the flood plain or if flood control is tightened.

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