

# Report on Rice Husk Fired Clay Brick Road Paving, Vietnam

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English Version June 2009



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**DFID** Department for  
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Development

# Foreword

This report has been initiated and funded by the global Transport Knowledge Partnership (gTKP) for the benefit of developing and transition countries.

The gTKP is a platform for making effective use of the best available transport knowledge and facilitating strong participation from developing and transition countries.

gTKP is driven by the needs of its users and has a strong focus on the participation of transport practitioners around the world. Through its work, gTKP arms practitioners with knowledge and builds partnerships to improve decision making and help to alleviate poverty.

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This report is aimed at persons or organizations interested in facilitating low cost transport infrastructure for poor urban and rural communities in developing countries and those in transition. The report illustrates the potential for the introduction of fired clay brick paving using rice husk (or possibly other renewable/waste material) as a brick making fuel. The technique will be of particular interest to areas that experience local shortages of hard stone resources suitable for road building. The document illustrates that where suitable clay resources and renewable fuel materials exist, and using small scale, low capital production facilities, a durable, low maintenance paving suitable for most vehicles can be provided using local labour methods and the minimum of equipment.

This report is based on the work carried out under the DFID and World Bank funded Rural Road Surfacing Research (RRSR) undertaken by Intech-TRL, ITST and TEDI in conjunction with the Rural Transport Project (RT2), Ministry of Transport, in Vietnam, and follow up investigations funded by gTKP.

The views expressed are not necessarily those of gTKP, the DFID or any other of the supporting organisations.

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# Table of Contents

Foreword	02
Abbreviations & Acronyms	04
Executive Summary	05
1. Introduction	06
2. Historical clay brick use in Vietnam	07
2.1 General	
2.2 Marriage Pledges	
3. Manufacture of Clay Bricks	09
3.1 Clay for Brick Making	
3.2 The Firing Process	
3.3 Kiln Technology	
4. Environmental Issues	11
5. Global Perspective	12
6. Recommended Follow Up	13
References	14
<b>Appendices:</b>	
Appendix 1 – Illustrations of fired clay brick paving	16
Appendix 2 – Rural road surfacing trials experiences	18
Appendix 3 – Typical Details of Small Scale Kilns used for Firing Bricks using Rice Husk	22
Appendix 4 – Test Results of Brick Kiln Clay for firing by Husk in Dong Thap Province	29
Appendix 5 – Results of RRST II Brick Testing	32
Appendix 6 - Recommended Fired Clay Brick Paving Specification from RRST, Vietnam	33

## Abbreviations & Acronyms

<b>DFID</b>	Department for International Development
<b>gTKP</b>	Global Transport Knowledge Partnership
<b>kg</b>	kilogramme
<b>km</b>	kilometre
<b>mm</b>	millimetre
<b>MoT</b>	Ministry of Transport
<b>N</b>	Newton
<b>PDoT</b>	Provincial Department of Transport
<b>RHA</b>	Rice Husk Ash
<b>RRSR</b>	Rural Road Surfacing Research
<b>RRST</b>	Rural Road Surfacing Trials
<b>RT2</b>	Second Rural Transport Project (Vietnam)
<b>SEACAP</b>	South East Asia Community Access Programme
<b>T</b>	Tonne
<b>TRL</b>	Transport Research Laboratory

## Executive Summary

This report illustrates the potential for the introduction of fired clay brick road paving using rice husk (or possibly other renewable/waste material) as a brick making energy source. Fired Clay brick paving is used in many economically developed and developing countries as a durable, low-maintenance road surface. In developing regions it can have particular attractions for use on urban and low traffic volume rural roads where it can optimise the use of local resources (materials, labour, skills and enterprises). The technique will be of particular interest to areas that experience local shortages of hard stone resources suitable for road building.

A particular attraction of the rice husk fired brick paving technique, is the use of a local renewable energy source (agricultural waste), compared to the production of high carbon footprint binders (bitumen and cement) traditionally used in durable road paving construction. The local small scale production also substantially reduces road works materials transport costs and carbon footprint.

The document illustrates that where suitable clay resources and renewable fuel materials exist, and using small scale, low capital production facilities, a durable, low maintenance paving suitable for most vehicles can be provided using local labour methods and the minimum of equipment and capital.

The report describes the experiences of the application of rice husk fired clay bricks in Vietnam under the Rural Road Surfacing Research (RRSR) carried out by the Ministry of Transport, Vietnam, with the assistance of the UK Department for International Development and the World Bank. Rice husk fired clay brick paving can be constructed from about US\$25,000/km for a 3.5m wide surface.

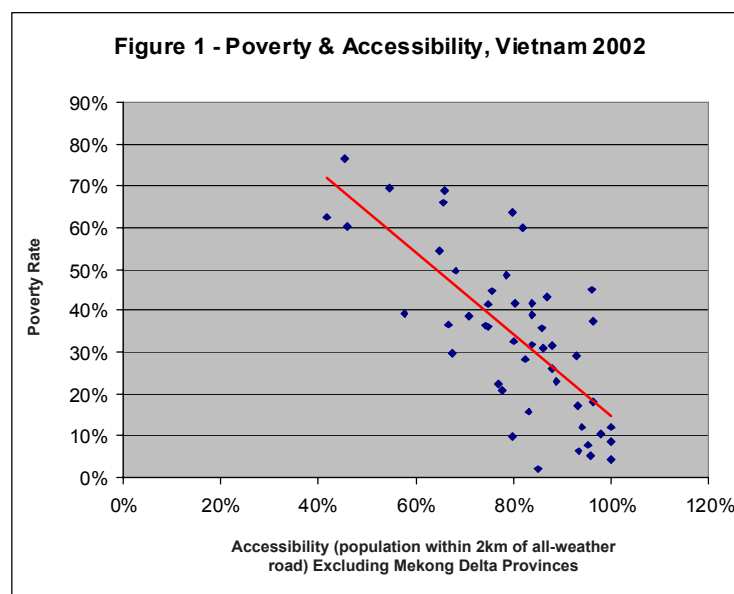
Successful introduction of these techniques will require careful consideration of the local physical and operational environment, and development of standards, specifications and contract documentation and arrangements tailored to the local conditions. Appropriate training and support will probably be required for the production, supervisory and contracting cadres, and suitable quality assurance arrangements should be established. It may be appropriate to arrange local trials and demonstration of the fired clay brick paving techniques to secure local acceptance and refine the techniques in the local environment. It is intended that this report will provide the evidence and support for such a process.

Every ton of rice paddy milled produces about 220kg of rice husk (22% by weight); sufficient to burn about 450 bricks (enough for about 4 square metres of finished brick road paving). With World Rice Production of about 650 million tons per year (FAO 2007), of which Vietnam contributes about 36 million tons, there is obvious scope for widespread adoption of the rice husk fired clay brick technique for road paving and a significant contribution to providing durable, low maintenance, rural road access and poverty alleviation.

## 1. Introduction

Government surveys have shown the strong link between access and poverty (Figure 1).

The Government of Vietnam, principally through the Ministry of Transport (MoT), has been constructing rural roads throughout Vietnam to provide year-round access to communes hitherto suffering from lack of this basic infrastructure facility. Two important programmes providing these new access roads have been the World Bank and DFID supported Rural Transport Project 1 (RT1) and Rural Transport Project 2 (RT2).



Source: Vietnam 2002 Living Standards Survey

The majority of RT1 & RT2 rehabilitated road links are constructed to gravel or in some cases stone macadam pavement standard; because of the limited investment rate per kilometre provided under the programmes. The experience has been that in many provinces, these pavements have deteriorated quickly due to the particularly aggressive environment in Vietnam. (Reference 6). High rainfall (up to about 4,000mm/year), intense storms and flooding, topography and other environmental factors cause high surface material losses and a substantial maintenance burden; counteracting the generally low initial construction costs. The Mekong delta and some other areas without local gravel or hardstone deposits also suffer from high road construction and maintenance costs relating to the long haulage distances for transporting gravel and stone. Gravel roads also cause environmental pollution due to dust in the dry season (especially undesirable near markets, schools, hospitals etc.), and create a burden for local communities who are principally responsible for the maintenance of the local rural roads.

MoT, DFID and World Bank have funded Rural Road Surfacing Research (RRSR) to identify appropriate alternative surfacings for district and community roads. A range of proven paving techniques has been investigated and documented for local application. Trial sections in a range of environments are being monitored for long term performance and maintenance needs. Fired Clay Brick pavement is one of the options being investigated as part of this Surfacing Research. Bricks are made from locally excavated clay, moulded into a suitable solid shape and then 'fired' in a kiln, permanently transforming the material into a hard durable brick, which can be laid as a road surface material over a suitably prepared base or foundation. Usually coal or wood is used as the brick kiln fuel in Vietnam, however this report focuses on the use of rice husk. The particular advantage of rice husk is that previously this material was often discarded frequently causing river pollution, or simply burnt and used as fertiliser on the land. By using rice husk to fire clay bricks,

a step is introduced in the process, effectively creating another product 'for free', as the resulting waste ash can still be sold on as a fertiliser.

This report illustrates the potential for the introduction of fired clay brick paving using rice husk (or possibly other renewable/waste material) as a brick making fuel. The technique will be of particular interest to areas that experience local shortages of hard stone resources suitable for road building. The document illustrates that where suitable clay resources and renewable fuel materials exist, and using small scale, low capital production facilities, a durable, low maintenance paving suitable for most vehicles can be provided using local labour methods, local small enterprises and the minimum of equipment.

With whole life costs becoming an increasing concern for any infrastructure provision, and the high costs of energy in many construction processes, the use of durable brick for paving and other applications using local production provides considerable economic, social and environmental attractions for communities and governments. Local small scale production requires little capital, provides local productive employment and substantially reduces the materials transport costs. The traditional small scale production methods can co-exist and complement the modern brick factories.

## 2. Historical Clay Brick Use In Vietnam

### 2.1 General

Burnt clay bricks have been used for centuries in Vietnam for the construction of buildings, structures and roads. Brick roads are found in many communities in various regions of Vietnam. The widespread availability of clay in the delta and lowland areas, and the accessibility to suitable fuels such as wood and coal, make this an appropriate construction material in many locations. At the most mechanised level clay bricks are currently burnt in production line kilns usually using coal fuel, producing consistent quality products. However good quality bricks can also be produced in relatively small scale kilns using a variety of fuels.



*Figure 2 – Ancient Brick Bridge*

Some ancient clay brick structures have already survived for thousands of years despite the challenge of time and the extreme weather experienced in Vietnam. For example, the annual rainfall in most of Vietnam exceeds 1,500mm and in some locations exceeds 4,000mm, and typhoons bring very high intensity rainfall.

Until now it has been difficult to find records regarding the past techniques of construction material manufacturing, construction methods, construction equipment, and mobilisation of resources etc. It is expected that the study of the past experiences could benefit the present applications of clay brick paving for rural access and community roads.

When visiting communes and villages in Vietnam, travellers can see that bricks are used in many structures such as temples, pagodas, tombs, irrigation canals, village roads etc. Bricks are of different sizes and different pattern reflecting their historical development and usage. Fired clay bricks can be solid, indented, perforated or hollow.

At present, national and provincial roads in Vietnam are usually constructed using asphalt concrete, macadam or cement concrete surface. However, it is not possible to apply these types of surfacing to many rural district and commune roads due to the high costs. Meanwhile, many villages and communes already have roads surfaced by bricks, hand packed stone and dressed stone etc. Some have existed for hundreds years and are still providing satisfactory performance. These were constructed at a time when there was no cement, or modern construction equipment such as stone crushers, trucks, rollers etc.

Clay bricks have traditionally been burnt in small local kilns using coal or wood as fuel. The skills are well established in many communities. The traditional binding materials for the joints between bricks were basic mortars consisting of hydrated lime, sand, and in some cases with the addition of honey and salt.

The only construction equipment required was hand or animal carts, pulleys, boats etc. for hauling the raw materials and finished products. The processes have been largely labour based with simple hand tools, and little capital investment requirements in equipment or production facilities as the kilns themselves are constructed from burnt bricks.

### **2.2. Marriage Pledges**

In the past, in some communities, when a girl was married to a boy from another village, then the boy's family had to pay 500 to 1,000 pieces of brick to the girl's village for community infrastructure. This kind of traditional custom existed in many communities before 1945 but has now lapsed.

Apart from the bricks contributed by the groom's family, the recipient village people paid or arranged for the other materials such as lime and sand and the hire of a construction team to build the section of road.

This was an important contribution to development of the community infrastructure.

When consulted about their views on brick paving as part of these investigations, the communities' response was generally that brick road surfaces are viewed as appropriate as they can be constructed at reasonable cost and with locally available resources. Brick pavements are considered to be cheaper than cement concrete. They are easy to build with local skills, without requiring heavy equipment such as graders, rollers etc.. The brick paving is durable, requires little maintenance, and is anyway easy to maintain; worn broken or damaged bricks can be easily replaced. Investment can be made in small stages as resources become available.



### 3. Manufacture Of Clay Bricks

Bricks are still manufactured by traditional manual methods in most provinces in Vietnam. The exception is for some provinces, where there are not sufficient clay deposits. The most common method is to use coal dust as the firing fuel. Manufacturing technology is simple, apart from the material requirements of suitable soil composition. The process includes kiln construction, excavating, breaking up, and, mixing the clay to the required condition with water, moulding, drying to produce the 'green' clay bricks, producing the coal brickettes, and arranging bricks and fuel in the kiln and burning.

Many families are able to build a kiln inside their garden, and manufacture bricks for building houses. However, bricks cannot be manufactured in some locations in the Mekong delta because the clay composition of local soil is not suitable for making fired bricks (see Section 3.1).



Figure 3 – Beehive or bell shaped kilns for rice husk firing of clay bricks

Some kilns use wood for a fuel and for provinces in the Mekong delta, husks from rice are used for burning the bricks. Some kilns can use either wood or rice husk, depending on availability and costs. The husk is considered to be a waste product from the widespread rice production which crops at up to 3 times per year. Formerly the husk would sometimes be dumped in watercourses causing pollution. More commonly it would be burnt for ash as fertilizer for the following crop planting. The use of the husk for clay brick firing virtually provides a 'free' energy process as the resulting brick making ash is usually still sold on for fertilizer.

Appendix 5 summarises some of the test results from the RRST II trials and shows that the strength of rice husk fired clay bricks can be at least as high as coal fired factory production. The shape tolerances of the husk burnt bricks are also comparable to the large scale factory coal fuelled bricks.

Appendix 1 provides illustrations of the brick production and use.

#### 3.1. Clay for Brick Making

The Vietnamese Standards set out the following requirements for clays for fired clay brick making: Clay specifications (Vietnamese Standards TCVN 4353):

- o Particle sizes (mm):
  - > 10: none
  - From 2 to 10: < 12%
  - < 0.005: from 22% to 32%

- o Ratio of SiO<sub>2</sub>: from 58% to 72%
- o Ratio of Al<sub>2</sub>O<sub>3</sub>: from 10% to 20%
- o Ratio of Fe<sub>2</sub>O<sub>3</sub>: from 4% to 10%
- o Ratio of (MgCO<sub>3</sub>+CaCO<sub>3</sub>): ≤ 6%

### 3.2. The Firing Process

The clay bricks are moulded and fired at a sufficiently high temperature and for a period adequate to achieve the required irreversible chemical changes and required characteristics in the material.

The firing time and temperature influence the properties of the final brick, such as, compressive strength, water absorption, flexural strength, weight loss, firing shrinkage and densities. For a given clay and method of manufacture, higher compressive and flexural strengths, higher density and lower absorptions are usually associated with higher firing temperatures.

Firing temperatures for good quality bricks are typically in the range 900 - 1,100°C.

Firing period to achieve road surface quality bricks is usually about 7-12 days.

From the RRSR trials, a clay brick strength of 20N/mm<sup>2</sup> is recommended as the target requirement for Low Volume Rural Roads and Minor Urban Roads.

From consideration of pavements laid many years ago and still in satisfactory current use, pavement service lives well in excess of 20 years can be expected, even under modern traffic conditions, provided the recommended brick strengths are achieved.

### 3.3. Kiln Technology

For firing clay bricks, the basic concept of brick kiln technology in Vietnam has changed little over the past hundreds of years.

Kilns first started in pits, walls were then added. The addition of a chimney stack, improved the air flow or draw of the kiln, thus burning the fuel more completely and efficiently. Several variations have been invented over the years with varying degrees of efficiency and cost implications.

Brick kilns in use in Vietnam generally fall into one of the following categories:

#### Clamps

The simplest of kilns are called 'clamps'; constructed using 'green' bricks and sealed externally with a plaster of sand-clay-water. These incorporate simple firing tunnels in the base of the clamp. Wood or coal brickettes are the usual fuel type. The clamp is a 'one-use' process and is completely dismantled after the firing. The outer, only partially burnt, bricks may be set aside for possible future re-firing. Clamps tend to produce variable and lower quality bricks suitable for low cost building construction (not of sufficient quality for road

paving).

### **Intermittent or Periodic**

Re-usable kiln structures are the most common type of kiln in use in Vietnam. They are 'permanent structures' usually constructed from fired clay brick material and the 'green' bricks are stacked inside. Firing using the selected fuel is commenced and the internal temperature is allowed to increase and be sustained over a period according to firing experience. Firing is easier to control and is more uniform in these kilns. After the firing process is complete, both the kiln and bricks are allowed to cool sufficiently before the bricks can be removed by hand. Kilns are re-stocked with 'green' bricks and the firing process is repeated as required. Due to the relative ease and low cost of construction, these are the kilns types primarily used in developing countries for higher quality bricks.

Fuel is introduced at the base of the kiln and kept supplied throughout the firing process. The combustion heat rises through the green bricks and is exhausted through chimneys/vents at the top.

These kilns are usually cubical in shape (e.g. vertical shaft), or beehive or bell shaped in the case of those developed for rice husk fuel.

Simple conveyor belts can be used to assist with loading and unloading the kilns which is a labour-based process. Road surface quality bricks can be produced from Intermittent-Periodic kilns.

Due to the relative ease and low cost of construction, the Clamp and Intermittent-Periodic kiln types are commonly used in developing countries.

### **Continuous (or Tunnel)**

These are large scale, industrialized continuous firing process kilns; the 'green' bricks are moved on rail systems through a stationary firing zone, like a train through a tunnel. Firing is achieved through a combination of coal dust mixed into the 'green' bricks and external heating, usually by coal, electricity or gas. Consistently high quality products can be produced. These kilns require considerable capital expenditure in the mechanized production line and reduce labour requirements and costs. They also require a guaranteed continuous fuel supply.

## **4. Environmental Issues**

The fundamental characteristics of using rice husk fired bricks for road paving have the following benefits:

- Low capital requirements for brick making facility
- Use of low cost, local, abundant materials (clay)
- Labour intensive production (local skills and employment at all stages from materials excavation, through production to site works)
- Use of abundant waste agricultural materials as the prime energy source

- Minimization of materials transport costs if road site close to kiln
- Durable construction technique
- Low maintenance road surface and simple to repair
- Attractive Whole Life Cost attributes.
- Acceptable surface for low-medium speed traffic of all vehicle types.

On the negative side, possible concerns could be raised if the kiln design and burning process is not efficient, causing unacceptable air pollution. Further investigations on designs of kilns and exhaust filters would clarify this issue. The most durable brick paving technique requires some cement for the construction of the edge restraints (kerbs) and jointing to make the road paving surface waterproof.

It appears that the process could be at least carbon neutral, as the CO<sub>2</sub> produced by the husk burning process is only a proportion of the CO<sub>2</sub> taken up by the rice crop in the growing phase. This issue deserves further investigation as the process could have significant advantages over traditional high carbon footprint bitumen and cement based road construction. If this is demonstrated, then agricultural waste, fired clay brick production for road paving could warrant support in carbon offset initiatives.

## 5. Global Perspective

Every ton of rice paddy milled produces about 220kg of rice husk (22% by weight); sufficient to burn about 450 bricks (enough for about 4 square metres of finished brick road paving). With World Rice Production of about 650 million tons per year (FAO 2007), of which Vietnam contributes about 36 million tons, there is obvious scope for widespread adoption of the rice husk fired clay brick technique for road paving and a significant contribution to providing durable, low maintenance, rural road access and poverty alleviation.

Global cereal production is estimated to be over 2 billion tons per year. Global roundwood consumption amounts to over 3 billion m<sup>3</sup> per year. Timber industry waste and sustainable timber production also offer other potentially 'green' fired clay brick fuel alternatives. Investigations of other agricultural waste and acceptable carbon footprint options for firing clay bricks are therefore warranted.

## 6. Recommended Follow Up

This document provides sufficient justification for the wider dissemination and uptake of rice husk fired clay brick paving in developing regions.

However, a number of issues would benefit from further investigation to refine the technique and provide an improved knowledge base.

These recommended follow up aspects include investigation or implementation of:

- Detailed 'carbon footprint' of rice husk fired clay bricks and other road surface options
- Possible refinement of kiln designs to reduce emissions.
- Other agricultural waste or sustainable agri-crop firing options for clay bricks.
- Broken fired clay brick as road base and sub-base options
- Establishment of trial-demonstration kilns and surface sections in other global locations with suitable characteristics.
- Continued monitoring of the SEACAP trial pavements in Vietnam.
- Mainstreaming of the clay brick paving technology knowledge in Vietnam and other educational and training institutions, and with practicing engineers.

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# Appendices

- Illustrations of fired clay brick paving
- Rural road surfacing trials experiences
- Typical Details of Small Scale Kilns used  
for Firing Bricks using Rice Husk
- Test Results of Brick Kiln Clay for firing  
by Husk in Dong Thap Province
- Results of RRST II Brick Testing
- Recommended Fired Clay Brick Paving  
Specification from RRST, Vietnam

## Appendix-1: Illustrations Of Fired Clay Brick Paving

Provided by Bach The Dzung and Intech Associates

NOTE: Some of the illustrations show hollow bricks, which are not suitable for brick road surfacing. Surfacing bricks should be solid or with very small perforations.



Gathering rice husk from stockpile.



Husk feed hopper at kiln entrance.  
Firing in process.



Raking ash and feeding rice husk onto  
fire frame



Unloading fired bricks through the kiln  
entrance with the aid of an electric  
powered conveyer. (Note that the  
hollow bricks shown are not suitable  
for road paving).



Burnt clay bricks stacked ready for use.



Rice Husk Burnt Clay Brick





Laying bricks in 'herringbone' pattern between previously laid kerb edge restraints (bricks bedded and jointed in sand-cement mortar, on a conventional road base).



Brick paving laid and ready for sand-cement mortar jointing.



Completed brick paving road in service.

### Alternative Non Rice Husk Fired Brick Production



Bricks are burnt inside a tunnel on a railbased production line.



Vertical Shaft Kiln

# Appendix-2: Rural Road Surfacing Trials Experiences

## 1. Introduction

The Rural Road Surfacing Trials were developed from an appreciation that gravel surfacing is not the best solution for rural roads in many circumstances in Vietnam. Therefore, the Government of Vietnam's Ministry of Transport (MoT) in 2002 requested studies of alternative surfaces for Rural (District and Commune) Roads under their second Rural Transport Programme (RT2).

These studies became known as the Rural Road Surfacing Research (RRSR) initiative, through which the Rural Road Surfacing Trials (RRST) and the complementary Rural Road Gravel Assessment Programme (RRGAP) were carried out. This research programme and its extensions were subsequently incorporated into the South East Asia Community Access Programme (SEACAP).

The SEACAP 1 research project, has been investigating the effective use of alternative surfacing and paving options. These include the use of stone, cement, lime, emulsion and brick in innovative and traditional ways to build low-cost, sustainable roads in Vietnam. Using local resources will enhance affordability of the roads, and could provide a useful income for local enterprises and benefit communities. 168 trial pavement/surfacing sections have been constructed in 12 provinces of Vietnam with diverse characteristics.

## 2. Innovative Approach

The project took a realistic approach to road design, taking into account local conditions and the road environment, traffic characteristics and loading, maintenance resources, technical and implementation options, environmental and whole life cost considerations.

The effectiveness of a range of alternative surfacing and paving technologies using local materials was assessed. Although these options may have a higher initial investment cost than gravel, over the whole life cycle of the road they should prove more durable, needing less maintenance and repair, and therefore they are potentially more cost effective. Feasible options range from the low cost 'hardening' of earth roads where these are only used by non-motorised transport or motorcycles, up to robust paving which could cope with heavily loaded trucks. The emphasis is on appropriate use of local material resources.

For example, Southern Vietnam has a thriving brick making industry and very few hard stone deposits for road building. Clay is locally available and the established small local brick kilns make use of rice husk as a renewable energy source to fire the bricks. These traditional bricks have been shown to be ideal material for road building. The bricks are as strong and regular as factory made coal-fired products. They are generally solid/perforated and up to 10cm x 20cm and 7-10cm thick. For the trials they were laid by hand on a thin, 3-5cm, sand bed over a prepared and compacted road base. The joints are then filled with

sand-cement mortar and the surface is then lightly compacted before the mortar sets.

Other trialled techniques included stone chip and sand seals, bamboo reinforced, steel reinforced and

un-reinforced concrete, concrete bricks, dressed stone, cobble stone, stone macadam and stabilization by cement, lime or emulsion. Appropriate shoulder arrangements have also been trialled. Long term monitoring of the trials has commenced to enable deterioration, maintenance and whole life cost attributes to be determined.

An important element of these surface options is that many of them have a high labour and local resource input, leading to increased rural employment and income diversification. In addition, many of them require no special equipment beyond what would be available to a local general contractor. Hence they open up opportunities for more enterprises to compete and participate in the works. Both of these effects will potentially have substantial benefits for the local poor and the rural economies.

Beside the alternative pavement options, which were proposed by Intech-TRL, clay brick option was proposed for Hung Yen and Dong Thap provinces. There are many brick kilns along the Red river in Hung Yen province. Clay bricks are available and one of the main products of Hung Yen. They have previously been used for road paving in the province. There is established clay brick production in Dong Thap province in the Mekong delta area, burnt by rice husk technology. But before the trial, local people have never used brick for road surfacing purposes.

In fact, brick road pavement has many advantages:

- Social and economic benefits to the communities through local brick manufacture.
- Local labour employment both in labour based construction and in ongoing maintenance.
- Good durability, load bearing and load spreading characteristics provided specification-compliant bricks are used.
- Currently produced brick sizes may be used, with smaller bricks being laid on edge in either “herringbone” or “stretcher” bond.
- Low maintenance and easy to repair.

Principal Concerns:

- Appropriate only when local brick manufacturing can supply bricks of consistently suitable quality.
- Current locally applied construction procedures for village roads need to be improved for Class A or Class B use.
- Needs careful control of construction using string lines within preconstructed edge constraints (kerbs).

### 3. Trials Experience

The trials investigated two principal techniques:

- i) Sand bedded and jointed bricks within mortared kerb edge restraints and bitumen-sand sealed to prevent water penetration.
- ii) Sand bedded and sand-cement mortared joint within mortared kerb edge restraints.

From the follow up monitoring (SEACAP 27 – Reference 4), the sand-cement mortared joint option has

proved to be more suitable than the bitumen-sand sealed, sand joint, option. Adhesion between the bricks and bitumen seal proved to be problematic.

The deterioration and maintenance requirements of the monitored sand-cement mortar jointed clay brick paving has been shown to be acceptably low.

#### 4. Costs (Construction cost)

Costs are for 3.50 metre wide carriageway and for the costs of pavement and shoulder construction above formation level in 2005 prices.

##### Dong Thap province

- Fired clay bricks on edge 10cm thick, cement mortar joints, on 5cm sand bed over 15cm lime stabilised sub-base – **US\$ 23,999 /km**
- Bitumen emulsion sand seal on fired clay bricks on edge 8cm thick, sand joints on 5cm sand bed over 15cm cement stabilised sub-base – **US\$ 23,472 /km**

##### Hung Yen province

- Thuy Loi road - Sand bitumen emulsion seal on 10cm burnt clay brick, sand joint on 5cm sand bedding on 12cm dry bound macadam sub-base. Quarry-run shoulders (12cm) – **US\$ 38,302 /km**
- Nhat Quang road -Sand bitumen hot seal on 10cm burnt clay brick, sand joint on 5cm sand bedding on 12cm dry bound macadam sub-base. Quarry-run shoulders (12cm) – **US\$ 46,134/ km**



#### 5. Lessons Learned

The RRSR and RRSR research work has allowed the following conclusions to be made regarding the planning, evaluation, design, construction and maintenance of rural roads in Vietnam:

- The Rural Road design approach should be improved to incorporate issues of road task, road environment, local materials available, construction and maintenance regime,
- Unsealed Gravel surfacing is inappropriate for many road environment conditions. Clear criteria have been defined for its appropriate use.

- Improved design of shoulders, drainage & earthwork slopes is also desirable, It is commonly known to engineers that water or moisture is the enemy of roads. The trials have also highlighted the importance of designing all aspects of the road for the Vietnam environment; including drainage structures and system, earthworks, sub-grade, pavement, shoulders and slopes.
- Water needs to be prevented from entering the structure and foundation of the road pavement wherever possible, to avoid softening/weakening. Provision for subsurface drainage needs to be made for porous paving. Shoulders constructed of pervious materials should be sealed and maintained to prevent water ingress into the road pavement and sub-grade.
- A requirement has been identified for more appropriate technical standards.
- Greater emphasis on appropriate surface and pavement selection taking into account available resources, is desirable at PDoT level.
- A Cost Model, new Cost Norms and Standard Specifications have been developed for future management and technical application on rural roads in Vietnam.
- There are a number of Rural Road Contracting Regime issues that should be addressed to improve the performance of the sector and improve value-for-money for the considerable volumes of public funds invested. These include aspects of training and guidance for contractors and supervisors, contract documentation, contractor selection procedures, involvement and training of local consultants, improved supervision arrangements, promotion of appropriate plant hire, promotion of the optimal use of local materials, improved payment arrangements, improved quality assurance and testing regime.
- It is suggested that further major initiatives are required to tackle the awareness, funding, institutional, technical, management and operational deficiencies of the current rural road maintenance system.
- Due to the very limited data available on high/over-loading of commercial vehicles in Vietnam, and its potential for causing very extensive and expensive damage to existing road and bridge infrastructure, it is recommended that the incidence, extent and effects of this phenomenon should be further investigated.

## Appendix-3: Typical Details of Small Scale Kilns Used for Firing Bricks Using Rice Husk

### 1. General information:

- Name of brick kiln owner: Phan Nghia Chanh.
- Address: 176, Hamlet 4, Binh Hang Trung commune, Cao Lanh district, Dong Thap province, Vietnam.
- Telephone number: 067914103
- The year of establishment: 1992
- Annual capacity of brick plant: 3,900,000 brick /year (4 kilns are in 2 locations)
- Annual utilization of husk: 320 Tons/ kiln/year.
- Profit: 30% on investment.

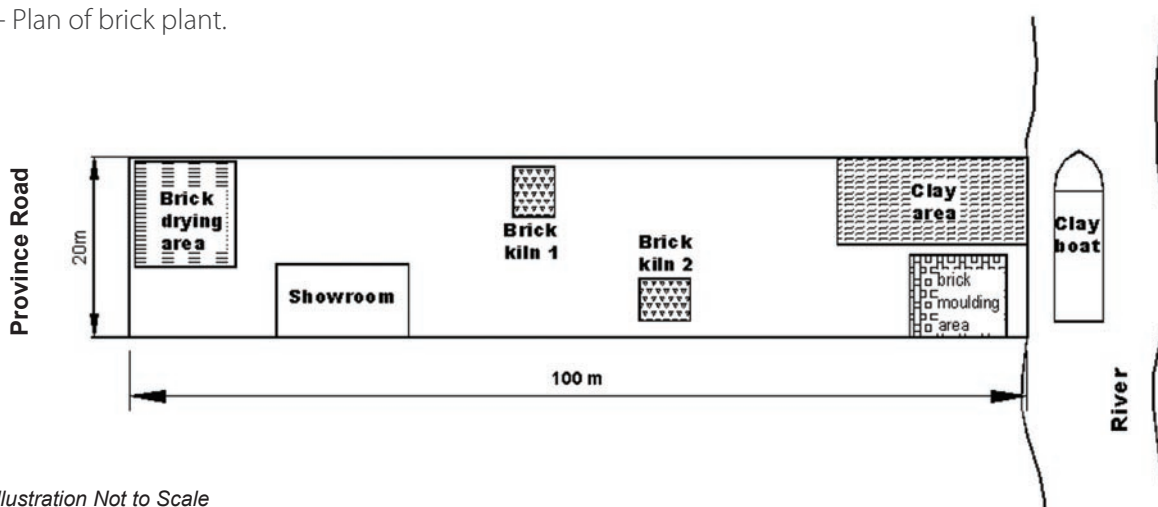
### 2. Clay specifications (Vietnamese standards, TCVN 4353):

- Particle sizes (mm):
  - > 10: no
  - From 2 to 10: <12%
  - < 0.005: from 22% to 32%
- Ratio of SiO<sub>2</sub>: from 58% to 72%
- Ratio of Al<sub>2</sub>O<sub>3</sub>: from 10% to 20%
- Ratio of Fe<sub>2</sub>O<sub>3</sub>: from 4% to 10%
- Ratio of (MgCO<sub>3</sub>+CaCO<sub>3</sub>): ≤6%

**3. Fuel** (husk, wood or coconut fibre): dry, not rotten, the wood can be cajeput, rubber, waste from sawmills or wood processing workshops etc.

### 4. Brick kiln:

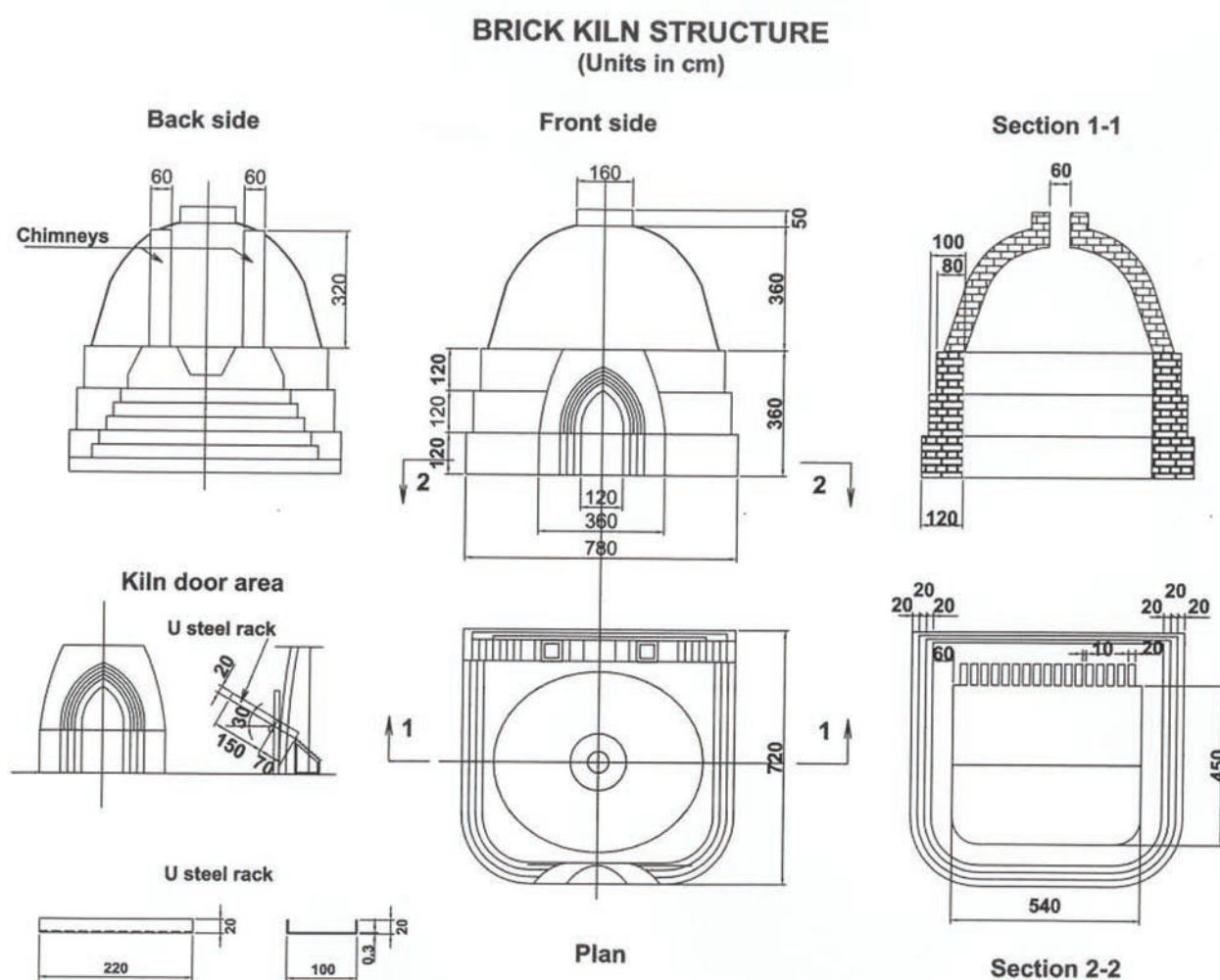
- Plan of brick plant.



\* Illustration Not to Scale

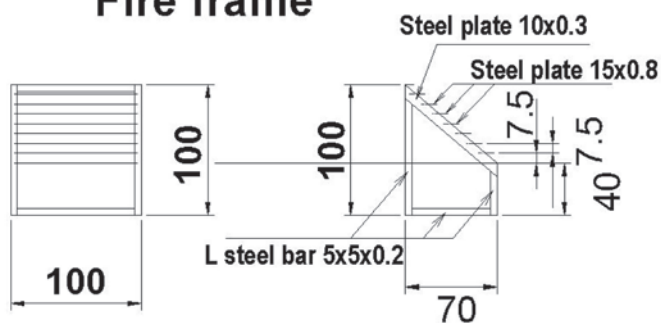
- Cost of kiln construction, batch capacity (bricks/kiln):

- Cost of kiln construction: VND 95 millions (US\$5,940) including costs of 120,000 solid bricks (sizes 5 x 10 x 18) & 120 fire bricks and labour input. The time required for kiln construction is from 10 to 15 days. The mortar for kiln construction includes mud from the river bed and 30% of waste ash of kiln. The kiln arch is covered by river mud mixed with waste ash (with 3cm thickness), as insulation materials for retaining heat.
- Kiln maintenance: about 5 years, the kiln arch can be renewed – the arch will be dismantled and rebuilt with the previously used bricks.
- Batch capacity:
  - Small kiln (size 4.5 x 5.4 m on plan): 85,000 bricks/ kiln.
  - Medium kiln (size 5.4 x 6.3 m): 95,000 bricks/kiln
  - Big kiln (size 6.3 x 7.2 m): 130,000 bricks/ kiln



\* Illustration Not to Scale

## Fire frame



\* Illustration not to Scale



### 5. Details of brick making process:

- **Number of labourers** used for each stage:

- Brick moulding, drying: 5 workers.
- Stacking: 2 workers.
- Loading kiln, unloading kilns and stockpiling for sale: 8 workers
- Firing: 2 workers.

- **Clay preparation, moulding:** Clay is bought, transported by boats and loaded onto the clay store (clay area) and brick moulding area of plant. Clay has to be tested to comply with the clay specifications. For example: The soil sample was taken from Dong Thap brick kiln and tested. The test results of this sample are showed in Appendix 4. The results show that this soil is clay with particle size: 45.5% passing sieve size 0.002 mm (The Vietnamese standard TCVN 4353 of Clay for production of burnt tiles and bricks – Technical requirements: from 22% to 32% passing sieve size 0.005 mm). The plasticity index is 26.41% and organic content 7.5%. The team of 5 workers move the clay to the moulding machine making adobe (green) bricks. By this machine about 13,000 bricks are made for 1 shift (8 hours).

- **Drying:** Adobe bricks are transported for air drying for 3 days (sunshine), 5 days (cloudy), 10 days (raining, covering the bricks by protective roofing). The dried bricks are stacked near the kiln.

- **Loading kiln:** The team of 8 workers transports the dried bricks and stacks them into the kiln using hand carts and electrically powered conveyer belt for 3 days. The bricks are laid, to allow the hot air to flow through all brick rows following 3 directions (longitudinal, horizontal and vertical), see the photos below.

- **Firing:** 2 workers fire the kiln for 10 days: 5 days for dry fire (opening top of kiln with the area 8 x 4 cm so that the moisture can escape) and 5 days for high temperature (closing the top of the kiln). Burn techniques: Using the handle bar to control the fire:

- 4 first days: pushing 4 slits of steel plates (From the top of fire frame).
- The 5th day: pushing 5 slits of steel plates.
- The 6th day: pushing 6 slits of steel plates.
- The 7th day: pushing 7 slits of steel plates.
- The 8th day: pushing 8 slits of steel plates.
- The 9th day: pushing 7 slits of steel plates.
- The 10th day: pushing 6 slits of steel plates.
- The 11th day: pushing 5 slits of steel plates.
- Etc.

The number of slits can be changed based on the weather and temperature outside.



- **Cooling:** 5 days. Opening the top of the kiln so that the outside air can flow through from the kiln door through to the top of the kiln.

- **Unloading** kilns and stockpiling for sale: same team as for loading the kiln takes out the cooled bricks by hand carts and electricity conveyer belt for 3.5 days.



Clay is bought, transported by boat



Clay is moved to moulding machine



Adobe bricks are made by machine



Bricks are drying under sunshine



The hot air can blow through all brick rows. *(Note that the hollow bricks shown are not suitable for road paving).*



Firing the kiln

**Summary time scales** for each activity of 1 batch (85,000 bricks-small kiln):

- Brick moulding, drying: 10 days.
- Loading kiln: 3 days
- Firing: 10 days
- Cooling: 5 days
- Unloading kilns and stockpiling: 3.5 days

**o Productivity/output:**

- The number of days duration for all processes: about 1 month for small kiln, 1.5 month for big kiln.
- Quantities of rice husk used for a typical firing: 40 Tons/ batch (small kiln).

**o Machines/equipment:**

- Brick moulding machine (13,000 bricks/8hour):
  - Vietnamese machine (Vikimco) – Cost VND 8 millions (US\$500), fuel – petrol 18litres/ 8h.
  - Japanese second hand machine – Cost VND 16 millions (US\$1,000) , fuel – petrol 10litres/ 8h.
- Electricity powered engine conveyer belt for loading and unloading: Kiln owner made this equipment himself (The cost is VND 10 millions, US\$ 625).
- Hand carts

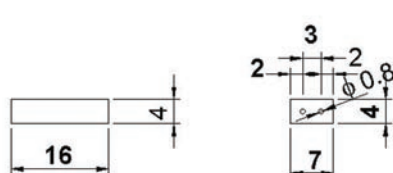


Brick moulding machine

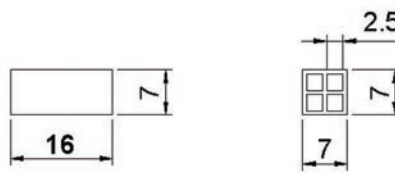


Unloading by conveyer belt

**o Sizes of finished brick available:**



2 hole brick (4 x 7 x 16)cm



4 void brick (7 x 7 x 16)cm  
(Note that the voided brick shown is not suitable for road paving).

**o Loss of size in the firing process:**

- Adobe (green) brick size: 2 hole brick (4.5x7.5x17)cm and 4 void brick (7.5x7.5x17)cm
- Finished brick size: 2 hole brick (4x7x16)cm and 4 void brick (7x16)cm

**o Labour involved in process – amount and cost component:**

- Brick moulding: 5 workers, VND 70,000/person-day (US\$ 4.375/person-day)
- Stacking, drying: 2 workers, VND 36,000/person-day (US\$ 2.25/person-day)
- Loading kiln, unloading kilns and stockpiling for sale: 8 workers, VND 120,000/person-day (US\$ 7.5/person-day)
- Firing: 2 workers, VND 70,000/person, day (US\$ 4.375/person-day)

**o Expected working life of a kiln:** 20 years.

**o Cost breakdown of completed brick production: per brick:**

- Labour: VND 253 (US\$0.015813)
- Materials: VND 85 (US\$0.005313)
- Fuel: VND 20 (US\$0.00125)
- Depreciation of brick kiln, overheads: VND 62 (US\$0.003875)
- Total cost of completed brick production: VND420 (US\$0.02625)
- Sale price (Market cost): VND 700 (US\$0.04375)

**o Comments on pollution and sustainability issues:** At present, the kiln smoke (waste air) goes out of the kiln directly to the environment. It is a pollution issue. Most brick kilns are located away from villages. The brick kiln owner in Dong Thap plans an initiative to filter the smoke of kiln. He wants to try this technology. He is seeking support by donor with half budget for the trial.

**o Disposal of the waste ash, quantity per batch and prices achieved:** Normally, the kiln owner has given farmers the waste ash free for fertilizer. If selling, the price of waste ash would be VND 1 millions (US\$62.5)/ 6 Tons (1 batch).

**o Training of labour:** the kiln owner can train the workers on the job in about 3 days. After this introduction, they can work with other skilled workers.

**o Safety:** The workers always wear gloves when working for safety precautions.

## 5. Comments

- At present, there are many developing countries planting rice. The Vietnam agriculture sector produces 34 millions to 35 millions Tons of rice equivalence per year with 6.8 to 7 millions Tons of associated husk. Some rice-husking factories in the Mekong delta have deposited the waste husk directly in the rivers. This produces serious pollution. There are some solutions for waste husk: for example, as the fuel for electricity generating stations, material for cement & steel & construction industries etc.. But using husk for these industries in Vietnam is quite new technology. Using rice husk for brick manufacture is one of the important solutions of waste husk in Vietnam in general and in the Mekong delta provinces in particular.

- The rice husk brick kiln technology is not complex. Besides Vietnam, there are many other developing countries growing rice. The experience of brick kiln owners in Dong Thap can be transferred to other developing countries with similar conditions.
- Our research shows very limited knowledge of brick kiln burnt by husk. Hence the production of this document. It is hoped that the brick kiln and production knowledge will enable other communities and enterprises to develop brick production using rice husk or other combustible agricultural waste. If there are any queries not addressed by this document, we will try to respond with our knowledge and links to the local industry. We are also ready to provide links with brick kiln owners in Dong Thap province.

Bach The Dzung  
Ha Noi, May 2009  
bachthedung@yahoo.com

## Appendix-4: Test Results of brick kiln clay for firing by husk in Dong Thap province

### SUMMARY OF SOIL TEST RESULT

Test NO	Sieve size(mm)			ATTEMBERG Limits			Specific Gravity G g/cm <sup>3</sup>	Organic content (%)	CLASSIFICATION	SOIL DESCRIPTION
	Percent passing	sieve size	size	Liquid limit W <sub>L</sub> (%)	Plastic limit W <sub>P</sub> (%)	Plastic Index I <sub>p</sub> (%)				
2594	4.75	2	0.425	0.075	0.002		2.66	7.50	A-7-6 ( 30 )	Clay soil, greyish brown.
		100	99.8	99.0	45.5	26.41				

Collected and computed by



Hoang Thuy Quynh

Checked by



Ngo Thu Ha

Ha Noi, 25/01/2008  
Vice director of Center



Pham Tuan Anh



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 TRUNG TÂM TVGS & THÍ NGHIỆM ĐỊA KỸ THUẬT CÁC CÔNG TRÌNH GIAO THÔNG VẬN TẢI - CENTER FOR CONSTRUCTION SUPERVISION AND GEOTECHNICAL TESTINGS  
 Địa chỉ (Address): Trung Văn - Từ Liêm - Hà Nội Tel : 04.8540323 - 04.5532920 Fax : 04.5111164

## GRAIN SIZE ANALYSIS

( STANDARD AASHTO T88 - 93)

Test No: 2594

Boring N<sup>o</sup>:

Sample N<sup>o</sup>:

Depth (m):

Date of test: 23/04/2008

### SIEVE ANALYSIS

Weight of Dry Soil, (g) : 50

Sieve No	Sieve opening (mm)	Wt soil retained (g)	% retained	% finer
2"	50.8			
1"	25.4			
0.75"	19			
0.375"	9.52			
4	4.75			
10	2			100.0
40	0.425	0.1	0.2	99.8
200	0.075	0.4	0.8	99.0
Pan		49.5	99.0	

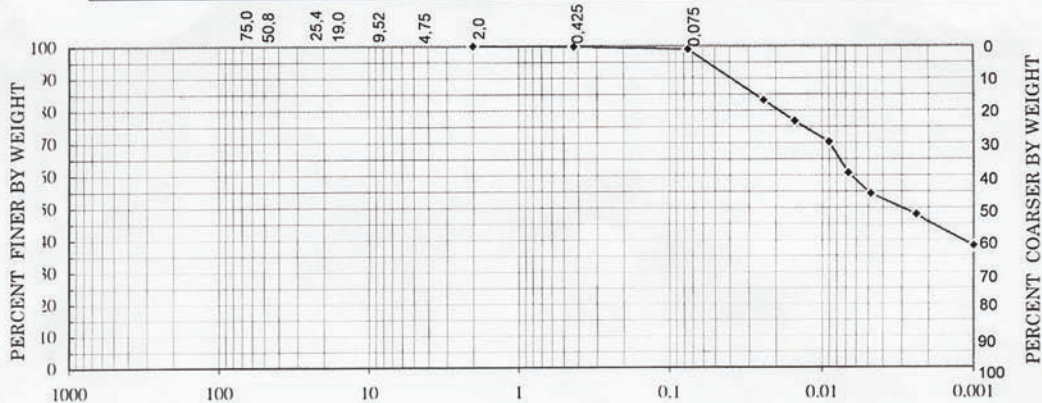
### HYDROMETER ANALYSIS

Weight of Dry Soil, W<sub>s</sub>, (g) : 50

Elaps. time (min)	Temp. (°C)	Tempa. Corr. Ret	R	P (%)	L (cm)	D (mm)	P' (%)
0							
2	26	-0.1	26	83.0	9.4	0.024	83.0
5	"	"	24	76.6	10.0	0.015	76.6
15	"	"	22	70.2	10.5	0.009	70.2
30	"	"	19	60.6	11.3	0.0067	60.6
60	"	"	17	54.2	11.8	0.0048	54.2
250	"	"	15	47.8	12.4	0.0024	47.8
1440	26	-0.1	12	38.1	13.2	0.0010	38.1

$K(X10^{-3}) = 10.92$	$a = 0.998$	Specific Gravity: 2.66
-----------------------	-------------	------------------------

$P\% = \frac{16.06 \times R' \times a \times 100\%}{w}$	$P\% = \% \text{ passing } N^{\circ}10 (2\text{mm}) \times P\%$	$D (mm) = Kx \sqrt{L/T}$
---	---	--------------------------



		100.0	99.8	99.0	45.5
Boulder	Gravel	Sand		Silt or Clay	
		Coarse	Fine		

Tested by:

*Hoang Phuong Lien*

Hoang Phuong Lien

Checked by:

*Hoang Thuy Quynh*

Hoang Thuy Quynh

Vice Director of Center

*Pham Tuan Anh*

Pham Tuan Anh



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## ATTERBERG LIMITS

(STANDARD AASHTO T89&T90 - 96 )

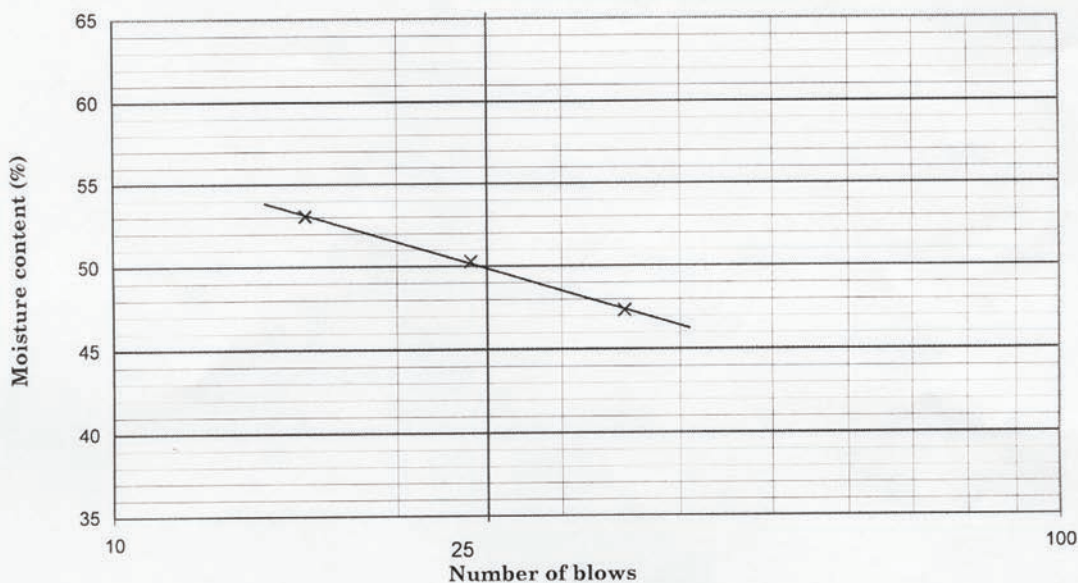
Test N<sup>o</sup>: **2594**

Boring N<sup>o</sup>:

Sample N<sup>o</sup>:

Depth (m):

Moisture content Determination	Moisture content W	Liquid limit W <sub>L</sub>			Plastic Limit W <sub>p</sub>	
		35	24	16	24.29	23.31
Number of blows		35	24	16		
Moisture content (%)		47.31	50.28	53.04	24.29	23.31
Average moisture content(%)	W =	W <sub>L</sub> = 50.21			W <sub>p</sub> = 23.80	



### RESULT

Plasticity Index	Liquidity Index
$I_p = W_L - W_p = 26.41$	$LI = \frac{W - W_p}{I_p} =$

Tested by:

Checked by

Vice Director of Center

*Thanh*

*Quynh*

*Pham Tuan Anh*

**Nauyen Kim Thanh**

**Hoang Thuy Quynh**

**Pham Tuan Anh**

## Appendix-5:

Results of RRST II Brick testing

Set	Sample	Location	Date	Dimensions mm	Test Method	Compressive Strength N/mm <sup>2</sup>	Water Absorption %	Unit Weight kg/m <sup>3</sup>	Comment
A	1	Dong Thap	14.07.2005	180x90x45	TCVN 246-86	25.4	24		Rice husk fired
	2	Dong Thap	14.07.2005	180x90x45	TCVN 246-86	25.9	23		Rice husk fired
	3	Dong Thap	14.07.2005	180x90x45	TCVN 246-86	26.2	24		Rice husk fired
	4	Dong Thap	14.07.2005	180x89x45	TCVN 246-86	25.7	24		Rice husk fired
	5	Dong Thap	14.07.2005	180x90x45	TCVN 246-86	27.2	19		Rice husk fired
B	1	Hung Yen	11.04.2006	205x95x 58	TCVN 6355-98	12.6	10	1637	Coal fired: submitted by contractor
	2	Hung Yen	11.04.2006	205x95x 58	TCVN 6355-98	17.0	9	2018	Coal fired: submitted by contractor
	3	Hung Yen	11.04.2006	202x92x 57	TCVN 6355-98	10.0	17	1855	Coal fired: submitted by contractor
	4	Hung Yen	11.04.2006	209x93x 58	TCVN 6355-98	14.9	14	2116	Coal fired: submitted by contractor
	5	Hung Yen	11.04.2006	207x88x 55	TCVN 6355-98	14.5	13	1896	Coal fired: submitted by contractor
C	1	Hung Yen	11.04.2006	202x94x58	ASTM C67-04	21.7	10	1952	Coal fired: submitted by contractor
	2	Hung Yen	11.04.2006	206x92x57	ASTM C67-04	23.8	13	1805	Coal fired: submitted by contractor
	3	Hung Yen	11.04.2006	205x94x57	ASTM C67-04	28.5	10	1811	Coal fired: submitted by contractor
	4	Hung Yen	11.04.2006	209x91x55	ASTM C67-04	18.0	9	2055	Coal fired: submitted by contractor
	5	Hung Yen	11.04.2006	200x95x55	ASTM C67-04	19.6	19	1861	Coal fired: submitted by contractor
D	1	Hung Yen	11.05.2006	220x104x61	ASTM C67-04	14.6			Sampled on Site by Intech-TRL
	2	Hung Yen	11.05.2006	220.104x60	ASTM C67-04	18.3			Sampled on Site by Intech-TRL
	3	Hung Yen	11.05.2006	219x105x60	ASTM C67-04	13.3			Sampled on Site by Intech-TRL
	4	Hung Yen	11.05.2006	219x105x59	ASTM C67-04	13.7			Sampled on Site by Intech-TRL
	5	Hung Yen	11.05.2006	220x104x60	ASTM C67-04	18.9			Sampled on Site by Intech-TRL



## Appendix-6: Recommended Fired Clay Brick Paving Specification from RRST, Vietnam

### SPECIFICATION RRST 302 FIRED CLAY BRICK PAVEMENT – MORTARED JOINTS

**302.1 DESCRIPTION** The work comprises providing, laying and placing a layer of on-edge bricks within edge restraints on each side of the pavement to lines, levels and dimensions as shown on the Engineering Drawings and as directed by the Supervising Engineer. The bricks are laid on a thin layer of cement mortar in a herring bone or other approved pattern as indicated on the Engineering Drawings. Joints between the bricks are in-filled with cement mortar.

**302.2 MATERIALS** The following paragraphs define target specifications for natural materials and products that should be used in the construction of this pavement layer. In the event that appropriate material or products cannot be reasonably obtained then the Contractor may submit alternative materials and products to the Supervising Engineer for approval. This approval may involve adjustments to the pavement design. Under no circumstances may the Contractor use non-specification materials without the prior approval of the Supervising Engineer.

#### Fired Clay Bricks

The raw material for brick manufacture should be a sandy clayey silt or silty clay of low to medium plasticity. The material should be uniform and comprise a relatively high proportion of silica (quartz) minerals. It must also be free from significant quantities of deleterious materials such as combustible vegetable matter, mica minerals and salts.

The fired bricks shall be of engineering standard with the following characteristics:

Dimensions:	200x100x70mm (or as agreed by the Supervising Engineer)
Dimensional Tolerance:	+/-3%
Water absorption:	<16% of their weight of water after 1 hour soaking
Unit weight:	>1200 kg/m <sup>3</sup>
Crushing strength:	>20MPa (as determined by TCVN 6355-5-98)

The bricks shall be solid, regular and uniform in shape and texture with sharp square edges and parallel faces. They shall be free from flaws, chips, stones and blemishes and shall emit a clear metallic ring when struck against each other.

#### Bedding and Joint Fill Material

Material for the bedding and joint in-filling shall be a cement mortar Grade 75 (fine sand).

**302.3 CONSTRUCTION METHODS** Prior to laying the brick paving, all drainage works necessary to keep the road formation and pavement layers free of standing water should be completed.

The Contractor shall establish sufficient setting out pegs and string lines to ensure that the final shape of the brick layer confirms with the Drawings, which shall be checked with a camber board, or straight edge, spirit level and tape.

Delivered bricks shall be stacked on or adjacent to the prepared formation in such a manner as to allow for continuity of operations, avoid damage to the bricks and to cause least inconvenience and danger to traffic.

The bricks shall be laid on edge (100mm depth) on a 20mm cement mortar bed on the pre-prepared and approved roadbase within edge restraints, as detailed on the Engineering Drawings and as required by the Supervising Engineer's Representative. Joint width between bricks shall be between 5 and 10mm.

Joints shall be filled as necessary with cement mortar to achieve satisfactory interlock between the bricks. Joints will be finished level with the top face of the bricks to provide a smooth finished surface.

All extraneous matter, or defective bricks shall be removed and made good with new material to the full thickness of the layer.

After the mortar has set, the mortared brick paving will be cured for a period of 7 days by keeping the surface damp with water. After 14 days the surface may be opened to traffic.

### **302.4 CONSTRUCTION EQUIPMENT**

Cement mortar will be mixed with a suitable concrete mixer of at least 80 litre mix capacity.

### **302.5 MEASUREMENT**

Mortared clay brick surfacing shall be measured by the square metres of placed and mortared brick layering on the road. The quantity for which payment shall be made shall be the product of the instructed average width (including edge restraints/kerbs) and the measured length along the centre line of the road.

The rates shall include the supply, placing, tamping and mortaring of the clay brick surfacing including edge restraints, as specified and shown on the Drawings.

The work as measured shall be paid for at the Contract unit price shown in the Bill of Quantities. Payment shall be full compensation for performing the work including supplying the materials, and providing all labour, tools, equipment, incidentals necessary, overheads and profit.

Pay Item shall be:

CLAUSE	DESCRIPTION	UNIT OF MEASUREMENT
302	Fired Clay Brick Pavement – Mortared Joints	Square metre

### 302.6 LABORATORY & SITE TESTING

#### General

The Supervising Engineer shall exercise control over quality of the materials incorporated and works performed through quality control tests carried out to the frequencies indicated here in under. The frequencies are the minimum. The Supervising Engineer shall have the authority to have these tests conducted at more frequent intervals, where quality of a material or work is in doubt.

#### Laboratory Testing

TYPE OF TEST	FREQUENCY OF TEST
Density of bricks	2 sets of 5 per material source (more frequently if material character changes) ) and one per km of road
Compressive strength of bricks	As above
Water Absorption of the bricks	As above

#### Site Testing

TYPE OF TEST	FREQUENCY OF TEST
Dimensional tolerance of bricks	Sample of 10 from each 1km

Visual inspections will be made to check compliance with the drawings and specifications.

A pavement layer quality and specification compliance inspection will be undertaken on all completed sections of the brick layer by the Supervising Engineer's Representative prior to acceptance of the Works.

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