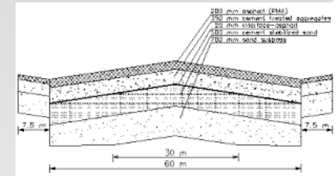
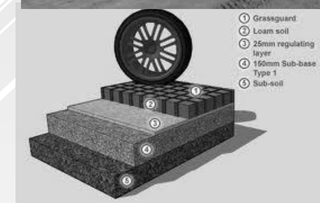
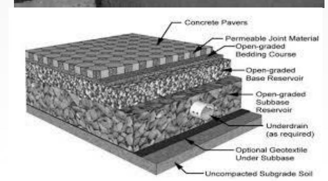
LECTURE 12:
Subgrade soils







12.1 Introduction

Subgrades usually consist of fine grained cohesive or non cohesive soils. All these materials exhibit a stress dependent behavior implying that both the stiffness and the shear strength increase with increasing confinement. The dependence of the stiffness modulus on the stress conditions is shown in figure 112. This stress dependency should ideally be taken into account when designing a pavement.

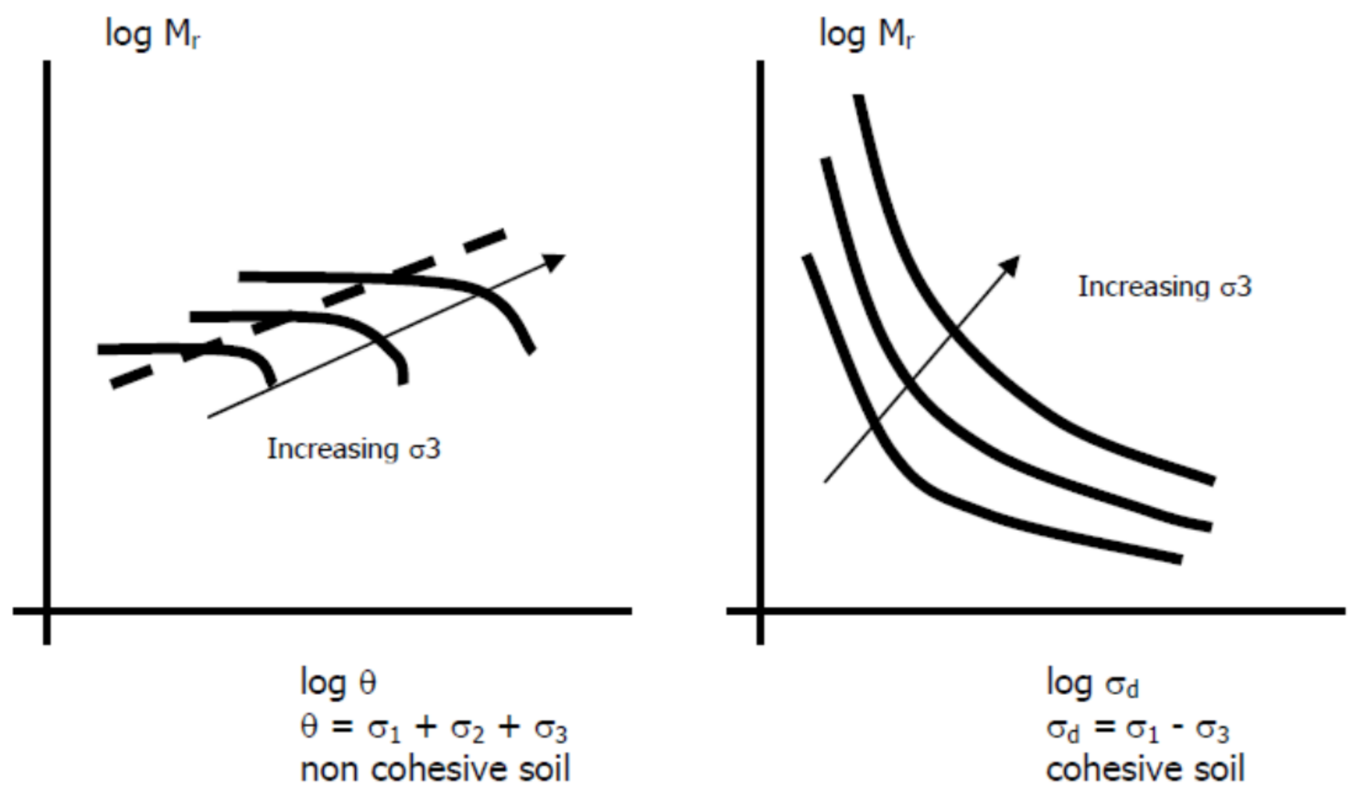


Figure 112: Stress dependent stiffness (resilient) modulus of non cohesive and cohesive soils.

- Because repeated load triaxial testing is still considered to be an “advanced” test it is not used very often for the characterization of pavement subgrades. Common practice is that one relies on relationships between e.g. CBR and the stiffness modulus of the subgrade and on so called subgrade strain relationships that have been developed by correlating observed pavement behavior to the stresses and strains calculated in the subgrade. Some of these relationships have already been presented in chapter 9.

- One also relies on equations that allow the stress dependent nature of the material to be estimated from physical parameters like gradation etc. In chapter 9 and [39] ample attention is paid to such equations developed for sand.

- Since it has been shown [39] that repeated load CBR testing can provide a good estimate of the dependency of the resilient modulus of fine grained materials on the degree of compaction, moisture content etc., this test is recommended if repeated load triaxial testing is not feasible.

- In most cases even repeated load CBR test results are not available and in that case one has to rely on empirical relationships that have been developed between the CBR and the stiffness modulus. A few of such equations will be presented hereafter.

12.2 Estimation of the subgrade modulus

Table 26 shows a number of relationships that have been developed to estimate the stiffness of soils and granular materials from the CBR.

Organisation	Equation
Shell	$E = 10\ CBR$
US Army Corps of Engineers	$E = 37.3\ CBR^{0.711}$
CSIR South Africa	$E = 20.7\ CBR^{0.65}$
Transport and Road Research Laboratory UK	$E = 17.25\ CBR^{0.64}$
Delft University, Ghanaian laterite	$E = 4\ CBR^{1.12}$

Table 26: Relationships to estimate the stiffness from CBR values.

Once again it is emphasized that one should be careful with these relationships because they show a significant amount of scatter. An example of the scatter that can occur is given in figure 113. Special attention should furthermore be given to the moisture content and degree of compaction since both have a large influence on the stiffness (resilient modulus) and shear strength of the material.

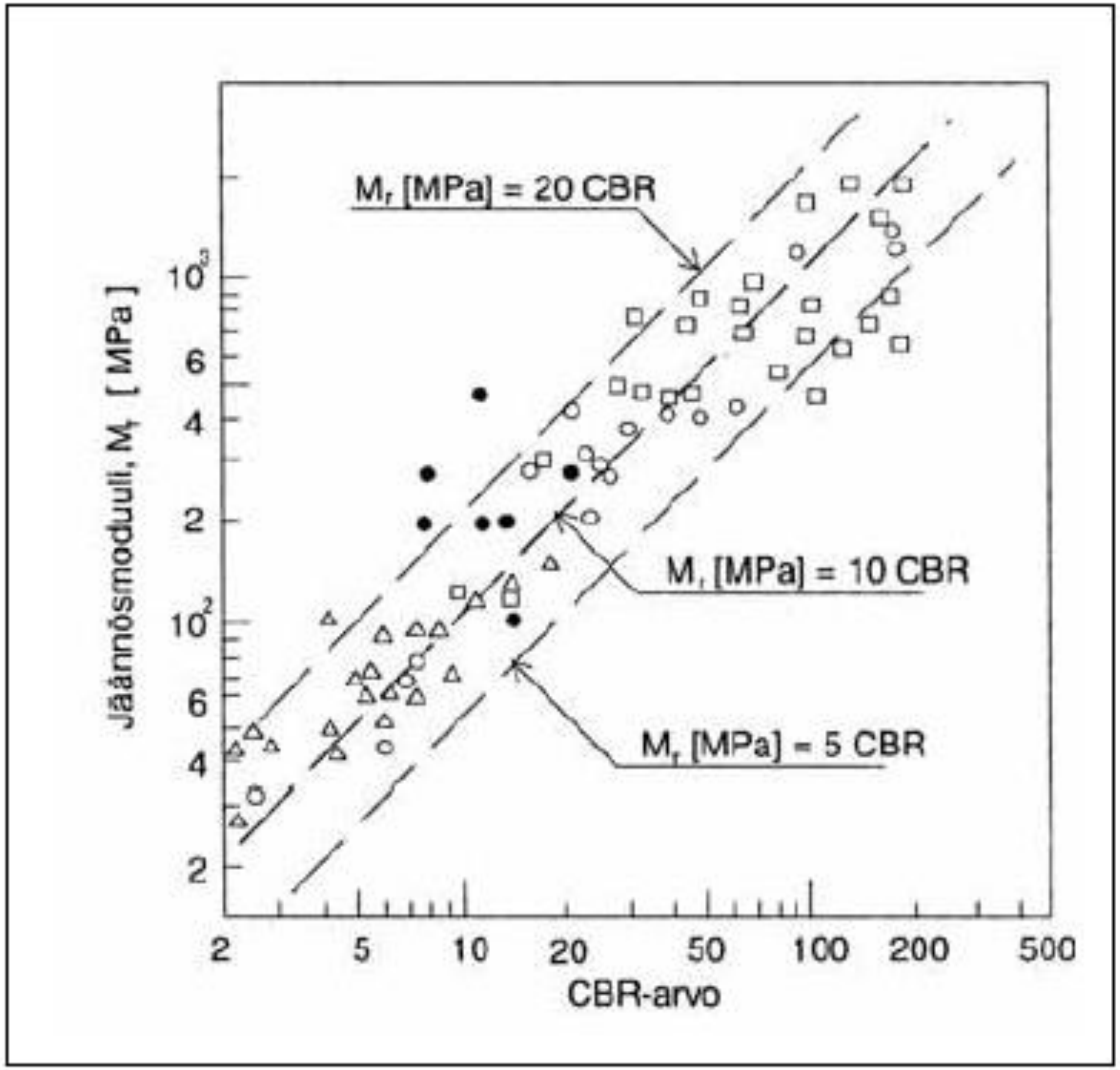


Figure 113: Scatter around the relationship E = 10 CBR.

The importance of knowledge of the moisture content in the subgrade is illustrated in figure 114 [46].

This figure clearly shows that good quality drainage of the base, subbase and subgrade is very important to obtain good performing roads.

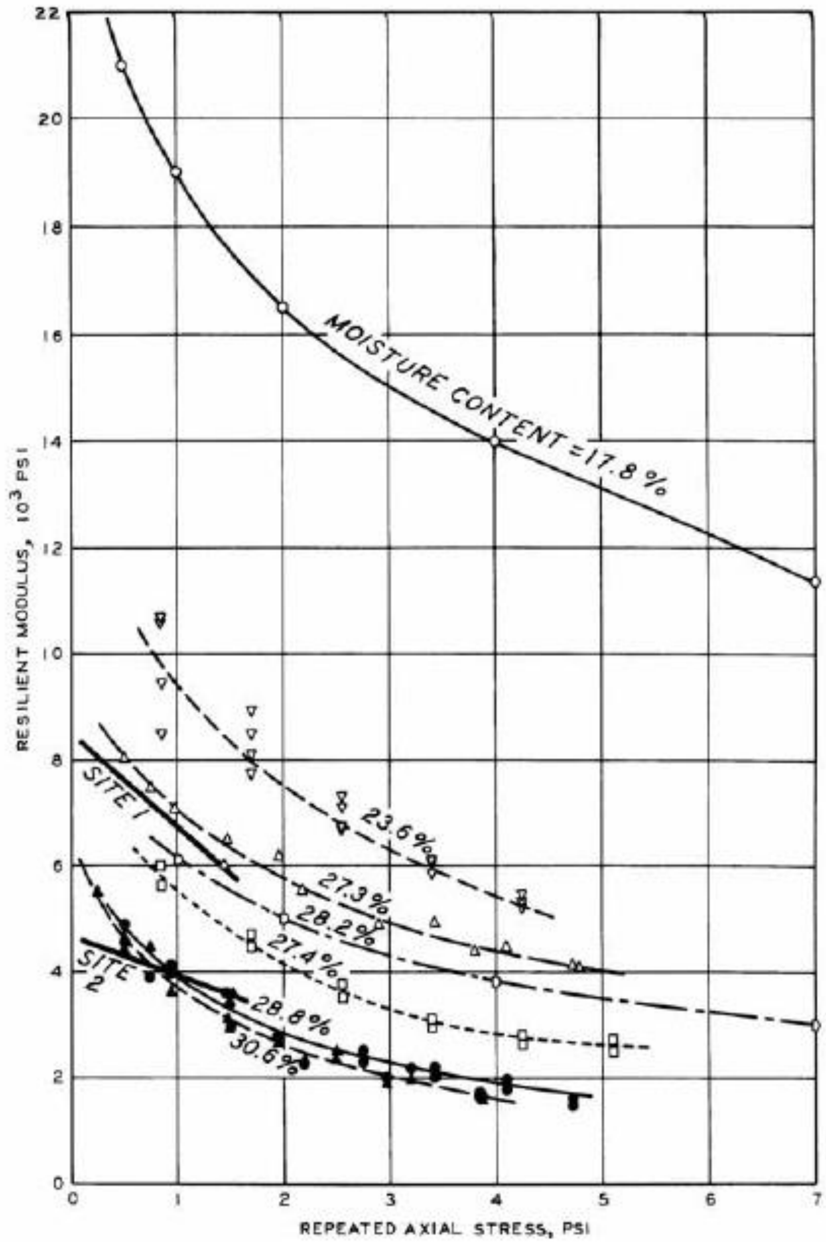


Figure 114: Influence of the moisture content on the resilient modulus of a silty clay subgrade.

12.3 Allowable subgrade strain

Results from accelerated pavement tests done at the Delft University on asphalt pavements placed on a sand subgrade allowed to develop a subgrade strain relation for the sand as used. The test results showed that the observed permanent deformation was entirely due to the deformation of the subgrade. The subgrade strain relationship was then developed by correlating the vertical compressive strain at the top of the sand subgrade to the number of load repetitions needed to obtain a rut depth of 18 mm. The following relationship was obtained.

$$\log N = -7.461 - 4.33 \log \varepsilon_v$$

Where:

ε_v = vertical compressive strain at the top of the subgrade [m/m],

N = number of load repetitions to a rut depth of 18 mm.

Similar relationships have been developed in South Africa and are shown below.

$$\log N = A - 10 \log \varepsilon v$$

Where:
N = allowable number of load repetitions to a specific rut depth,
A = constant depending on the allowable rut depth,
εv = vertical compressive strain at the top of the subgrade [μm / m].

Values for A are given in table 27.

Terminal rut depth [mm]	Reliability level [%]	A
10	95	33.30
10	90	33.38
10	80	33.47
10	50	33.70
20	95	36.30
20	90	36.38
20	80	36.47
20	50	36.70

Table 27: A values for the South African subgrade strain relationships.