ADB TRANSPORT FORUM
Asia on the move: energy efficient and inclusive transport

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Key Engineering Issues in Designing Sustainable Low Volume Rural Roads

by

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An appropriate quotation

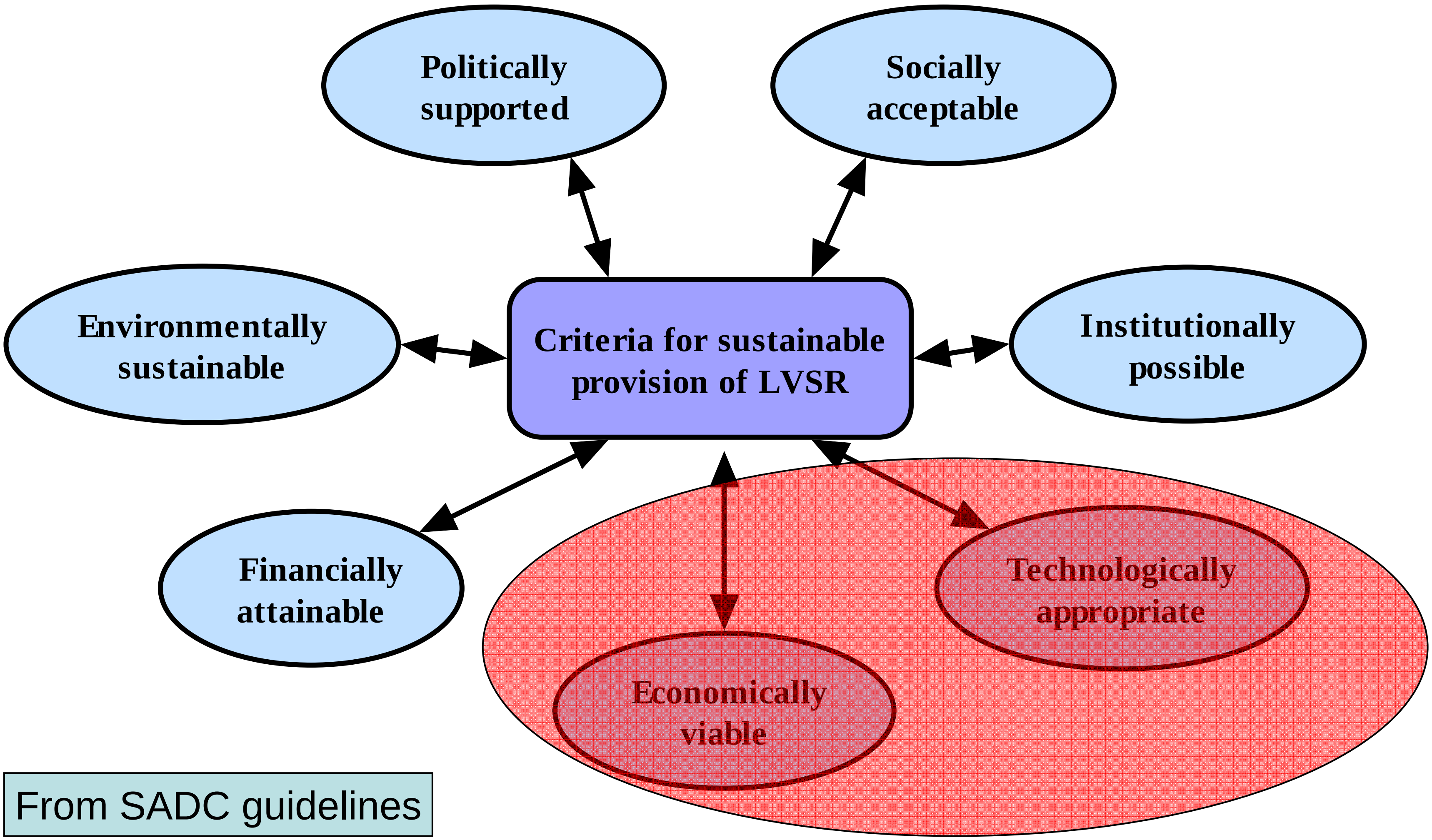
The challenge of pavement design for low volume roads

"I have always felt that it is easier to design a pavement for a high volume rather than a low volume road. On the low volume road we are continually striving for low cost, which makes our design extremely sensitive from the standpoint of thickness, quality of pavement and surfacing materials, geometric design, and many other factors."

Eldon Yoder

(one of the most prominent pavement designers of our time).

Sustainability



From SADC guidelines

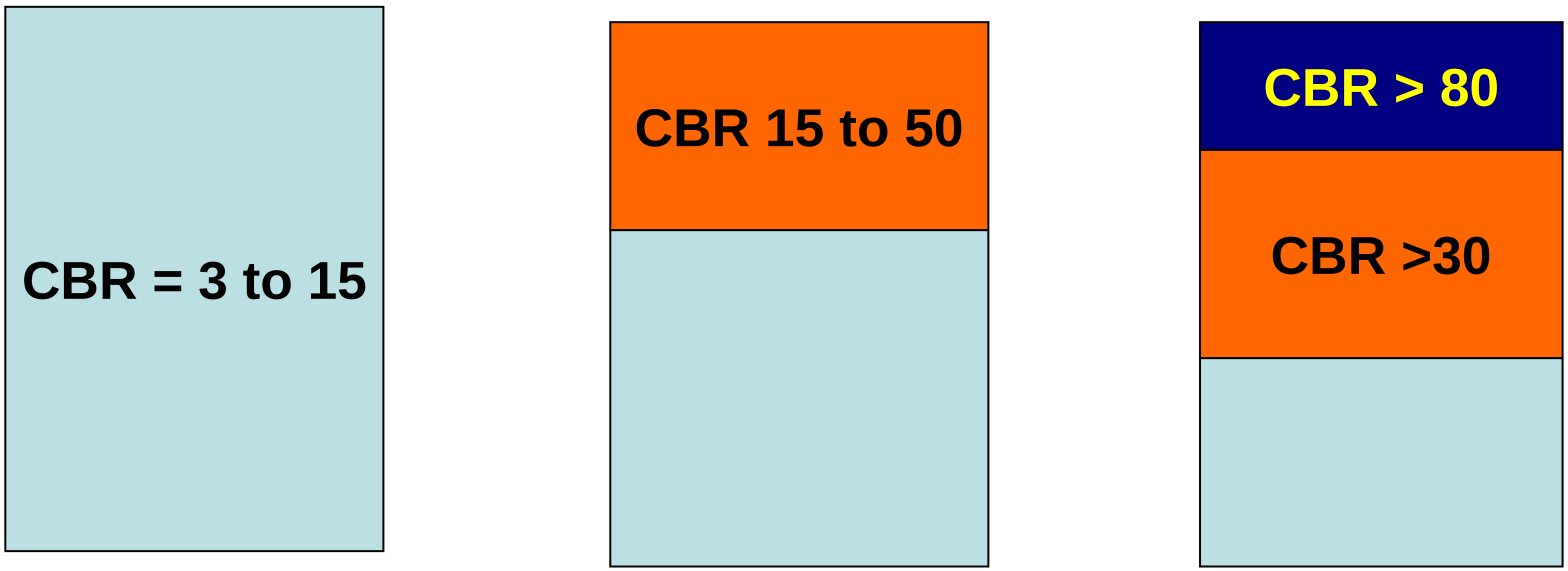
Content of the presentation

- Earth roads
- Gravel roads
- Paved roads

- Light traffic
- Heavier traffic

Basic Structures

- Earth
- Gravel
- Paved



An important decision

Many rural roads carry only relatively light vehicles

- **Do we design just for these light vehicles or do we try to cater for the possibility that heavy vehicles may use the road ?**
- **If we design for the light traffic only, how do we prevent heavy vehicles from destroying the road ?**
- ***[In terms of overloading, a similar question applies to the design of main roads. It is just as serious for LVRRs]***

Range of LVRRs

TRAFFIC

Low volume
Light weight

High volume
Heavier weight

STRENGTH

Thin & weak

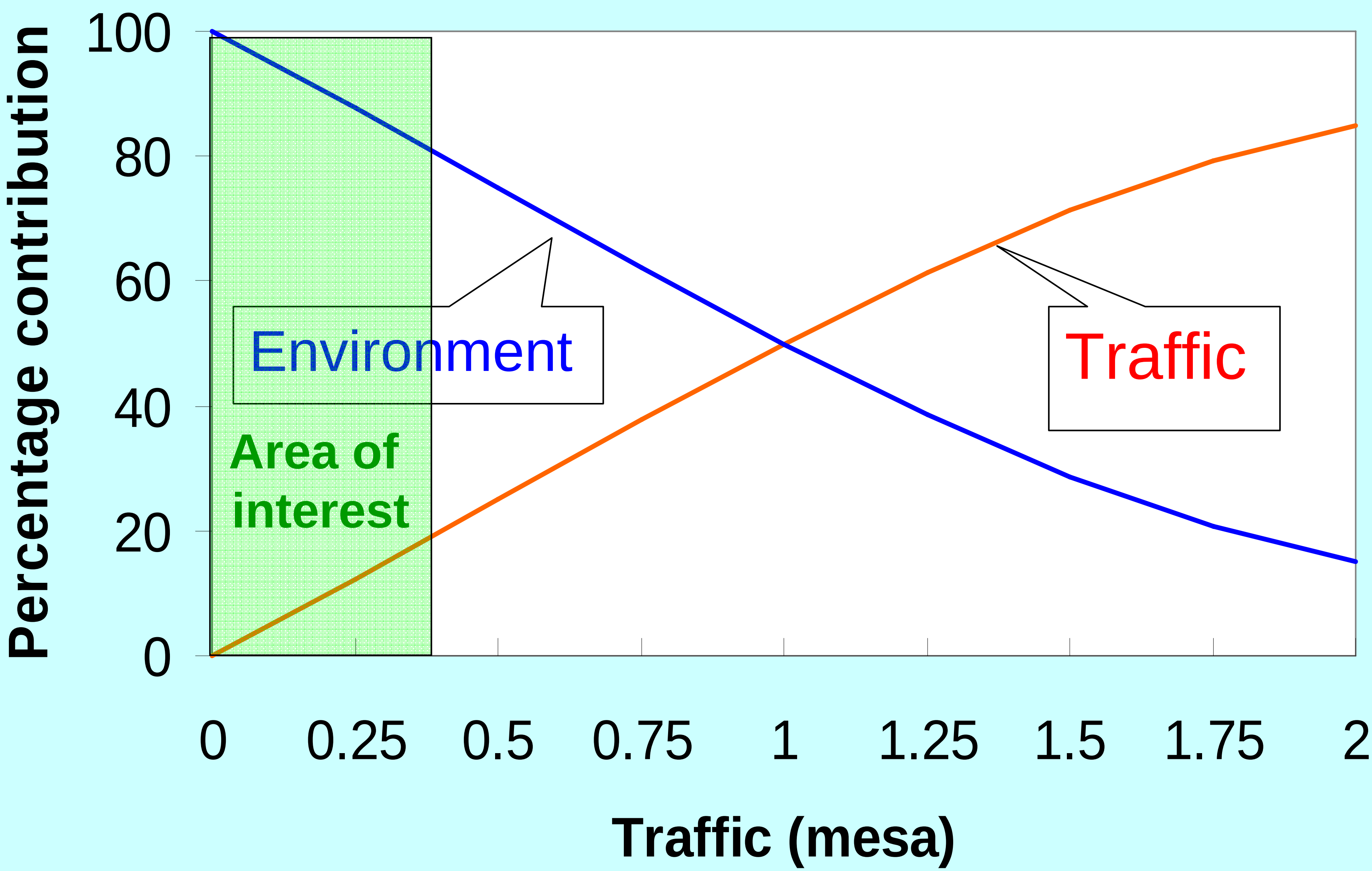
Thick & strong

MAIN CAUSE OF DETERIORATION

Environment
Tyre pressures

Different design philosophies

Axle loads (esa)



Percentage contribution
100
80
60
40
20
0
Environment
Traffic
Area of interest
0
0.25
0.5
0.75
1
1.25
1.5
1.75
2
Traffic (mesa)

EARTH ROADS

ENGINEERED NATURAL SURFACED ROADS

or

ENSRs

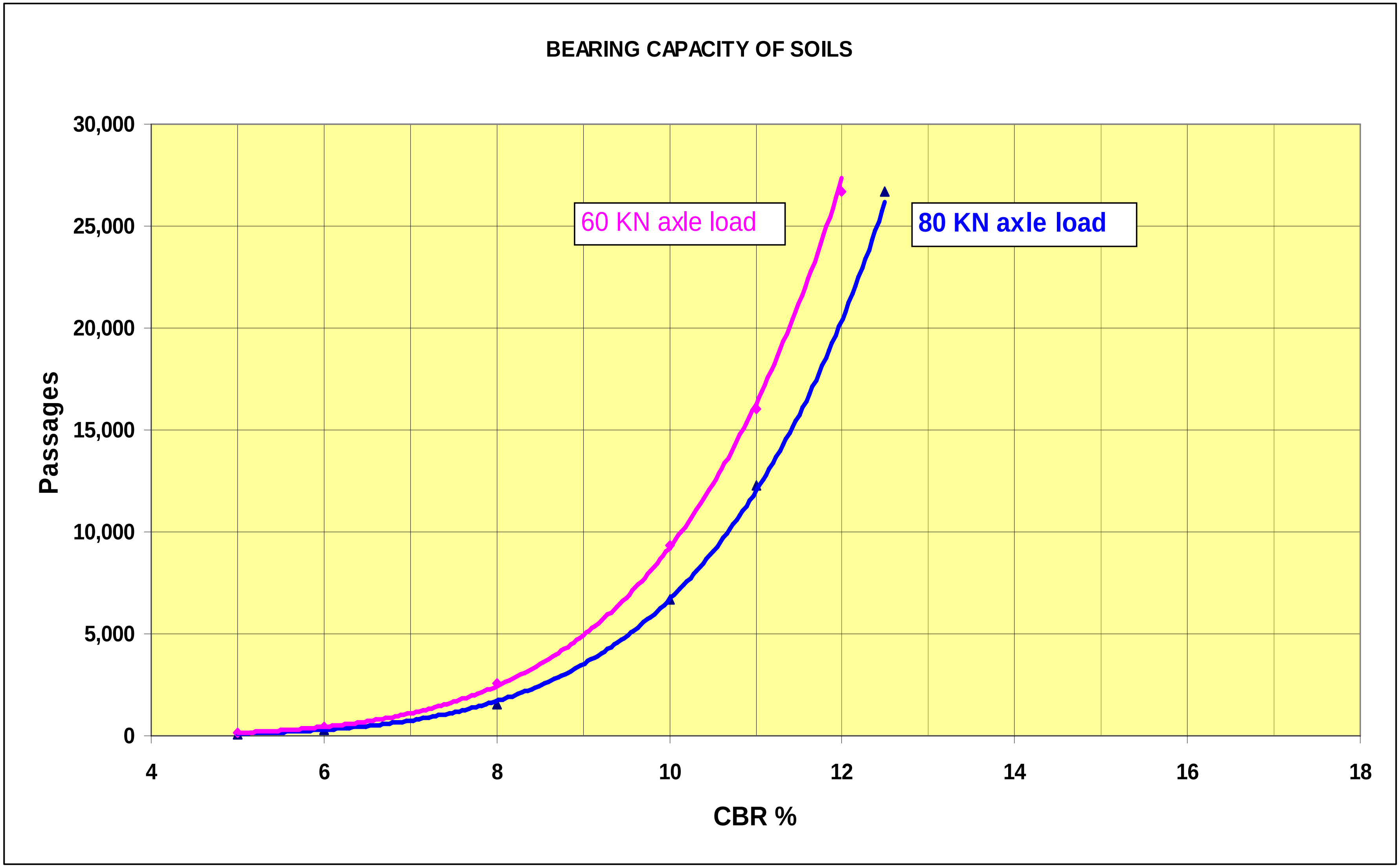
Philosophy - ENSRs

- Some soils will usually deteriorate too quickly for an ENS to be a viable option.
- Best choice of surfacing will depend on the whole life costs of all the options, including social and environmental effects
- This will depend on the alternatives that are available and the range of factors influencing performance at each road location
- RELIABLE KNOWLEDGE OF LIKELY PERFORMANCE IS ESSENTIAL FOR SUCH A WHOLE LIFE COST ANALYSIS

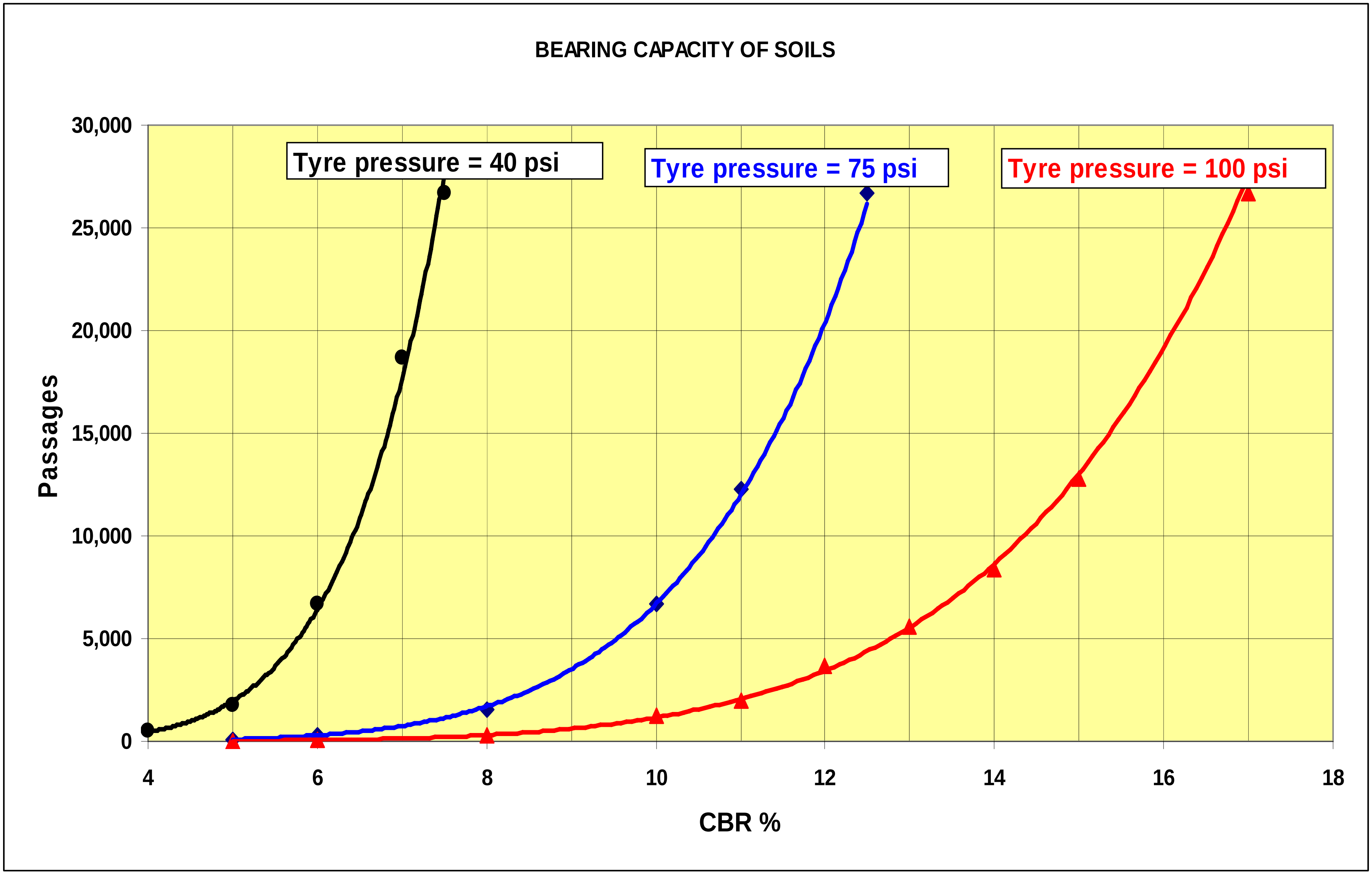
Traffic capacity of ENSRs

- **Estimating likely performance of ENSRs begins with estimating the traffic carrying capacity of the soils.**
- **Studies by the American Army in the 1960s and 1970s showed just how many vehicles of particular types could pass over soils of different strengths.**

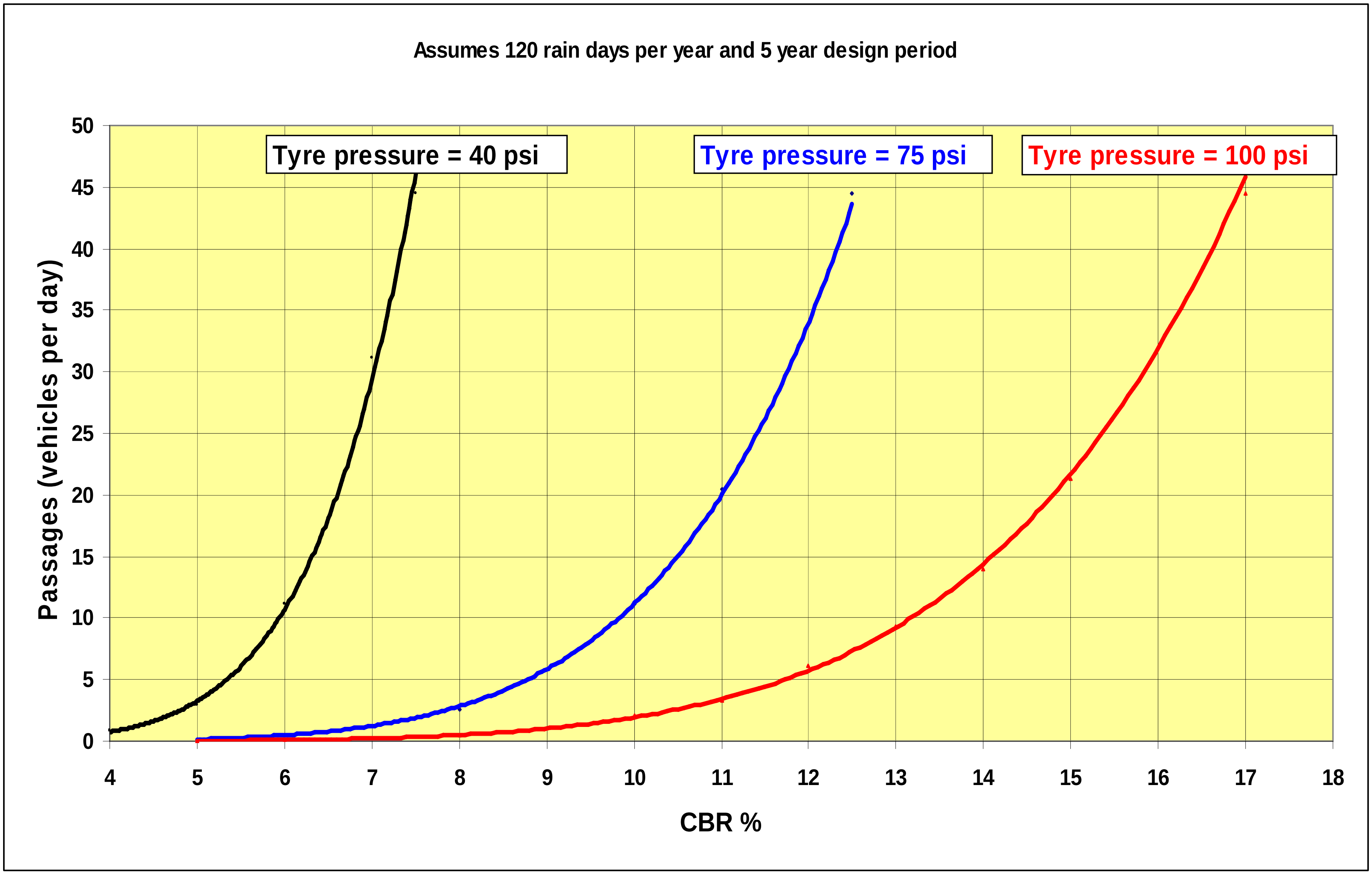
Effect of axle load on basic soil



Effect of tyre pressures



Effect of tyre pressures



Performance – the dependent variables

- Potholes
- Rut formation
- Erosion
- Slipperiness when wet
- Slipperiness when dry (loose material)
- Corrugations
- Dust
- Loss of material
- ++

Performance depends on…

- **Soil properties**
  - **Particle Size Distribution,**
  - **Plasticity,**
  - **Strength,**
- **Rainfall (amount and intensity)**
- **Traffic (type, volume and tyre pressure)**
- **Longitudinal gradient, width**
- **Quality of drainage**
  - **Ditches**
  - **Crown height**
  - **Camber**
  - **‘Run-off’**
- **Level of water table**
- **+++**

Additional issues

- **The complexity of behaviour is further complicated by the fact that several key factors behave non-linearly and may be two-valued.**
  - For example, behaviour improves as plasticity increases but, upon further increase in plasticity, behaviour deteriorates.
- **Many factors are not constant but change with time.**
  - Camber, for example, slowly decreases. Deterioration is expected to increase rapidly when the run-off of surface water becomes difficult

SEACAP 19

In a recent SEACAP study of the behaviour of ENSRs in Cambodia, 36 individual items of data relating to performance were measured on about 100 sections of road.

Analysis is now underway.

Definitions

Shrinkage Product =

Linear Shrinkage x P0.425mm

Grading Coefficient =

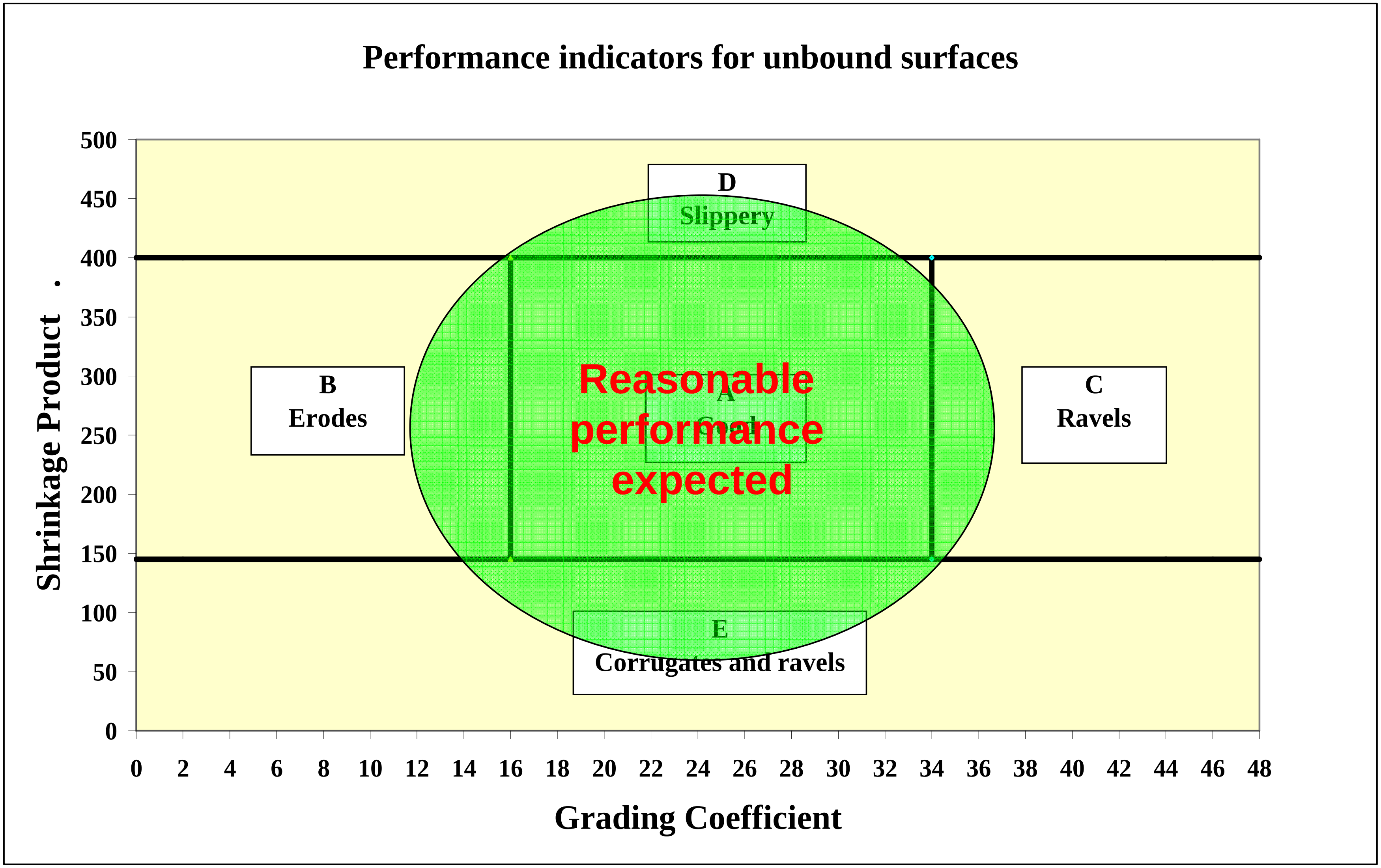
P4.75*(P26.5 – P2.0)/100

Linear shrinkage is strongly related to the clay content and its properties

Grading coefficient

- **The Grading Coefficient and has a minimum value of zero and a maximum value of 100.**
- **Low values occur when only gravel sizes are present (e.g. P4.75 is near zero) but also when only fine material passing the 2.0mm sieve is present (e.g. P26.5 = P2.0).**
- **Low values also occur when there is an abundance of material larger than 26.5mm.**
- **High values occur when only coarse sand is present (i.e. all the material lies between 4.75mm and 2.0mm).**
- **Thus both high and low values indicate material that is unlikely to perform well.**

General behaviour of earth and gravel roads



(Source: P Paige-Greene, 2007)

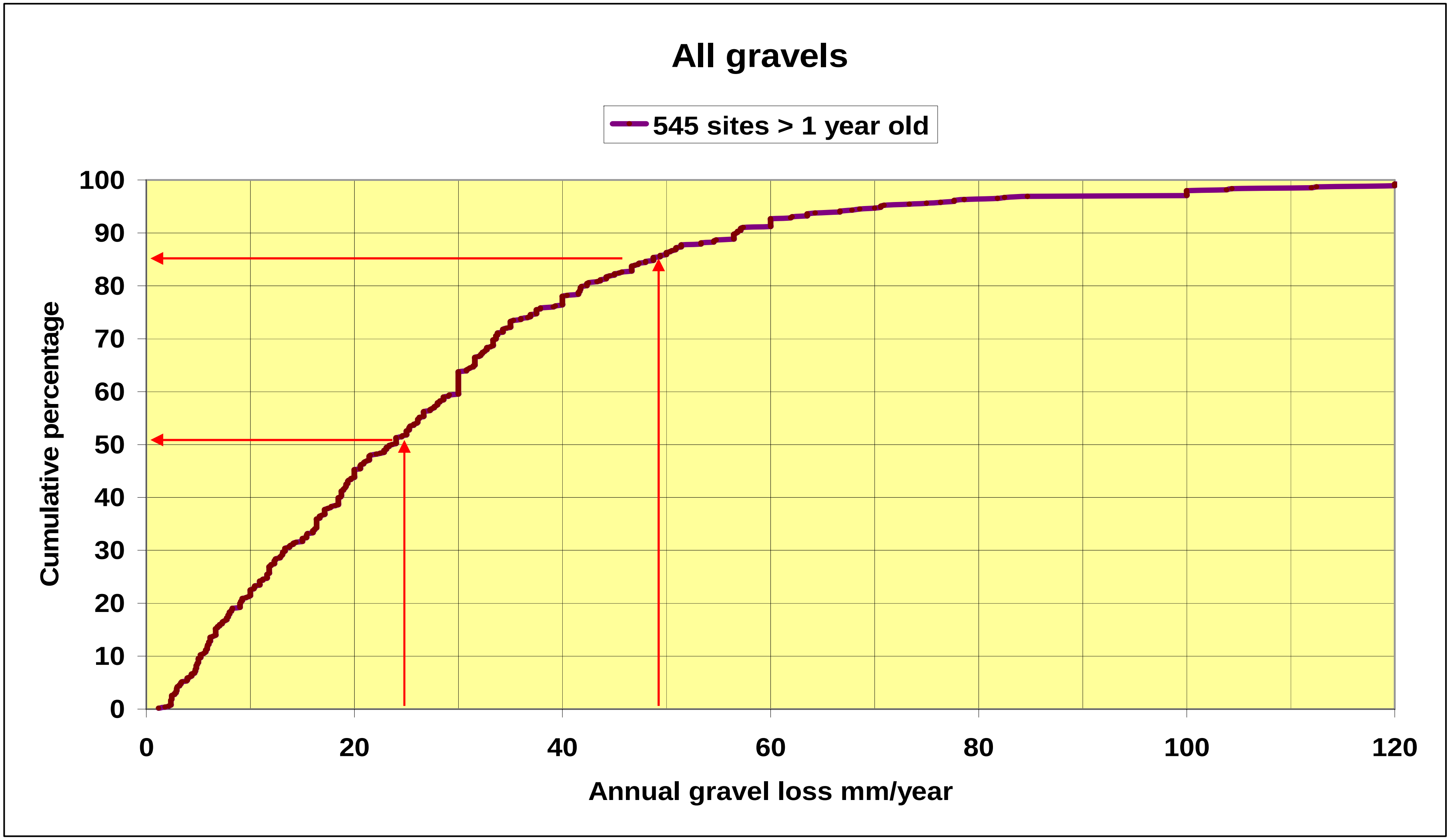
Gravel roads

Factors decreasing the traffic threshold for upgrading

- **Increasing shortage and cost of gravel**
- **Use of more appropriate pavement structural designs**
- **Use of more appropriate geometric design**
- **Inclusion of benefits from motorcycle and intermediate motorised transport**
- **Inclusion of benefits from non-motorised transport**
- **Adverse impacts of traffic on gravel roads (loss of gravel and dust)**
- **Reduced environmental damage from quarrying and haulage**
- **Realistic assessment of the likely maintenance that the roads will receive**

Adapted from SADC Guideline on Low-Volume Roads

Gravel loss in Vietnam



What is needed

- **All year access**
- **Good long term performance**
- **Low whole life cost**
- **Ease of construction (minimise risk of poor quality)**
- **Low maintenance**

+

- Suitable for local small scale contractors
- Construction provides advantage to local economy
- Possible employment opportunities for women

This also implies…

- **The pavement has good load spreading characteristics**
- **The sensitivity of the design to water is low**
- **The strength of the upper layers is sufficient to resist damage by heavy wheel loads**
- **Whole life TOTAL costs are lower than the alternatives**

Options

1. Make use of locally available and low cost materials that do not meet standard specifications (marginal materials)

2. Strengthen weak materials by stabilisation

3. Improve local methods using Environmentally Optimised Design (EOD) principles

4. Try more innovative solutions e.g. block paving, concrete roads

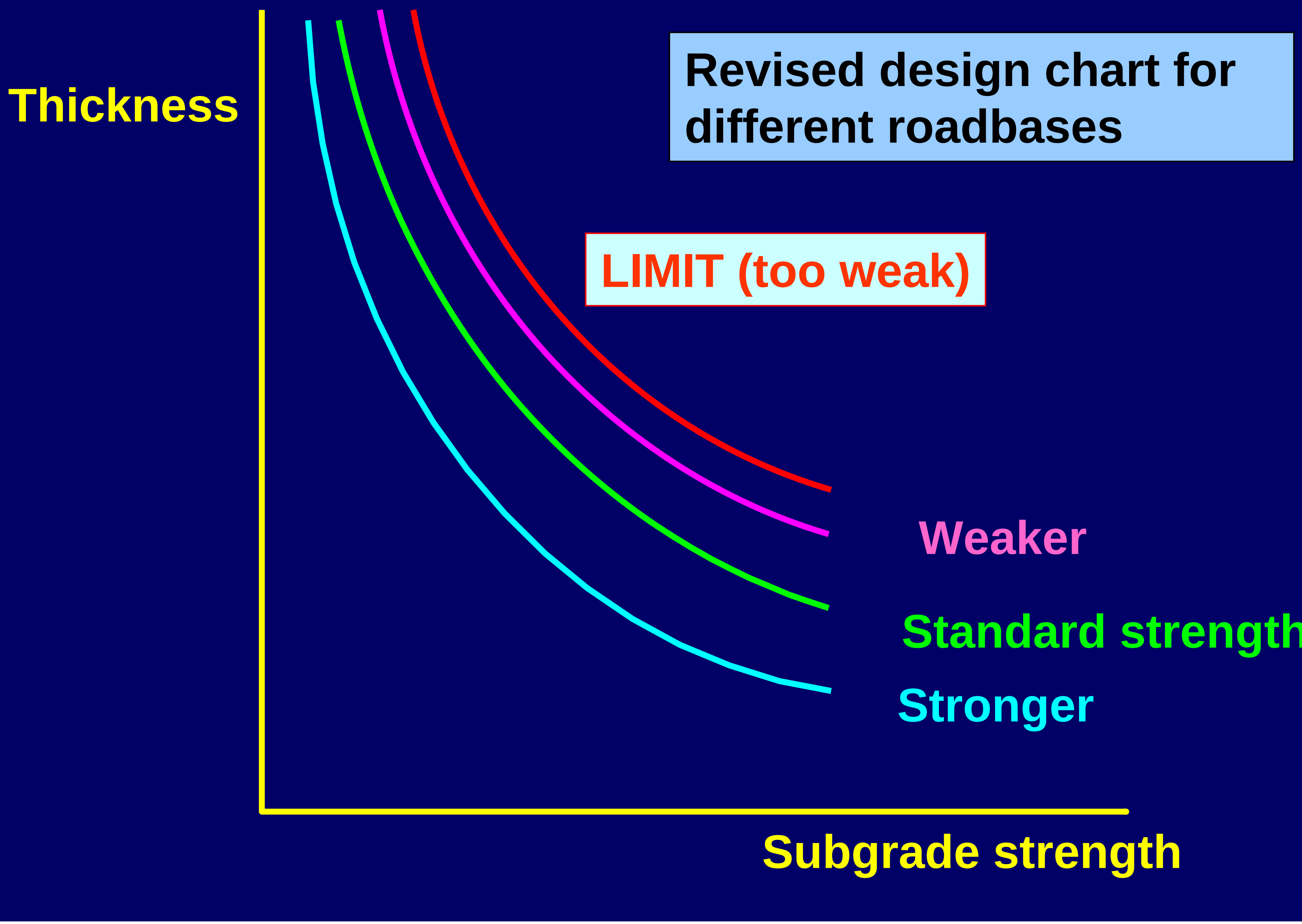
Key issues affecting choice

- Severe climate-terrain – erosion problems
- Lack of good road-building materials
- Characteristics of the materials that are available
- Likely traffic volumes and axle loads/tyre pressures
- High water tables and flooding
- Local construction skills and capacity
- Local maintenance skills and capacity

Using marginal materials

- A variety of material types (worldwide) have been investigated and suitable methods for their successful use have been derived (e.g. calcretes, laterites, volcanic ash, soft limestones, ++
- Greater care is required to make sure that some of these materials are not allowed to become too wet.
- This includes sealing shoulders, increased embankment height/ditch depth, good surface seals, ++
- This is the concept of Environmentally Optimised Design (EOD)

CBR DESIGN FOR 5 TONNE WHEEL



Alternative road designs

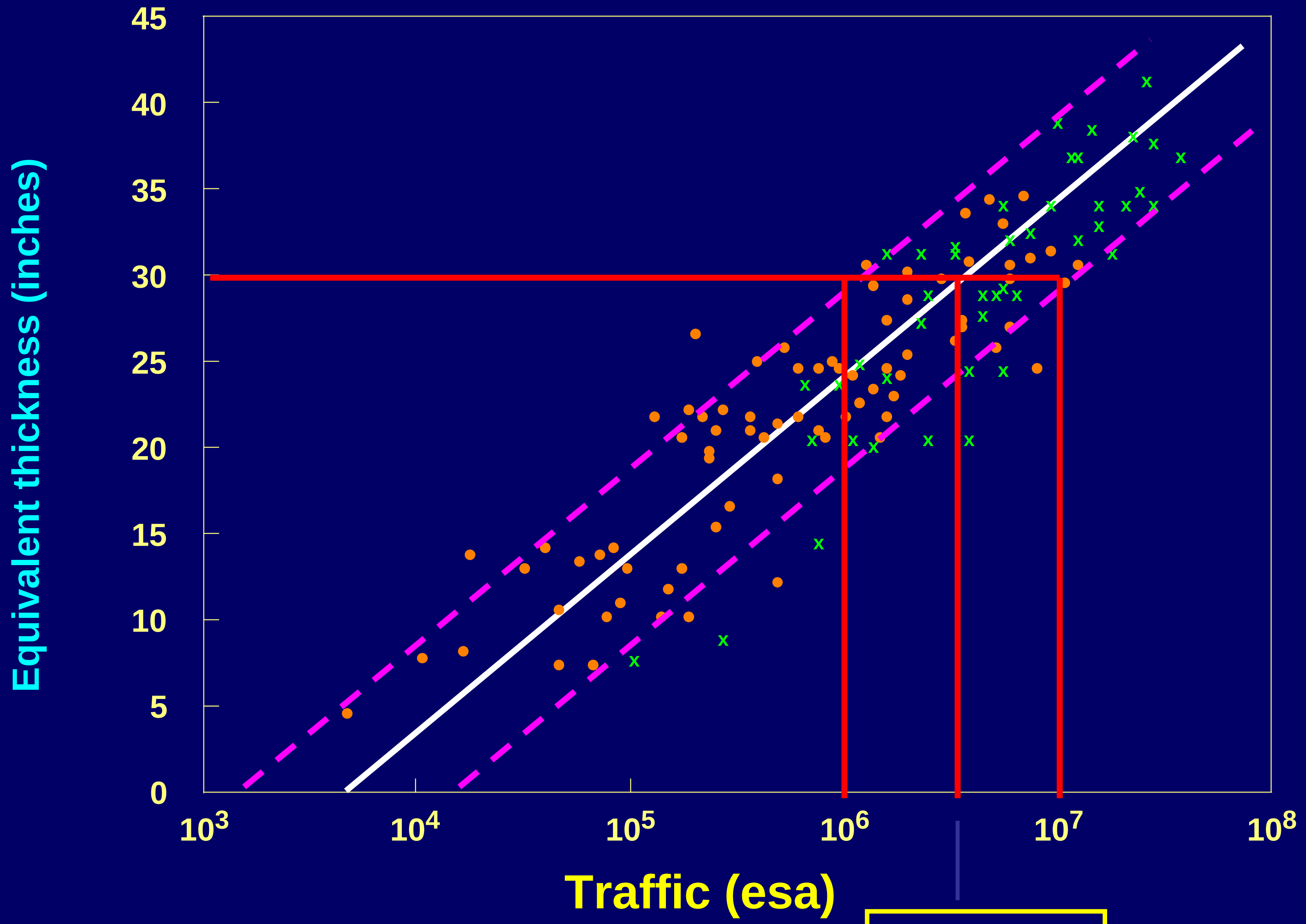
- lime and cement stabilised bases
- bitumen stabilised bases
- dry bound and water bound macadam bases
- dressed stone
- clay bricks
- steel, bamboo and unreinforced concrete
- chip seals
- penetration Macadam

Alternative surfacings

- graded aggregate seals (Otta seals),
- sand seals,
- slurry seals,
- hand-packed stone,
- stone setts and
- concrete blocks,

A key problem of all road research is variability

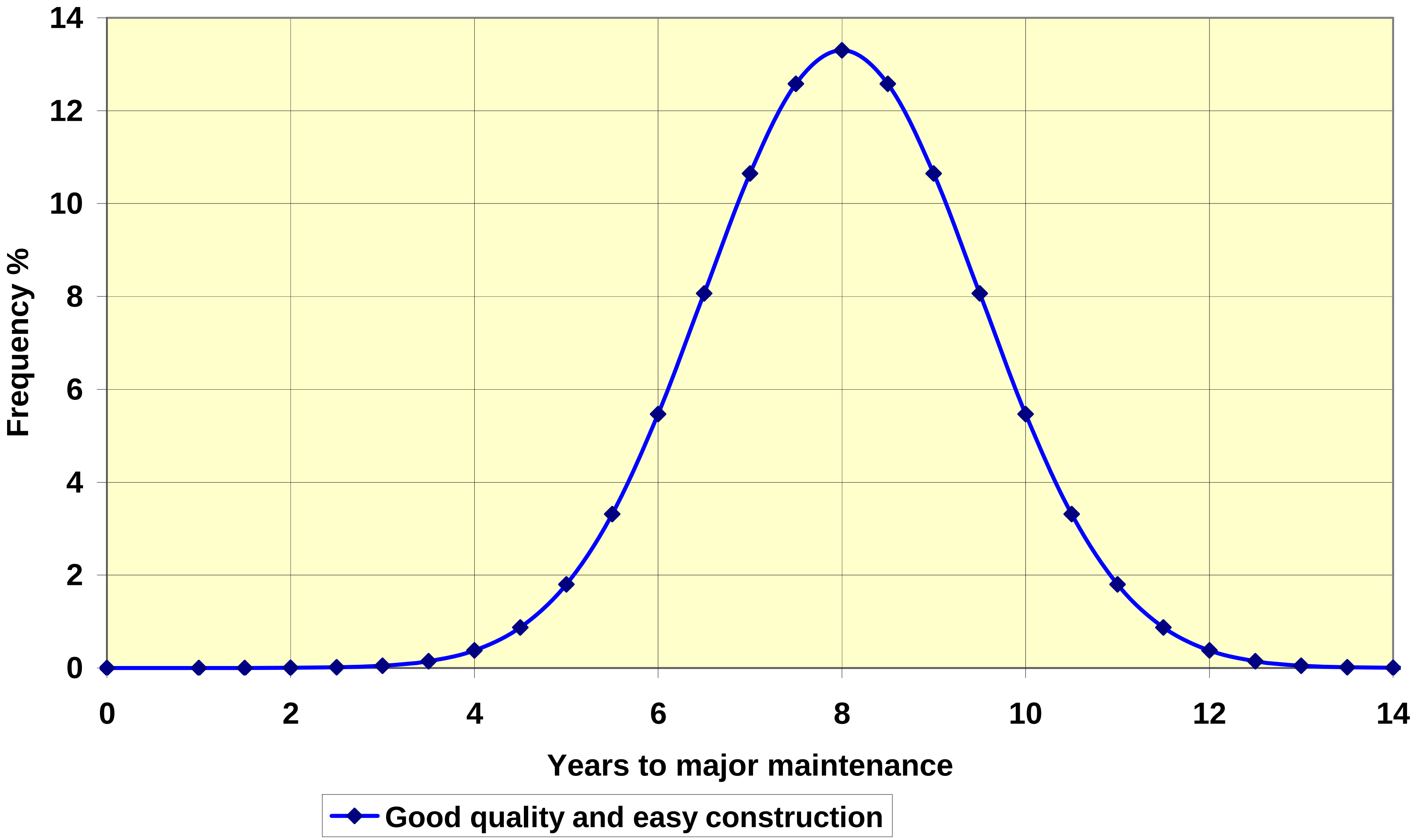
Variability in performance is one of the main reasons why we do not know the answers to many of our pavement problems



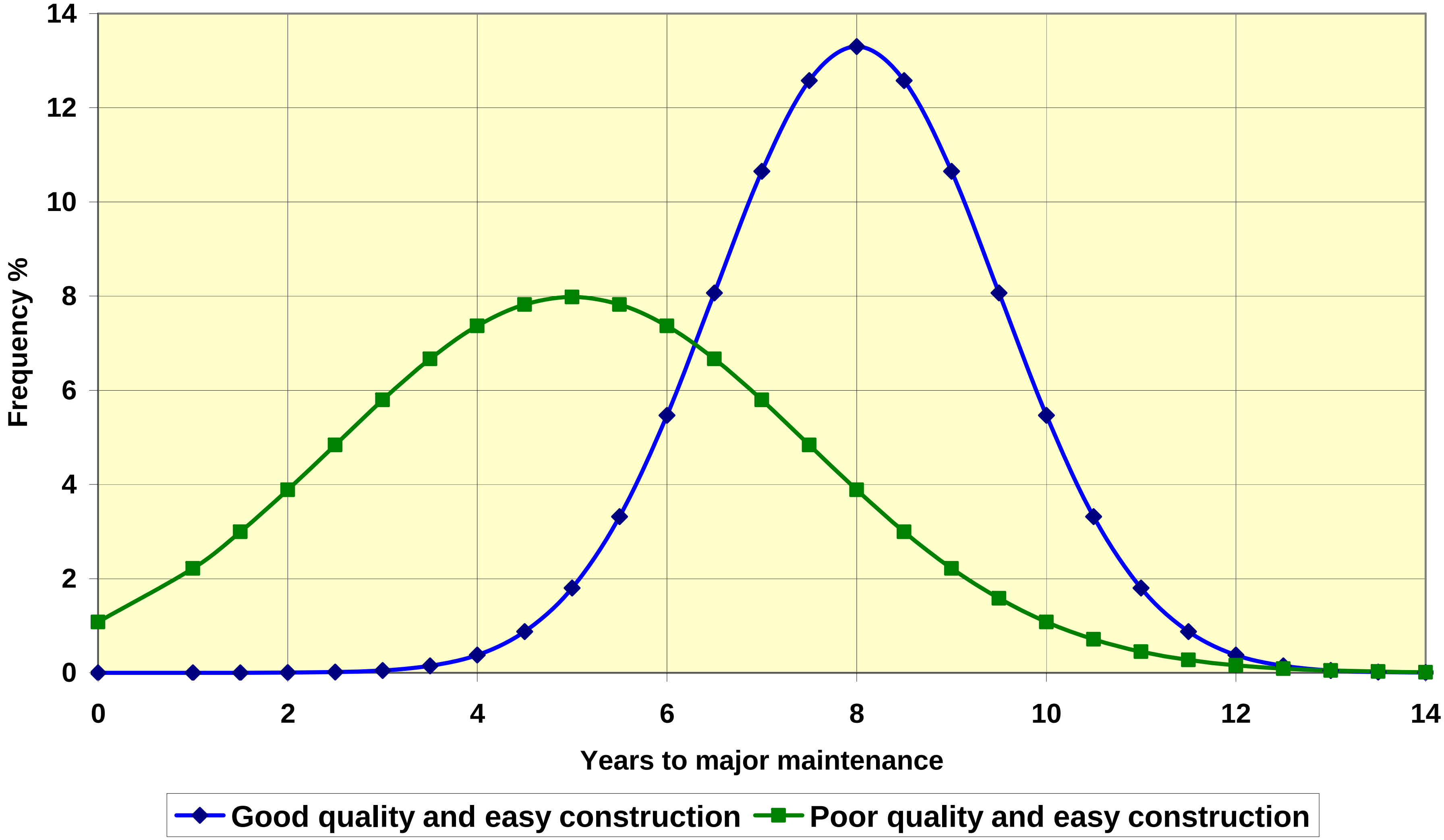
AASHO ROAD TEST DATA

A key problem of all road research is variability

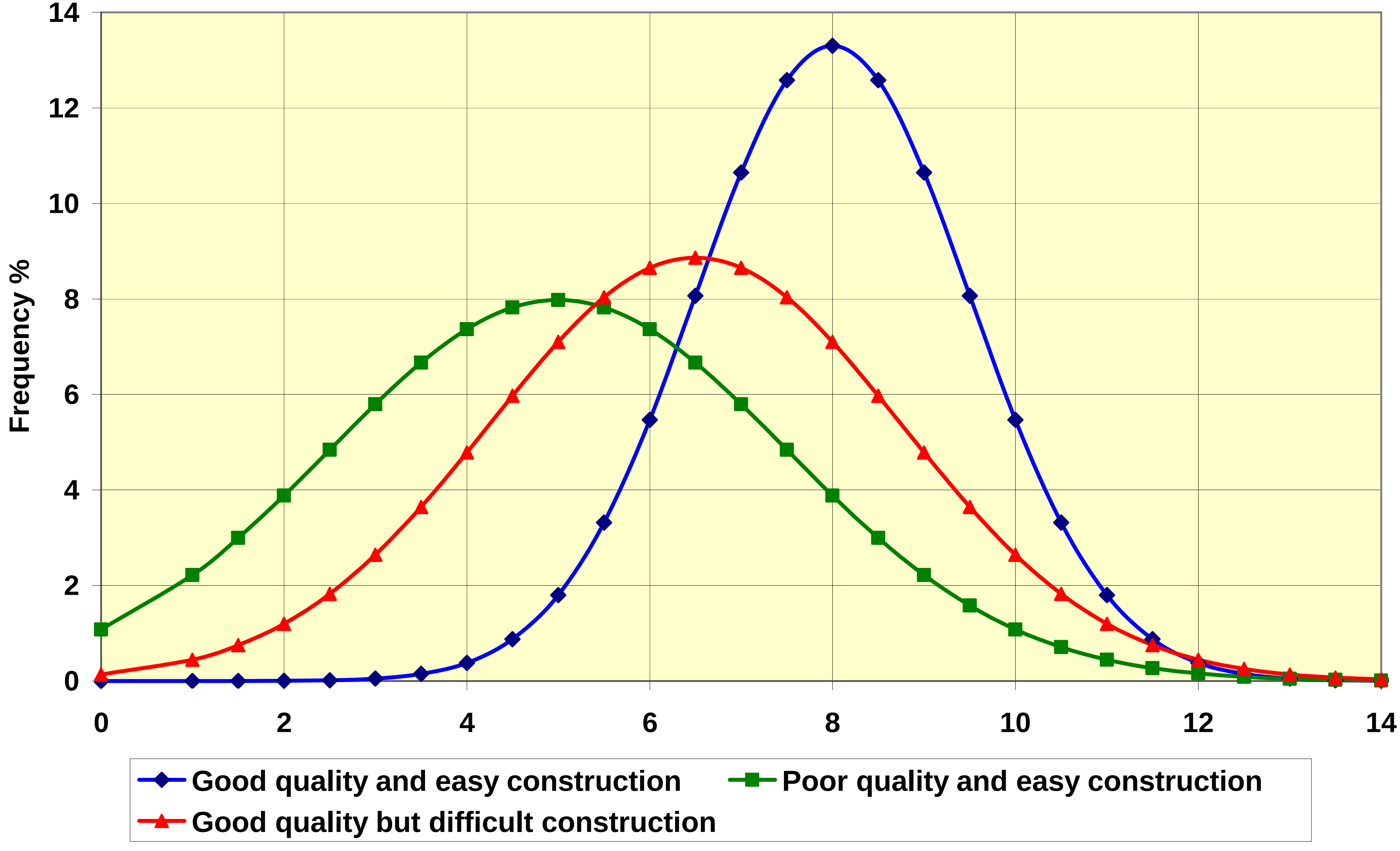
- **Variability in performance is one of the main reasons why we do not know the answers to many of our pavement problems**
- **Engineers usually do not like to confront this – much easier to build with a large safety factor (as we do for structures whose failure is life-threatening)**
- **We cannot afford to do this for roads, especially LVRRs**
- **The only way to determine performance reliably is to build up a large database of construction and performance data**
- **This is why the current and recent programmes of research are vital**

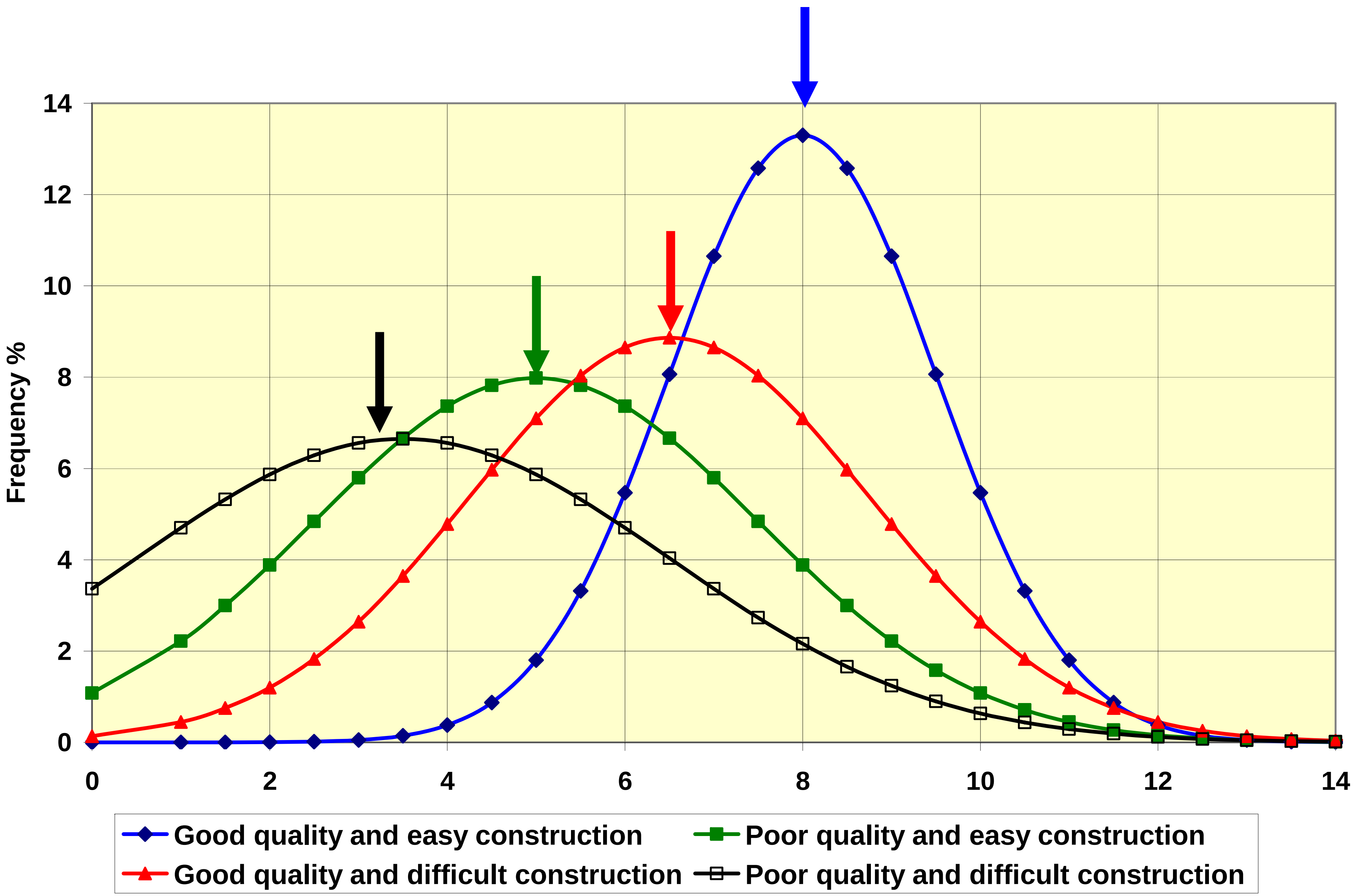


Frequency %
Years to major maintenance
0
2
4
6
8
10
12
14
Good quality and easy construction



14
12
10
8
6
4
2
0
Frequency %
0
2
4
6
8
10
12
14
Years to major maintenance
Good quality and easy construction
Poor quality and easy construction


14
12
10
8
6
4
2
0
Frequency %
0
2
4
6
8
10
12
14
Good quality and easy construction
Poor quality and easy construction
Good quality but difficult construction



Frequency %
14
12
10
8
6
4
2
0
0
2
4
6
8
10
12
14
Good quality and easy construction
Poor quality and easy construction
Good quality and difficult construction
Poor quality and difficult construction

The current position

Evaluation factors

- **Use of local materials**
- **Use of labour based techniques**
- **Ease of construction**
- **Maintenance demand**
- **Suitability for small scale contractors**
- **Advantage to the local economy**
- **Employment for women**
- ***Likely long term performance based on load spreading ability, susceptibility to water, estimated WLCs***

Next steps

- **The construction of the trials has been completed but estimation of WLC and selection of overall best options in particular circumstances requires long-term performance information and detailed analysis.**

- **This is now taking place**

Thank you for your attention