

Engineering Module 3

Pavement Option Selection and Design

DF 55: Dissemination of LVRR Knowledge and Experience

Summary

This module outlines a general approach to the selection and design of LVRRs that is based upon the task the roads have to perform; the environments in which they have to operate; and their anticipated whole life costs.

The pavement design process has to be compatible with existing Vietnamese Standards and based upon the collection and analysis of appropriate data. Options should take into account not only the immediate construction cost but also their likely maintenance costs – together making up what is termed the Whole Life Asset Costs



Points to Think About



How do I select a pavement option?
What information is needed for pavement decisions?
What is the real cost of rural roads?

DF 55: Dissemination of LVRR Knowledge and Experience



EM3.1 Key Issues

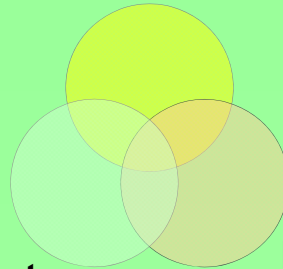
DF 55: Dissemination of LVRR Knowledge and Experience



Available Materials



**Road
Environment**



Road Task

SUSTAINABLE RURAL ROADS

DF 55: Dissemination of LVRR Knowledge and Experience

Gravel LVRRs

Until recently, the commonly applied solution for improving rural access in developing countries was to provide gravel roads. Superficially, the attractions looked convincing; low initial road cost, all-weather access and simple technology. However there significant shortcomings associated with gravel roads in Vietnam that have become apparent.

Gravel LVRRs

The old 'rule of thumb' used to be *“For flows up to 50 (motor) vehicles per day (vpd) use earth surface, 50 – 200 vehicles per day use gravel, and above that seal.”*. This approach does not take into account the previously defined road environmental factors.

Unsealed Gravel Studies

There are still many situations where gravel is still an appropriate and affordable LVRR surface option. However, recent years research in Vietnam has identified limits to the sensible use of gravel



Appropriate Use of Gravel

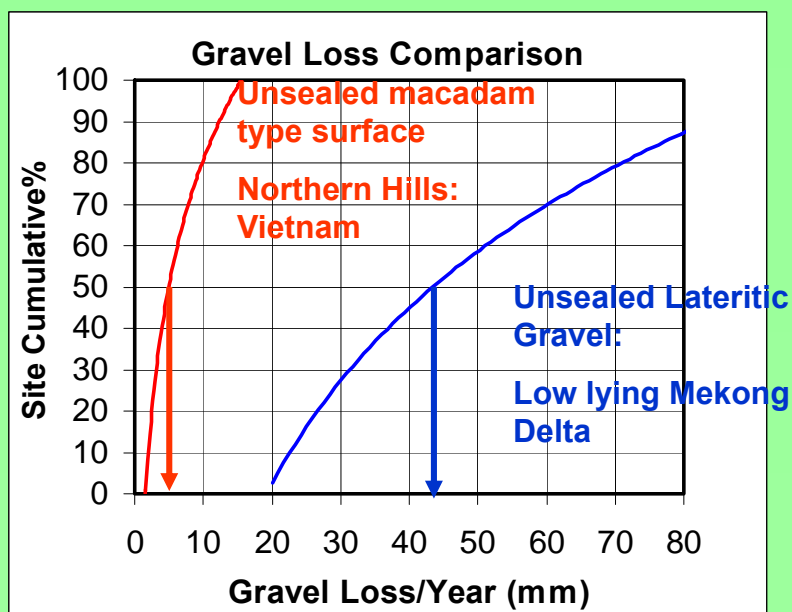
Significant technical constraints have been recommended on the use unsealed gravel pavements in terms of :

Long hauls, high rainfall, high traffic, poor material, steep gradients, flooding, poor construction practices and lack of maintenance capacity.

These recommendations have been incorporated into a gravel use flow chart

DF 55: Dissemination of LVRR Knowledge and Experience

There `Must be Appropriate Use of Materials



Appropriate Use of Gravel

The research has clearly indicated that there are appropriate uses for suitable quality laterite, colluvial and alluvial gravels:

- ❑ As an unsealed road surface or shoulder material in certain road environments
- ❑ As a base or sub-base material
- ❑ As a temporary road surface within a staged construction programme

DF 55: Dissemination of LVRR Knowledge and Experience

| | Thickness mm |
|----------------------------------|-----------------|
| Bamboo reinforced 20MPa concrete | 150 |
| Bedded on compacted sand | 50 |
| Natural gravel base CBR>30% | 100 |
| Sub-grade CBR 5-6% (H1, H2) | |

| | Thickness mm |
|----------------------------------|-----------------|
| Emulsion sand seal | 70 |
| Crushed stone armouring; CBR 50% | |
| Natural gravel, CBR >30% | 100 |
| Natural gravel, CBR >30% | 100 |
| Sub-grade CBR 3-5% (H9) | |

| | Thickness mm |
|------------------|-----------------|
| Natural Gravel | 100 |
| Natural Gravel | 100 |
| Sub-grade CBR 3% | |

Gravel may be used as a sub-base or base as well as being used as an unsealed option in appropriate situations

DF 55: Dissemination of LVRR Knowledge and Experience

Materials – A Key to Sustainable Road Construction

A fundamental principle, or message, that needs to be carried forward from current research into practice is that appropriate road construction materials need to be selected on a “fitness for purpose” basis; that this is related to their actual service performance.

DF 55: Dissemination of LVRR Knowledge and Experience

Locally Available Materials

Use of local materials is essential where reserves are limited or of marginal quality, as they are in certain rural areas of Vietnam. That means that specifications and designs must be suited to local materials.

Identifying Available Materials

Even for limited scope LVRR projects, materials testing should aimed at defining service performance in terms of:

- The load bearing capacity of the compacted material,
- Its volume stability in response to soaking-drying,
- Its component particle strength and durability (granular materials).



Local Materials

The use of locally available, but possibly non-standard, pavement construction materials plays a significant role within this concept



DF 55: Dissemination of LVRR Knowledge and Experience

Local Materials

| Region | Province | Crushed Rock | Stone Blocks | Sand | Clay (bricks) | Gravel |
|-------------|-------------|--------------|--------------|------|---------------|--------|
| Mekong | Tien Giang | | | | | |
| | Dong Thap | | | | | |
| C Coastal | Hue | | | | | |
| | Da Nang | | | | | |
| C Highlands | Gia Lai | | | | | |
| | Dak Nong | | | | | |
| | Dak Lak | | | | | |
| Red River | Hung Yen | | | | | |
| | Ninh Binh | | | | | |
| N Highlands | Tuyen Quang | | | | | |
| | Quang Binh | | | | | |
| | Ha Tinh | | | | | |

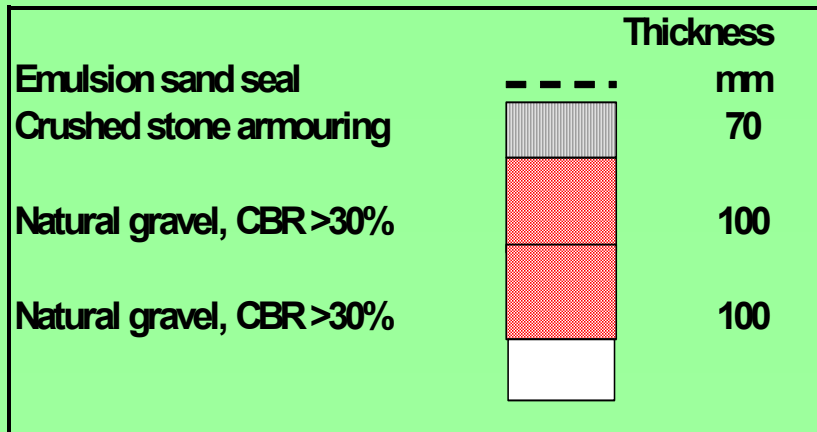
DF 55: Dissemination of LVRR Knowledge and Experience

Appropriate Use of Materials

It is important to use materials relevant to their role in the road, that is, to ensure that they are neither sub-standard nor wastefully above the standards demanded by their engineering task.

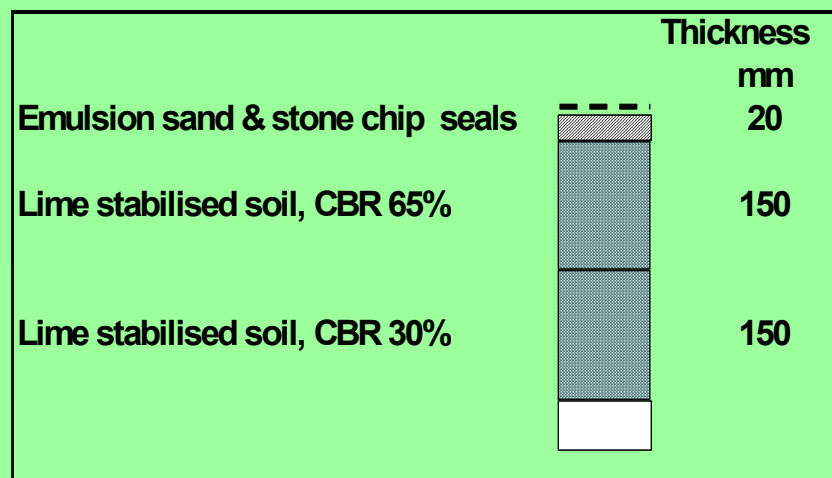
DF 55: Dissemination of LVRR Knowledge and Experience

Good Natural Gravel Available



DF 55: Dissemination of LVRR Knowledge and Experience

Lack of Good Aggregate



DF 55: Dissemination of LVRR Knowledge and Experience

Key Question For a LVRR Designer

What appropriate road can I build with these local materials ?

NOT

Where can I find materials to meet these general specifications?

DF 55: Dissemination of LVRR Knowledge and Experience

Maintenance

The Vietnam experiences to date is that the capacity and delivery of maintenance on LVRRs is generally poor, due to a range of factors such as:

- Insufficient funds,
- Unclear responsibilities,
- Insufficient appreciation of the vital importance of maintenance
- Insufficient capacity and management guidance
- Lack of motivation and cooperation of the principal stakeholders

Maintenance: Key to Sustainability

Issues:

Budget

Materials

Road Shape



Vital Points



1. It is a waste of budget, time and valuable resources constructing roads that cannot be maintained
2. Maintenance programme for unsealed roads that do not include the means to maintain road shape (crossfall) are largely useless
3. Do not make unrealistic assumptions at design stage about maintenance



Key Elements for Sustainable Application



- **Political**
- **Social**
- **Environmental**
- **Institutional**
- **Economic**
- **Financial**
- **Technical**

DF 55: Dissemination of LVRR Knowledge and Experience



Unless all the components of sustainability are satisfied, it is unlikely that a road project will bring long-term benefit to a rural community.

- Politically supported; the road project must be clearly supported at the relevant local authority level (CPC, DPC, PPC) as well as at Ministerial level
- Socially acceptable –the local people must benefit in the long term from the road.
- Economically viable –the benefits from using the road must be greater than the costs.

DF 55: Dissemination of LVRR Knowledge and Experience



- Financially sound – there must be adequate funding in place for construction and maintenance.
- Institutionally possible – the organisations and responsible for constructing and maintaining the road must have the necessary resources and knowledge.
- Technically appropriate – the proposed road design must be compatible with its task and environment.
- Environmentally sustainable – the road construction, use and maintenance should not cause environmental damage



Engineering Sustainability

Although as engineers we must be fully aware of all the sustainability components we are principally concerned with the last three components:

- Institutional Sustainability
- Technical Sustainability.
- “Green” Environmental

DF 55: Dissemination of LVRR Knowledge and Experience

EM3.2 General Approach To LVRR Design

DF 55: Dissemination of LVRR Knowledge and Experience

Road Design

The purpose of road design is to allow a road to perform a **Task** in a defined **Environment** within an affordable **Budget**

REMEMBER: To “Over-design” and “Under-design” are BOTH a waste of money !

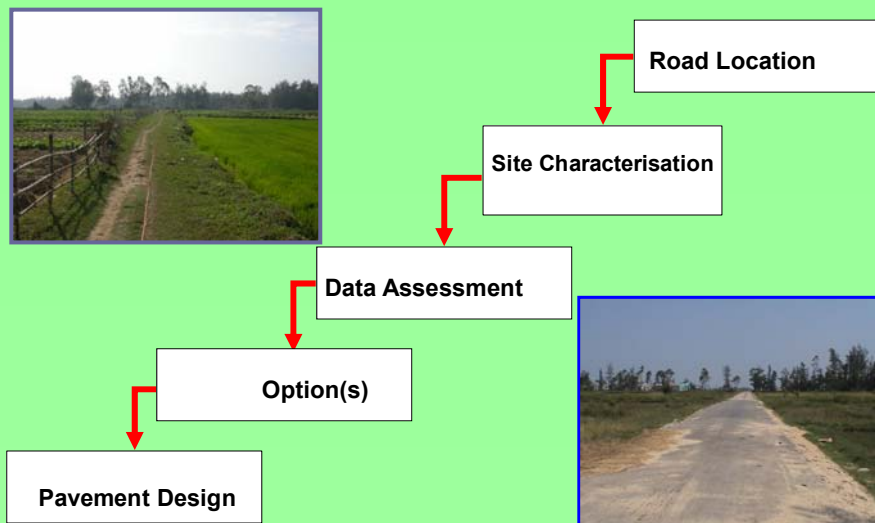
DF 55: Dissemination of LVRR Knowledge and Experience

Road Design Elements

- **Pavement**
- **Structures**
- **Drainage**
- **Alignment Geometry**
- **Earthworks**

DF 55: Dissemination of LVRR Knowledge and Experience

General Design Sequence



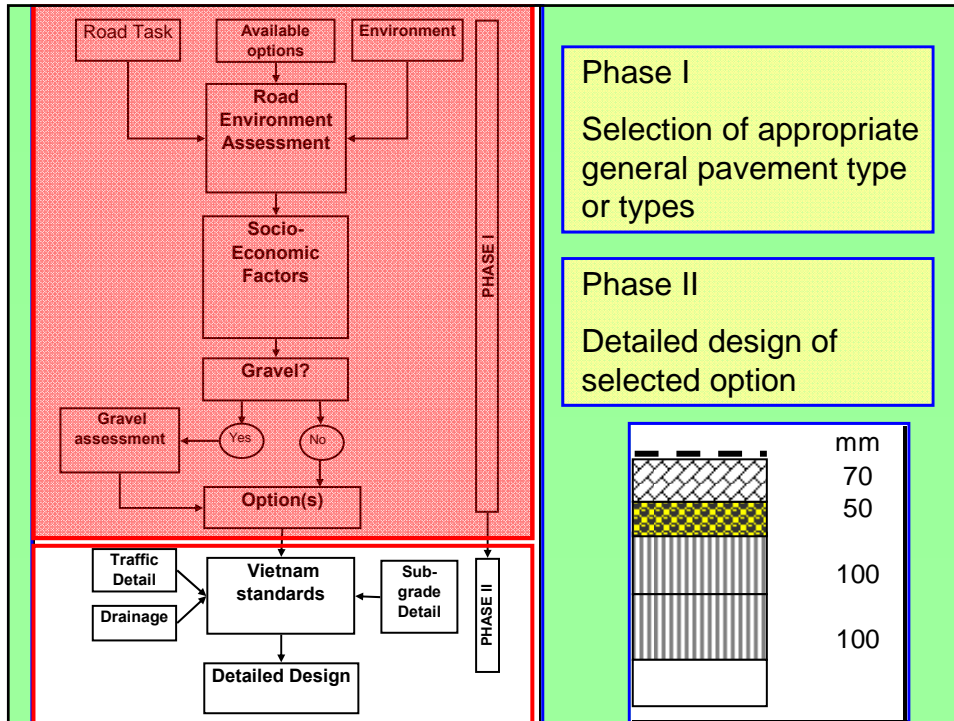
LVRR Pavement Selection

A new paving selection procedure has been developed from the SEACAP 1 and 4 research initiatives - based on two key principles:

1. Pavements must be fit for purpose in terms of traffic volume and axle loads,
2. Pavements should be compatible with the governing road environment factors, as discussed in the previous section.

A Two Phase Selection Approach

1. Phase I: Identification of appropriate pavement types compatible with the road environment.
2. Phase II: Detailed design of the selected pavement components (e.g. layer thicknesses) compatible with engineering standards and requirements – i.e. traffic, axle load and sub-grade strength.

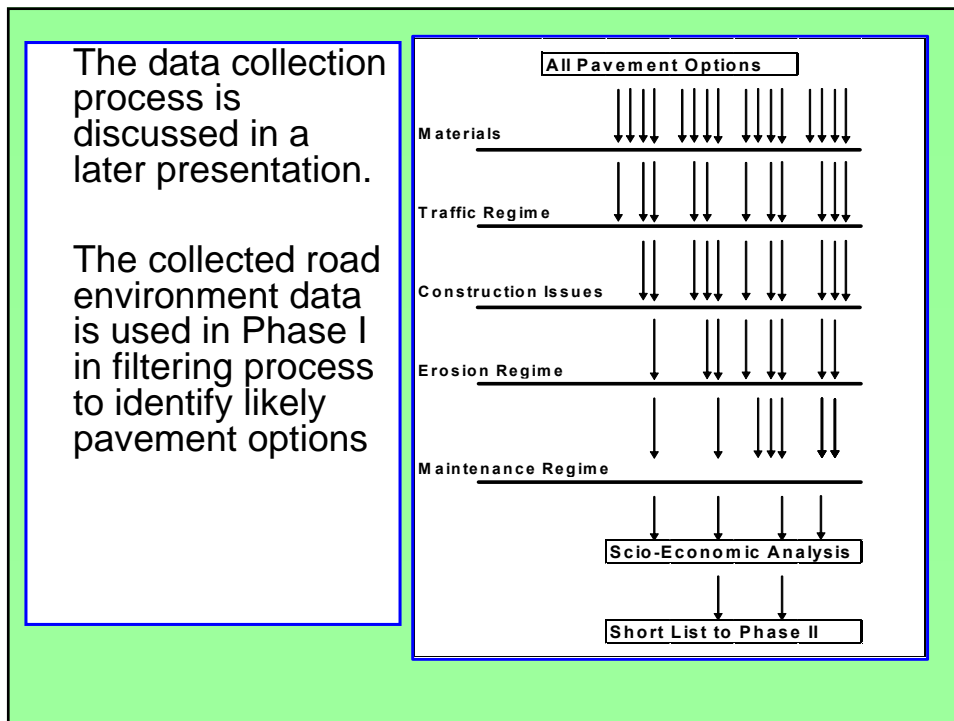


Particular Key Issues

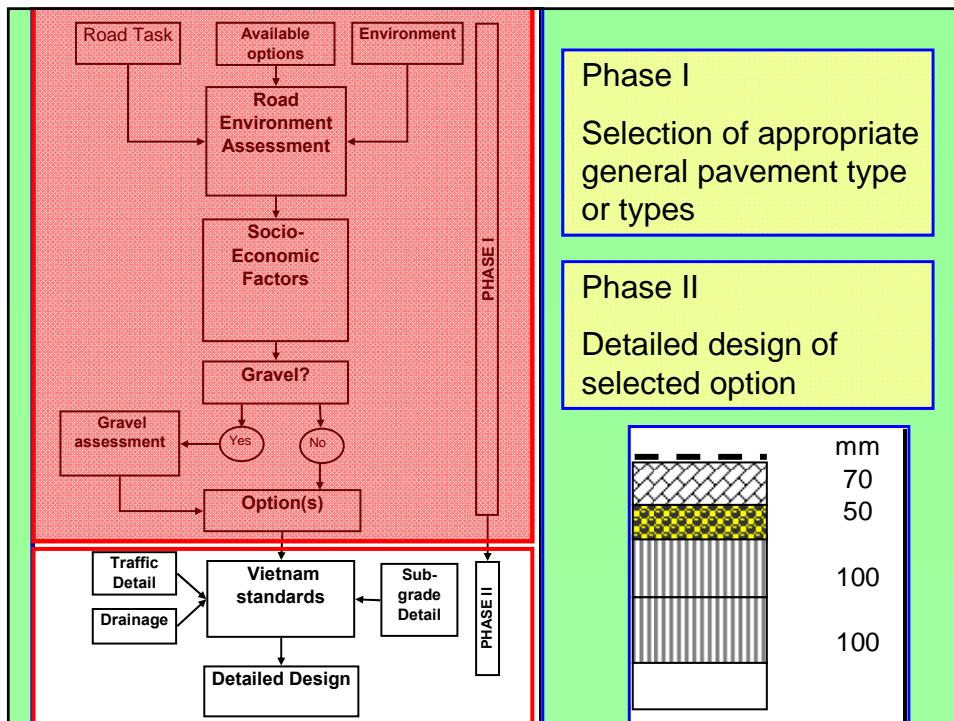
- High erosion climate-terrain
- The engineering character of materials
- Lack of construction materials
- Traffic and axle loading ,
- The construction & maintenance regimes,
- High water tables and flooding,
- Impact of earthworks in hill/mountain areas,
- Localised steep gradients,.

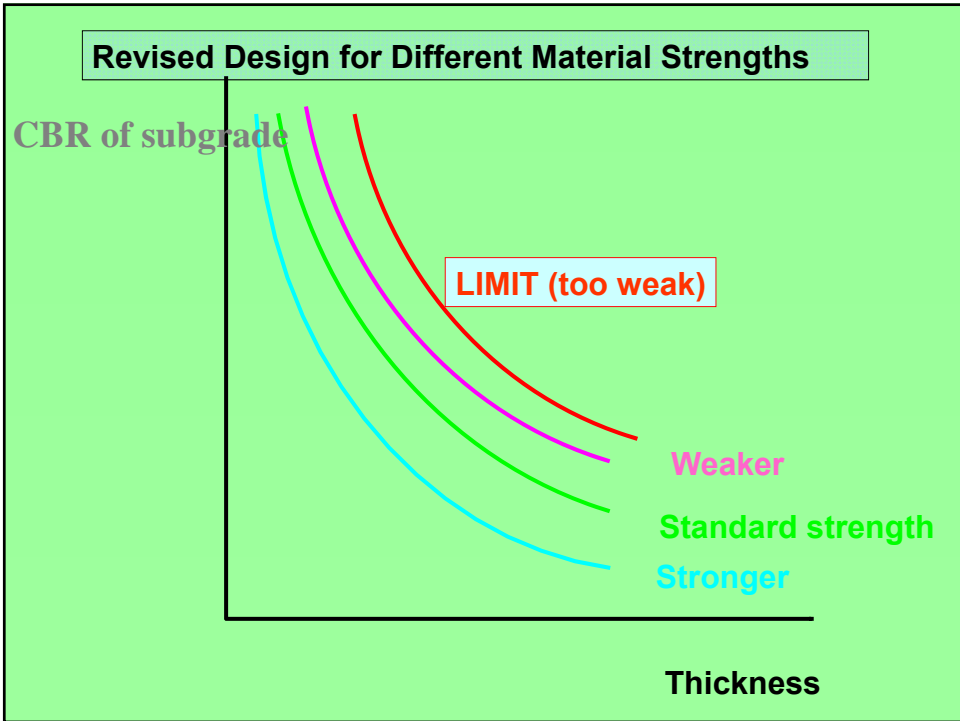
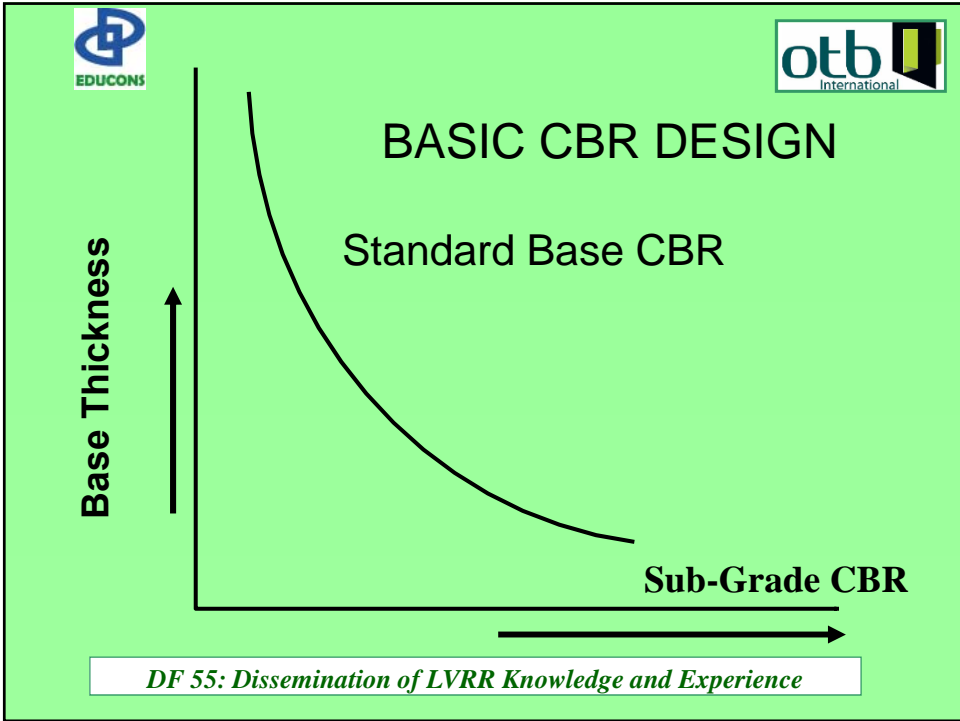
| Key Trial and Control Pavement layer | Key Markers | | | | | | | | | | | | |
|--------------------------------------|---------------------|--------------|----------------------|-----------------------|----------------|---------------------------------|-----------------------------------|------------------------------|--------------------------|--------------------------------|--------------------------|-------------------------------------|---------------------------------|
| | Local material Use* | Labour-Based | Ease of Construction | Maintenance reduction | Sustainability | Resistance to Rainfall/Flooding | Load Spreading on Weak Sub-Grades | Small Contractor Suitability | Local Economy Advantages | Resistance to Axle Overloading | Local Workmen Employment | Likely Whole Life Cost Advantages** | User advantages (Low Roughness) |
| Emulsion Sand/Stone Chip Seals | 0 | 1 | 0 | 2 | 2 | 2 | 0 | 1 | 0 | 0 | 2 | 2 | 2 |
| Lime stabilised Base/Sub-base | 1 | 0 | 2 | 0 | 1 | 0 | X | 1 | 0 | 0 | X | 2 | 0 |
| Cement Stabilised Base/Sub-base | 1 | 0 | 2 | 0 | 1 | 0 | X | 1 | 0 | 0 | X | 2 | 0 |
| Emulsion Stabilised Sub-Base | 1 | X | 0 | 0 | 0 | 0 | X | X | 0 | 0 | 0 | 0 | 0 |
| Sealed Dry-Bound Macadam | 0 | 0 | 2 | 2 | 1 | 2 | 0 | 2 | 0 | 2 | 0 | 2 | 2 |
| Sealed Water-Bound Macadam | 0 | 0 | 2 | 2 | 2 | 2 | 0 | 2 | 0 | 2 | X | 2 | 2 |
| Dressed Stone | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | X |
| Fired Clay Bricks | 1 | 1 | 2 | 1 | 2 | 2 | 1 | 1 | 1 | 2 | 1 | 2 | 0 |
| Concrete Bricks | 2 | 1 | 2 | 1 | 2 | 2 | 1 | 1 | 2 | 2 | 1 | 2 | 0 |
| Sealed Armoured Gravel | 2 | 0 | 2 | 2 | 2 | 2 | 0 | 2 | 0 | X | 0 | 2 | 2 |
| Steel Reinforced Concrete | 0 | 2 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 1 |
| Bamboo Reinforced Concrete | 2 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 2 | 1 |
| Non-Reinforced Concrete | 2 | 2 | 2 | 1 | 1 | 1 | 2 | 1 | 2 | 2 | 0 | 2 | 1 |
| Hot Bitumen Stone Chip seals | 0 | 2 | 0 | 2 | 2 | 2 | 0 | 2 | 0 | 0 | X | 2 | 2 |
| Unsealed Natural Gravel | 1 | 0 | 1 | X | X | X | 0 | 1 | 2 | 0 | 0 | X | X |
| Penetration Macadam | X | X | 0 | 2 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| Unsealed Water-Bound Macadam | 0 | 0 | 2 | X | X | X | 0 | 2 | 0 | 0 | 2 | 0 | X |

Notes : 1 Positive advantage 0 No advantage/disadvantage
2 Probable advantage X Definite disadvantage
* Assuming material locally available
** Anticipated "Best Performers".



| Primary Engineering Filter | | | | | | | | | | | | | | | | | |
|---|---------------------------------|-----------|---------------------|---------------------------|----------------------------|-------------------------|-----------------|-------------|--------------------------|-----------------|--------------------|------------------|----------------|-----------------|------------------------|----------------------|--------------------------|
| | Seals and Load Bearing Surfaces | | | | | | | Bases | | | | | | | | | |
| | Sand seal | Chip seal | Penetration macadam | Steel reinforced concrete | Bamboo reinforced concrete | Engineering clay bricks | Concrete bricks | Stone setts | Unsealed wet/dry macadam | Unsealed gravel | Waterbound macadam | Drybound macadam | Natural gravel | Armoured gravel | Cement stabilised soil | Lime stabilised soil | Emulsion stabilised soil |
| Economically available Materials | | | | | | | | | | | | | | | | | |
| Crushed stone aggregate | | √ | √ | √ | √ | | √ | | √ | | √ | √ | | √ | | | |
| Stone blocks | | | | | | | | √ | | | | | | | | | |
| Laterite gravel | | | | | | | | | √ | | | | √ | √ | | | |
| Colluvial/alluvial gravel | | | | | | | | | √ | | | | √ | √ | | | |
| Weathered rock | | | | | | | | | | | | | | √ | | | |
| Fired clay bricks | | | | | | √ | | | | | | | | | | | |
| Clay soil | | | | | | √ | | | | | | | | | √ | | |
| Sand | √ | | | √ | √ | | √ | | | | | | | | √ | | √ |
| Cement | | | | √ | √ | | √ | | | | | | | | √ | | |
| Lime | | | | | | | | | | | | | | | | √ | |
| Bitumen | | | √ | | | | | | | | | | | | | | |
| Bitumen Emulsion | √ | √ | | | | | | | | | | | | | | | √ |





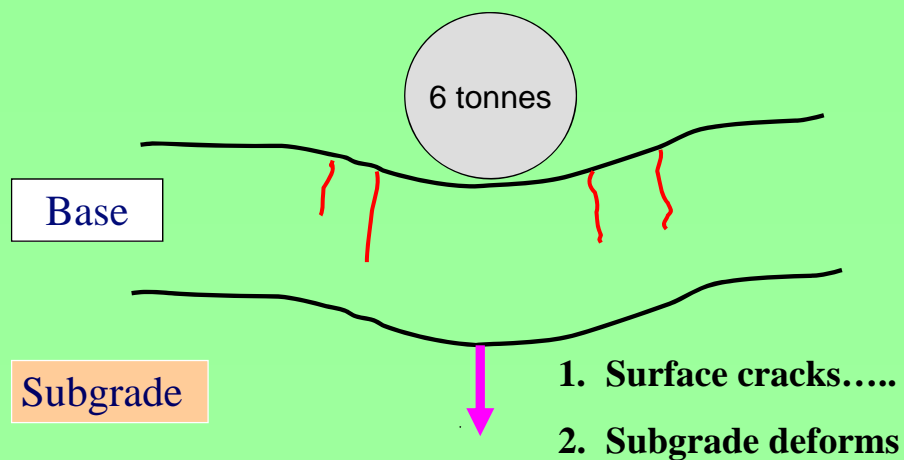
KEY QUESTIONS ?

What actually happens if the pavement is not thick enough?

What actually happens if the roadbase is not strong enough?

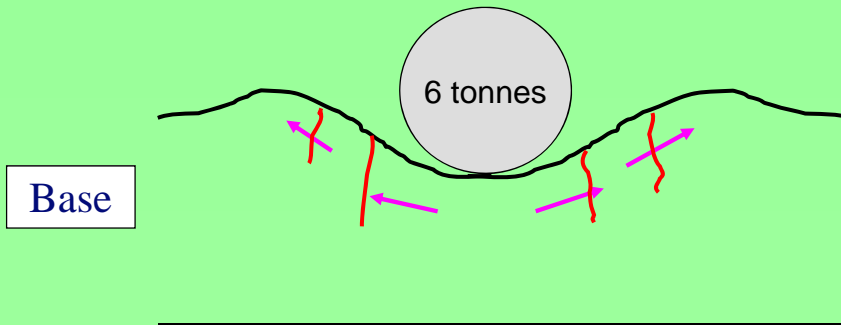
DF 55: Dissemination of LVRR Knowledge and Experience

Roadbase Thickness insufficient



DF 55: Dissemination of LVRR Knowledge and Experience

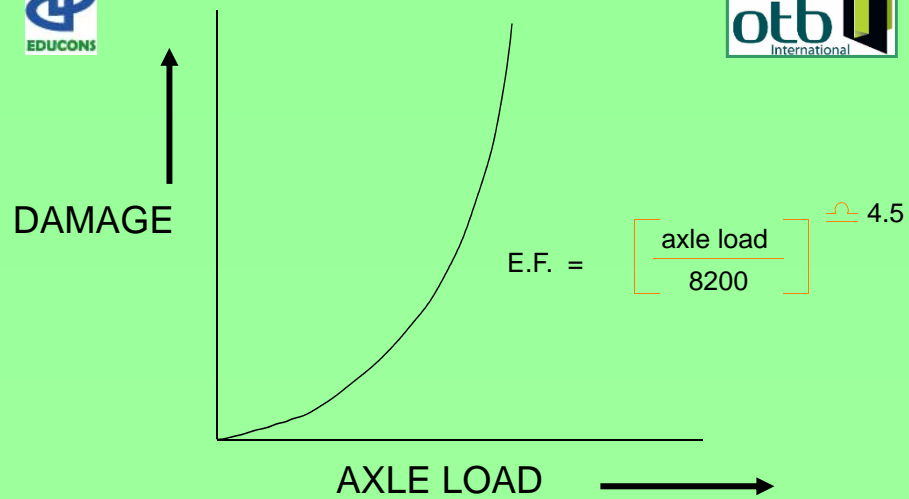
Strength of Base Insufficient



Subgrade

1. Shear failure, and heave
2. Surface cracks

DF 55: Dissemination of LVRR Knowledge and Experience



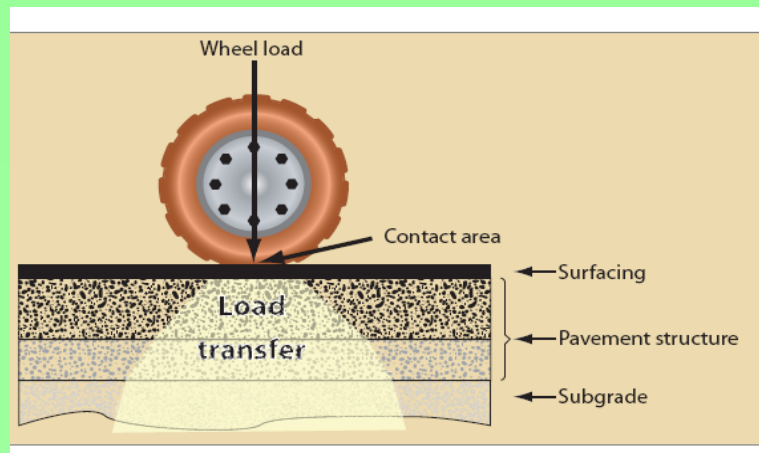
10 tonne axle = 2.4 e.s.a.

15 tonne axle = 15.1 e.s.a.

20 tonne axle = 55.3 e.s.a.

DF 55: Dissemination of LVRR Knowledge and Experience

Transfer of wheel load



DF 55: Dissemination of LVRR Knowledge and Experience

Tyre pressure

- ❑ Surface contact pressure is related to tyre pressure
- ❑ High contact pressure can damage a road surface
- ❑ Tyres are often over-inflated to allow higher vehicle loading
- ❑ Over-inflation should be prevented

DF 55: Dissemination of LVRR Knowledge and Experience

Flexibility in Pavement Design

Modify the material to suit the pavement options



Modify the options to suit the materials available,



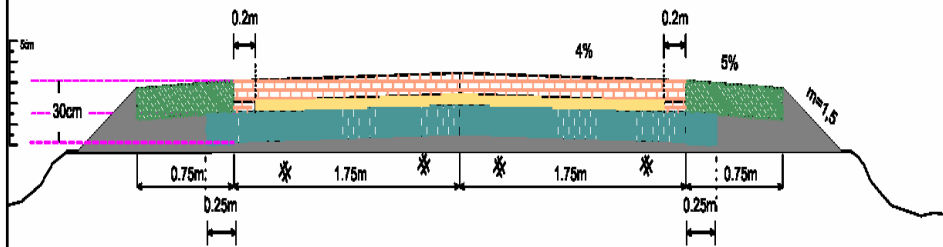
Rural road Pavement Selection

The initial selection of pavement type should be on a whole range of factors that cumulatively can be described as the “road environment”, namely:

- Construction materials
- Climate/rainfall
- Hydrology
- Terrain
- Traffic/axle load
- Construction regime
- Maintenance regime

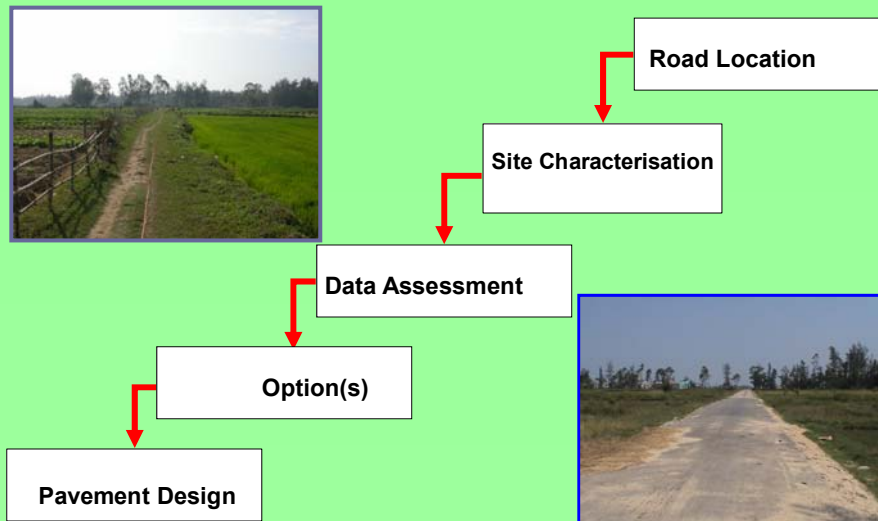


Cross sections



Clay brick over cement stabilised sandy soil

General Design Sequence





EM3.3 Vietnamese Standard Designs



Introduction



Rural road design standard 22TCN 210-92 was issued by MoT, 1992. This standard was used for almost projects in Viet Nam from local budgets and also international donor budgets. However, this standard was issued 16 years ago. It is not yet updated. Some items of this standard are limited. This lecture presents some main design items of standard. Other details can be referred to rural road design standard 22TCN 210-92.



General regulations



- Rural road network is a part of local transport linking to national road network for service of Agriculture, Fishing trade and socio-economic factors. This network ensures the transportation of medium & small motor vehicles, and motorbikes.
- The roads connect districts to communes and intercommunes: if necessary, the design should follow the technical specifications of road class VI of design standard TCVN-4054-85. Remain roads include the roads from communes to villages, intervillages and from villages to the fields, these roads can be divided into classes A and B.

DF 55: Dissemination of LVRR Knowledge and Experience 55



Vietnamese Specifications



- The road class A is the road for medium motor vehicles, standard axle loads. The design axle load is 6T/ axle. The road class B is the road for vehicles with design axle load 2.5T/ axle.
- The documents of flexibility study and detail design should be approved by competent authorities from Provincial/ City People Committees.

Rural road technical specifications are on the base of safety limit speed $V=10-15\text{km/h}$ of vehicle. It depends on suitable investment budget and road capacity.

DF 55: Dissemination of LVRR Knowledge and Experience 56



Technical Specifications



-Road class A and B

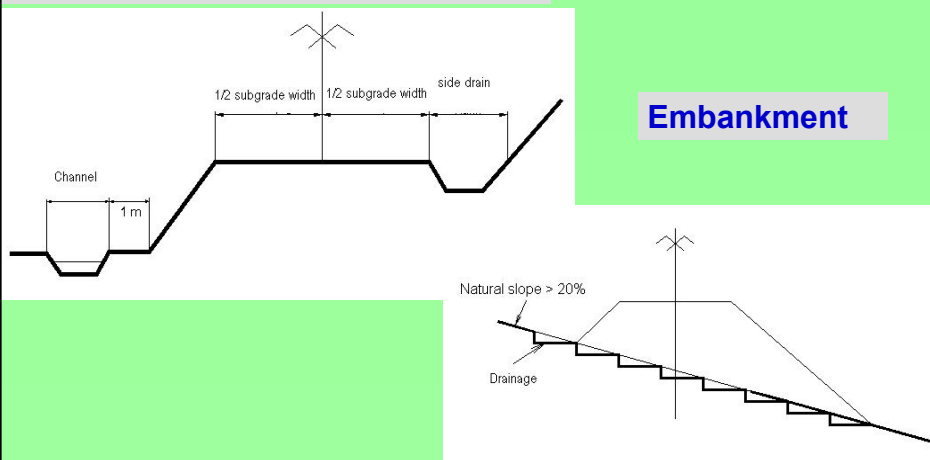
| Road class | Sub-grade width (m) | Pavement width (m) | Minimum radius (m) | Maximum longitudinal gradient (%) | Maximum length of gradient (m) |
|------------|---------------------|--------------------|--------------------|-----------------------------------|--------------------------------|
| A | 5,0 (4,0)* | 3,5 (3,0)* | 15 | 10 | 300 |
| B | 4,0 (3,5)* | 3,0 (2,5)* | 10 | 6 | 200** |



Vietnamese Standard Designs



Sub-grade technical specifications

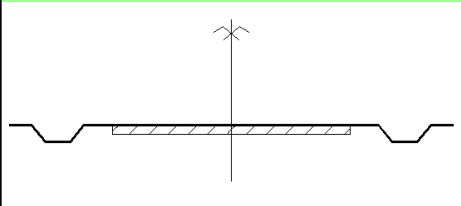


Embankment

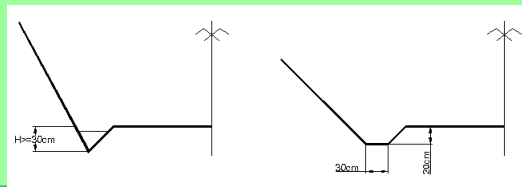
DF 55: Dissemination of LVRR Knowledge and Experience 58

subgrade is on natural terrain,
part-cut, part-fill subgrade

Vietnamese Standard Designs



Side drain forms are
triangle or trapezium.



DF 55: Dissemination of LVRR Knowledge and Experience 59

Vietnamese Standard Designs

Pavement technical specifications

Road pavement is effected directly by the wheels of vehicles and also the weather and climate. If vehicles want to go on the road comfortably, the pavement has to follow the conditions, as follows:

- Enough strength that pavement can be born the load of the wheels and also effect of weather and climate.
- Enough evenness that the vehicles can go smoothly and water does not stagnate on road surface.

DF 55: Dissemination of LVRR Knowledge and Experience 60



Standard Pavement Options



The normal pavement options for road classes A and B

| No. | Pavement options | Road class | |
|-----|--|------------|---|
| | | A | B |
| 1 | Cement concrete grade 150-200 | √ | |
| 2 | Macadam bitumen seal | √ | |
| 3 | Macadam cement mortar | √ | |
| 4 | Hand pack stone | √ | √ |
| 5 | Macadam, graded crush stone, quarry-run | √ | √ |
| 6 | Lime stabilized earth, laterite Cement stabilized sand, fine river gravel | √ | √ |
| 7 | Laterite | √ | √ |
| 8 | Sand river gravel | √ | √ |
| 9 | Broken brick, fired earth, slag, cinder. | | √ |
| 10 | Sandy soil | | √ |



Vietnamese Standard Designs

- Cross falls of surface and shoulder of rural road in general are, as follows: - surface: 4%. – shoulder: 5%.
- Road detail design follows the rigid pavement design standard **22TCN 223-95**. and flexible pavement design standard **22TCN 211-93**.

Road structures.

The road structures include bridges, culverts, retaining walls, submersible bridges, causeways, ferries, protection structures.

The road structures can be referred in detail by 22TCN 210-92 (Typical designs of road structures: culverts and bridges)

Standard Rural Road Design Procedures

Vietnamese Rural Road Design Procedures (Referring the Guidelines)

Survey documents include:

- Site survey record note book.
- Notes of survey.
- Plan, profile, cross section of alignment.
- Drawings of registration of drainage structures (Bridges, culverts).
- Geography records.
- Geology records.
- Local agreement – minutes of meeting.
- Survey and test note book of site subgrade/ pavement strength
- Electric files of above documents.



Vietnamese Standard Designs

Design documents include:

Technical report.

Alignment drawings: local map, plan, profile, cross section, road structures.

Quantity in detail and summary of quantity.

Cost estimation.

Electric files of above documents.



DF 55/001: Dissemination of LVRR



Knowledge and Experience



Thank you

DF 55: Dissemination of LVRR Knowledge and Experience **65**