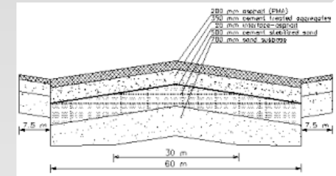
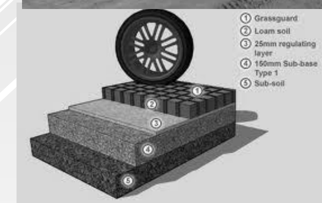
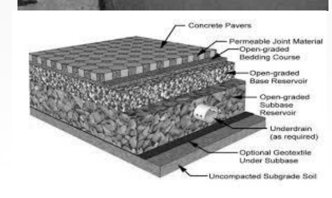
LECTURE 3:
Early design systems, the CBR method







Some knowledge on early design systems is necessary because

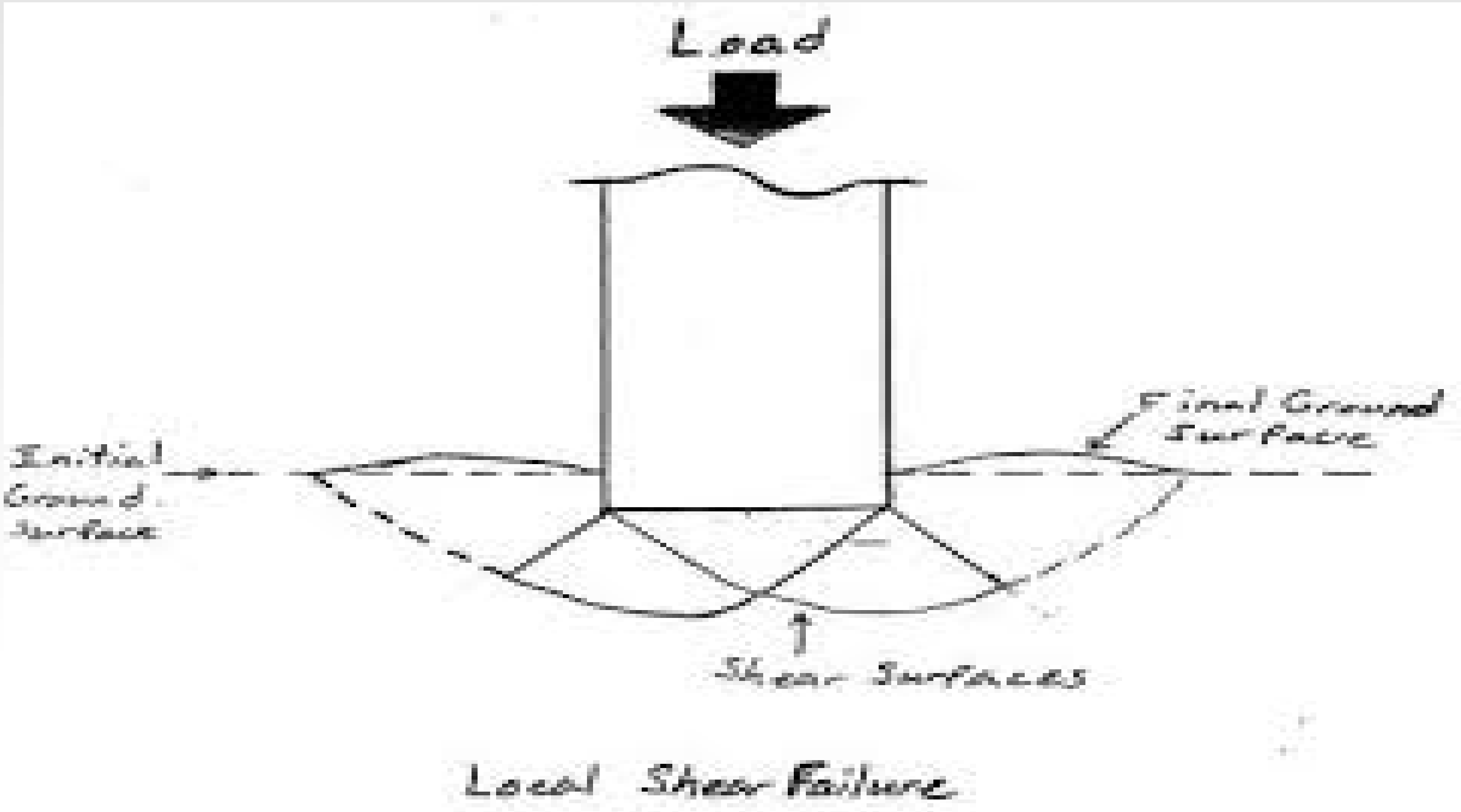
- they are still used in several parts of the world and
- because it gives an understanding on how and why design systems developed to the mechanistic empirical systems used nowadays.

An example of the problems one encountered in the early years of motorization. In those days most roads were earth or gravel roads and the strength of the pavement solely depended on the shear strength of the materials used.

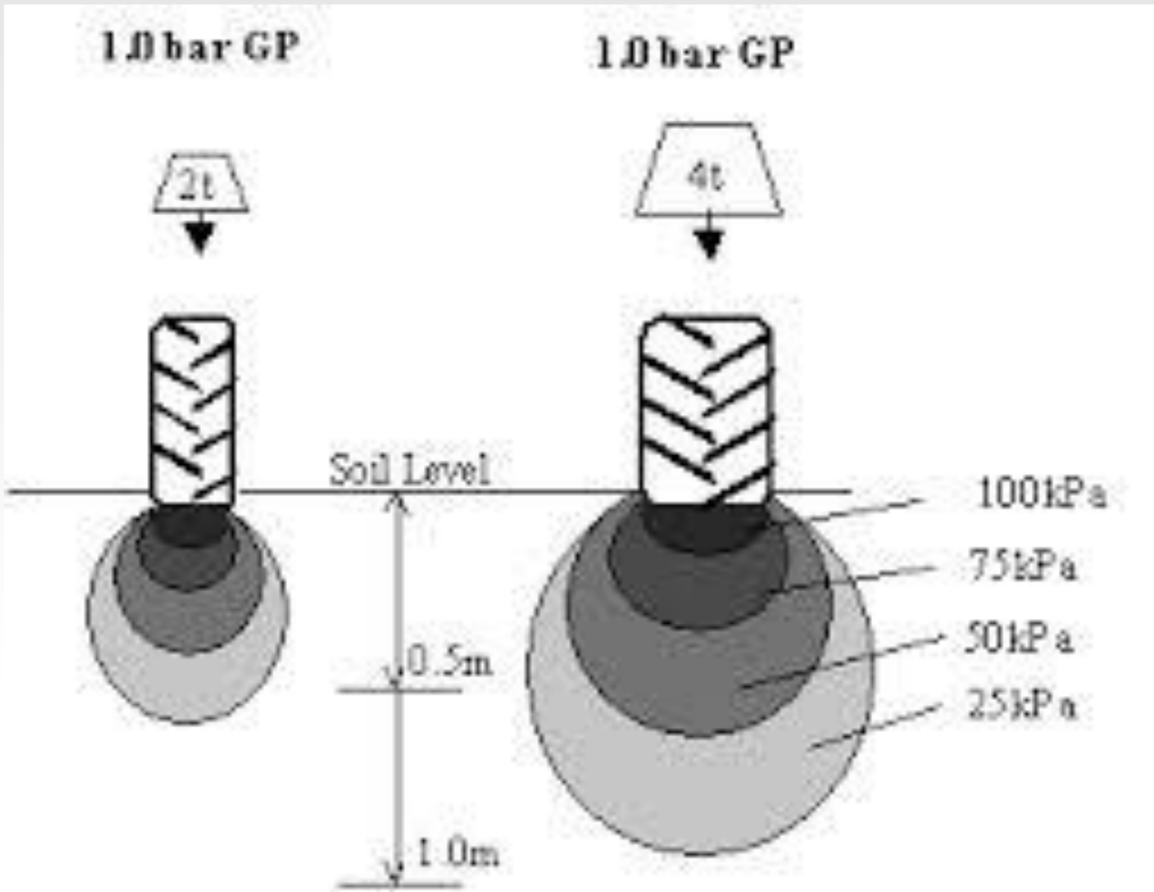
One has to realize that nowadays about 65% of the global road network still consists of earth and gravel roads. Problems as shown in figure before therefore still quite often occur as is shown in figures below.

Timber truck completely stuck on an earth road due to too high contact pressures and a too low shear resistance of the pavement material.

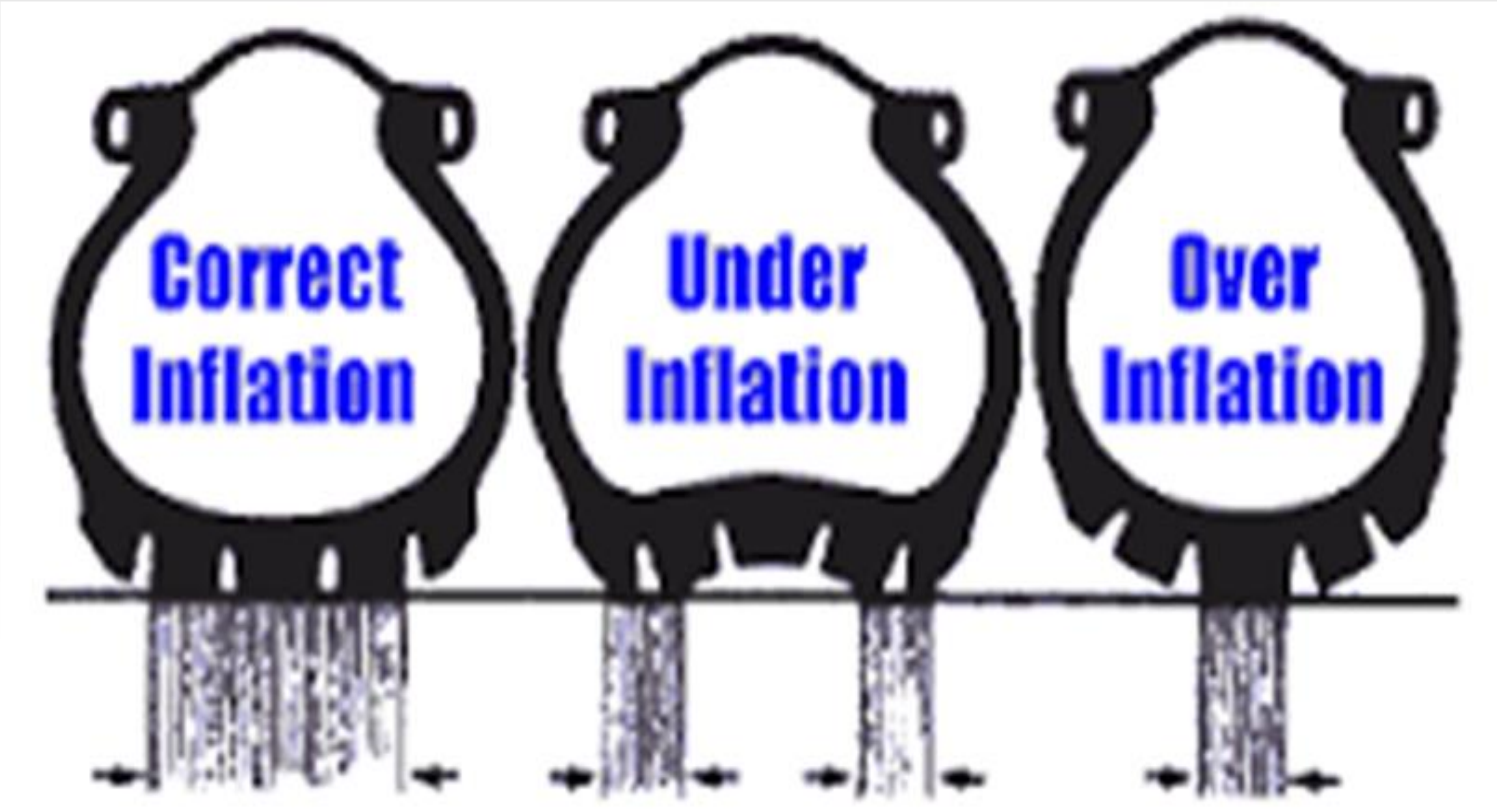
- In both cases it is clear that the stresses induced in the pavement are higher than the allowable ones resulting in shear failure of the pavement surface and resulting in the fact that in both cases the vehicle got "stuck in the mud"



- The question now is why a light vehicle suffered from the same problems as the heavy vehicle. This has to do with the fact that the contact pressures caused by the light vehicle are of the same order of magnitude as the contact pressures caused by the heavy vehicle



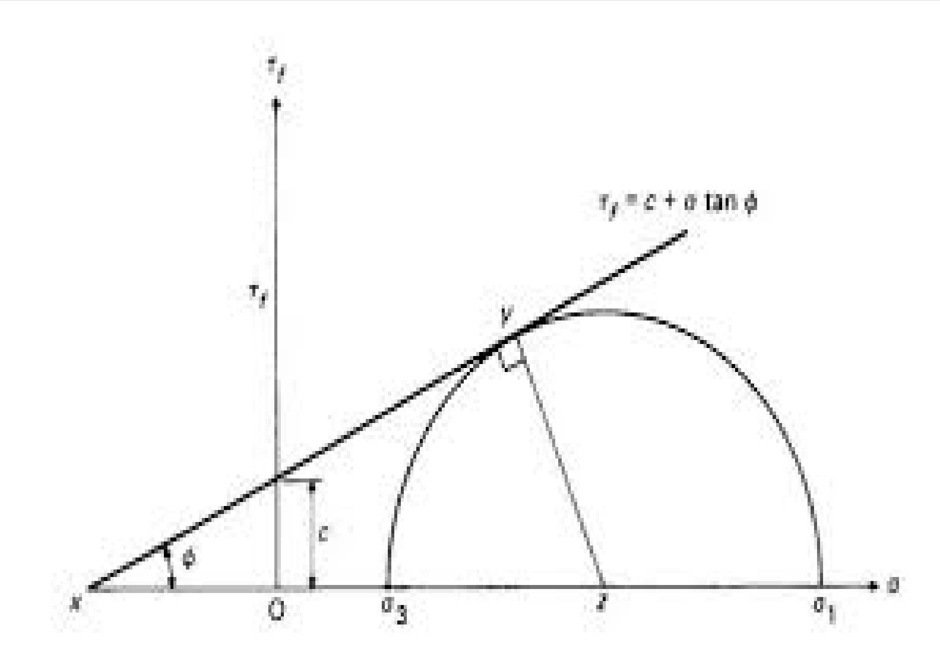
- The lesson we learn from this is that it is not really the weight of the vehicle that is of importance or the number of axles but the contact pressure distribution under the tires. This distribution not only depends on the wheel load but also on the area over which the wheel load is distributed. This depends to a very large extent on the **tire pressure**



- In the old days, solid tires were initially used and when pneumatic tires were introduced, high tire pressures had to be used because of the size of the tire. This resulted in small contact areas and high contact pressures (as comparison: the contact pressure under the tire of a race bicycle is high because these tires are inflated to 700 kPa pressure; the contact area is also small).

- All this means that the contact pressure due to the small vehicle could very well be the same as the contact pressure due to the heavy vehicle. Therefore similar types of surface defects can be expected.

- The other reason why both vehicles run into problems is the lack of bearing capacity of the pavement material. On both pictures we notice an excessive amount of water and from our lectures in soil mechanics we know that an excessive amount of water results in a low shear resistance especially in case of soils which contain a high amount of fine grained materials.



- We all know that the undrained shear strength of a saturated clay or silt is very low. In that case the cohesion is low and the angle of internal friction is about zero.

- From this example it is clear that precise knowledge on the pressures applied to the pavement and the strength of the materials used is essential in order to be able to design pavements that can sustain millions of load repetitions.

- The early design systems were, not surprisingly, based on determining the required thickness of good quality layers on top of the subgrade to prevent shear failure to occur in the subgrade. Of course the required thickness was dependent on the shear resistance of the subgrade and the amount of traffic.

- Furthermore the quality of the covering layers had to be such that shear failure didn't occur in these layers. This was the basis for the CBR thickness design method which is schematically shown below

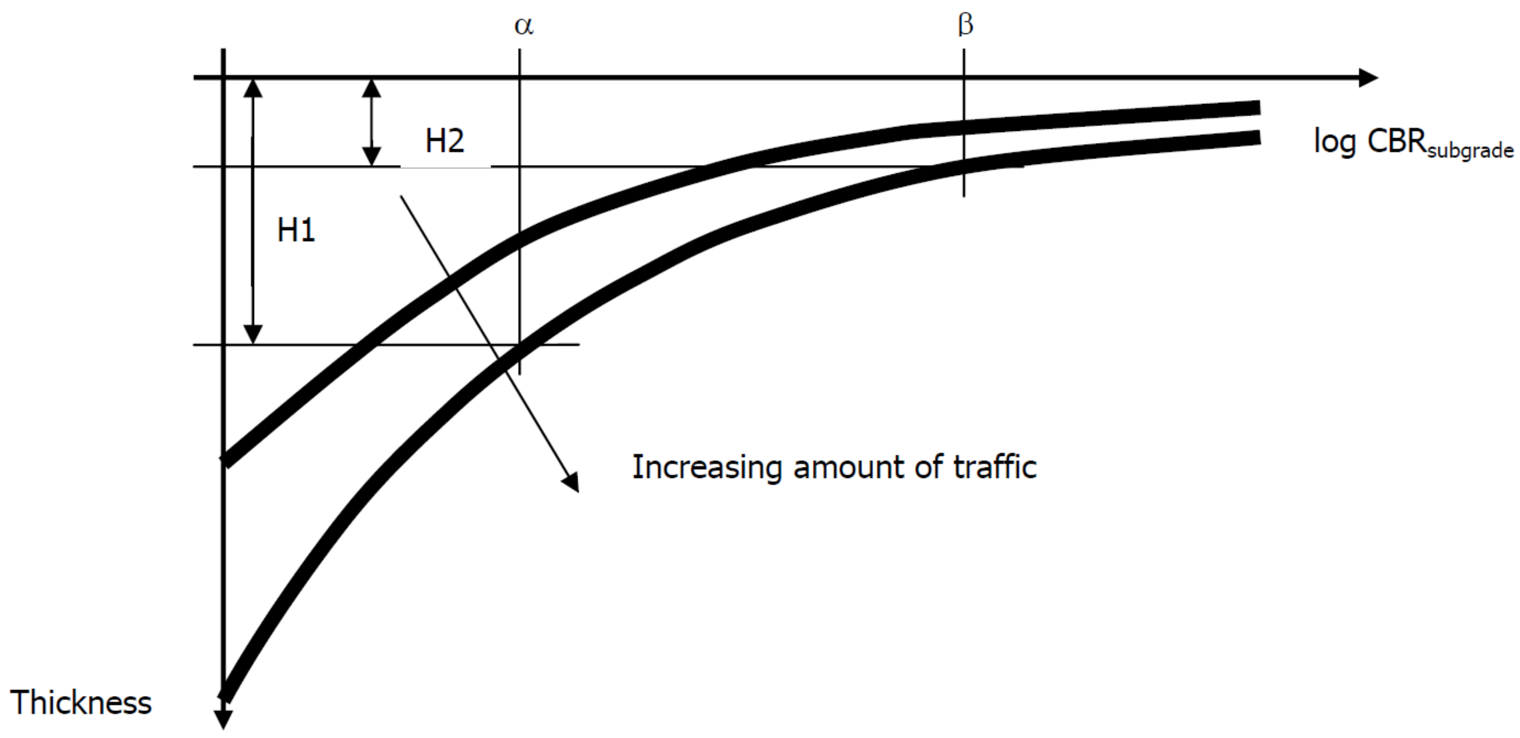


Figure 16: Principle of the CBR design charts.

- In the CBR design charts, the traffic load was characterized by means of a number of commercial vehicles per day and the shear resistance of the materials was characterized by means of their CBR value.

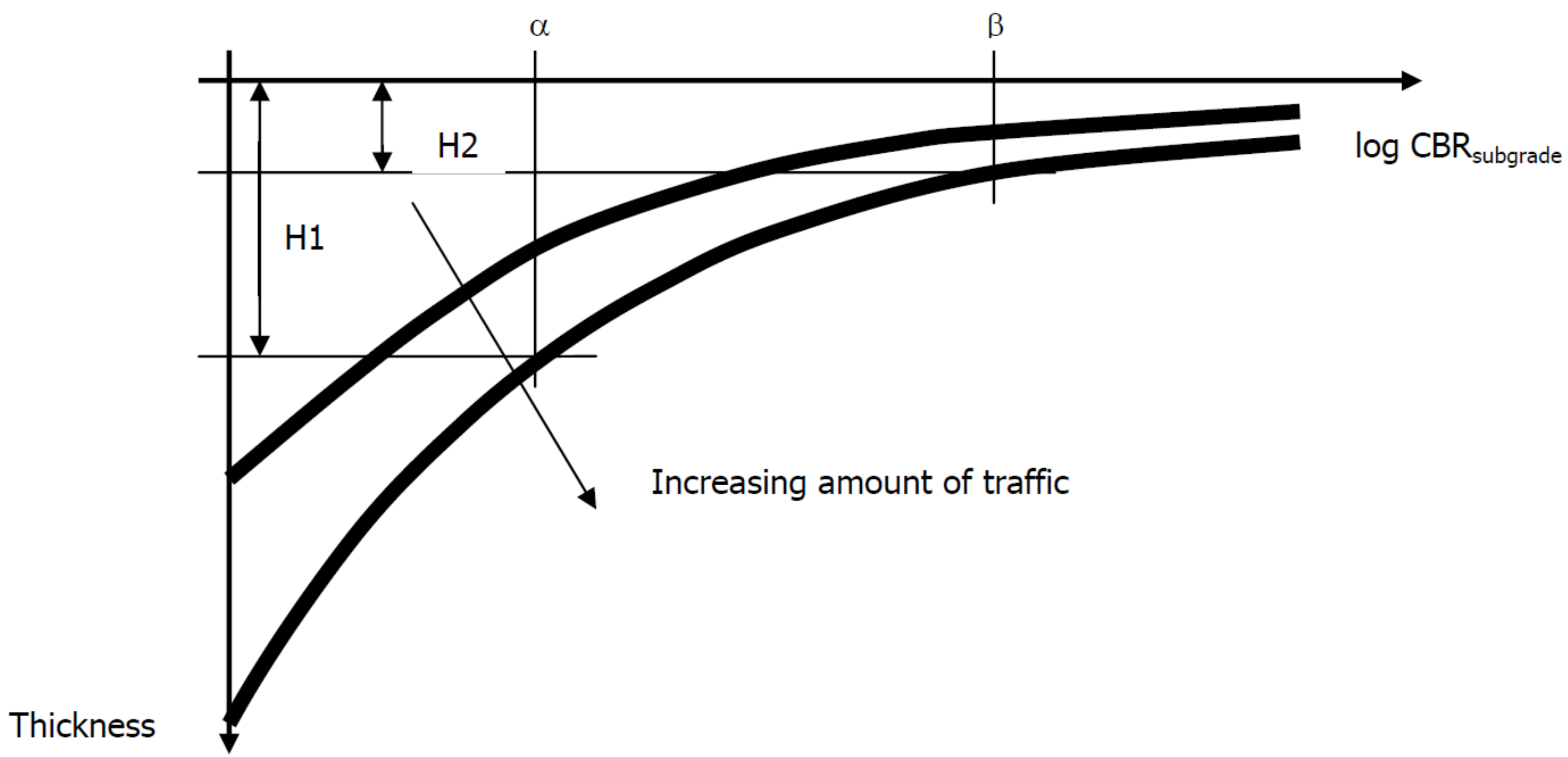


Figure 16: Principle of the CBR design charts.

- The charts were used in the following way:
  - First of all the number of commercial vehicles had to be determined. When this number was known, the appropriate curve had to be selected.
  - Next the CBR value of the subgrade needed to be determined and the required layer thickness on top of the subgrade could be estimated by means of figure 16; this will be illustrated by means of an example.

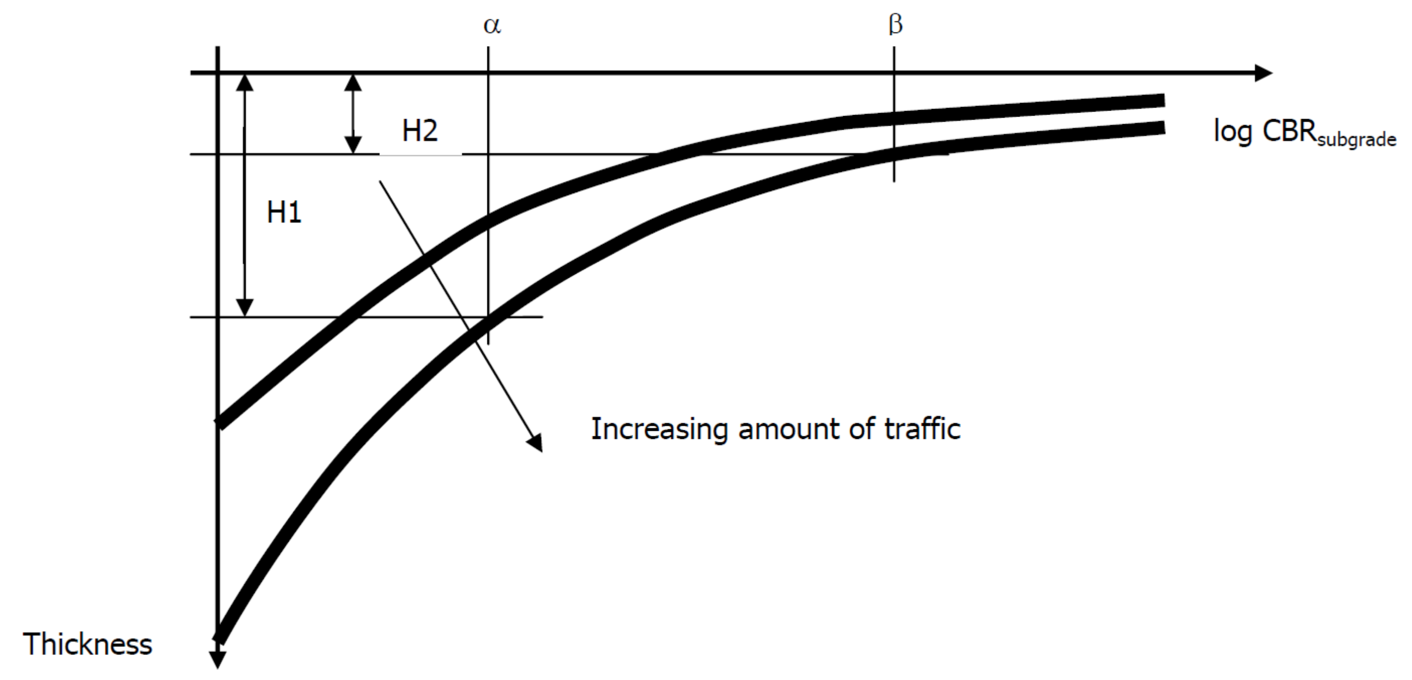


Figure 16: Principle of the CBR design charts.

If e.g. the subgrade CBR is equal to α %, then the total thickness on top of the subgrade of a better quality material should be H1. If the CBR of the base material (for reasons of simplicity no subbase is applied in this case) is equal to β, then the thickness of a better quality material (better than the base material) on top of the base should be H2. In most cases such a material would be asphalt concrete so H2 would be equal to the required asphalt thickness. The thickness of the base is then H1 – H2.

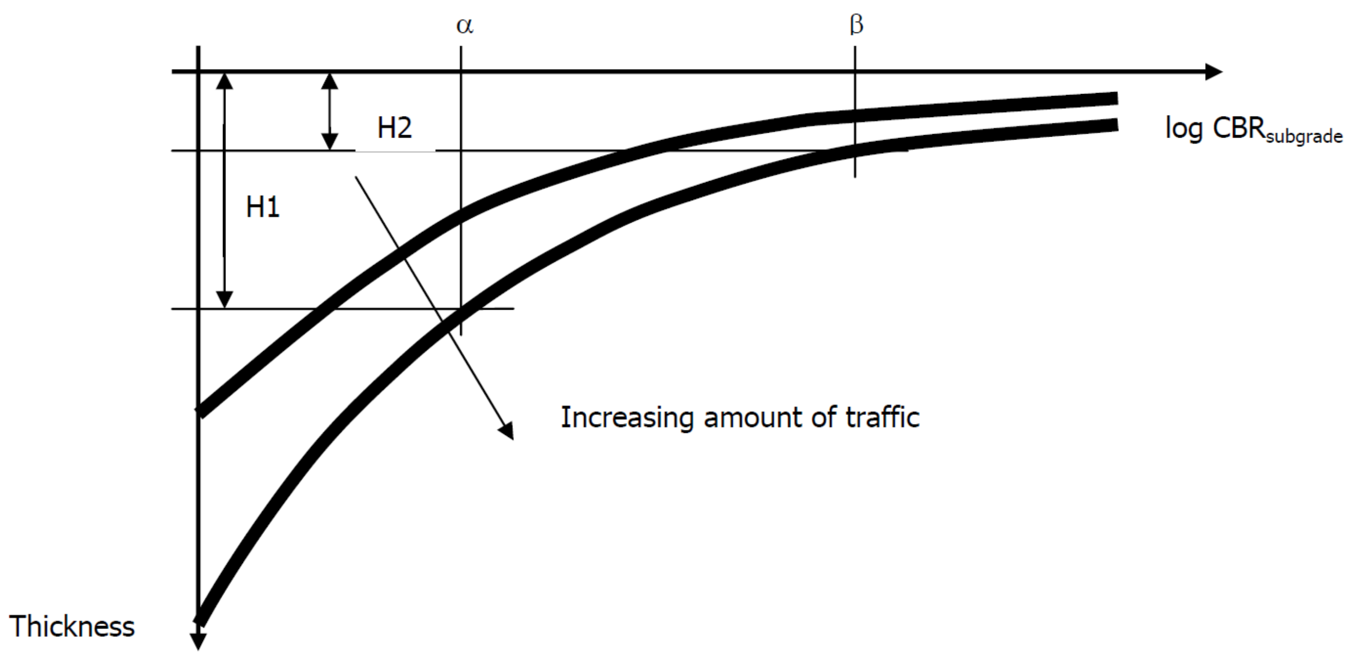
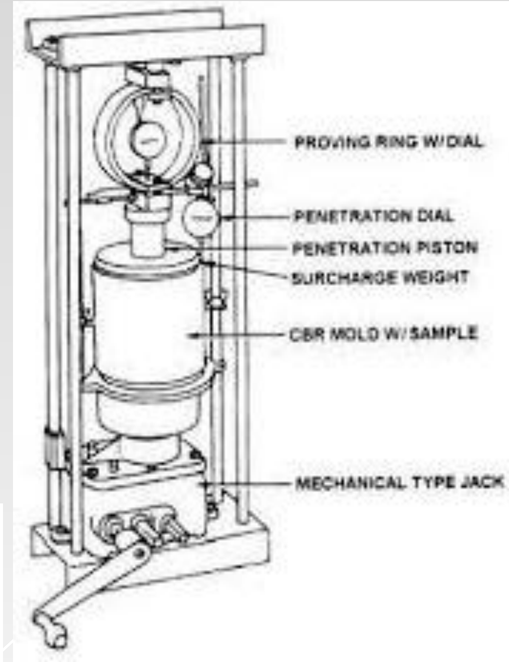


Figure 16: Principle of the CBR design charts.



- The minimum asphalt thickness to be applied was 50 mm.
- The CBR values of the unbound materials used in the pavement structure is determined by means of the CBR test which is schematically shown below.
- In the CBR test a plunger is pushed into the soil sample with a specific displacement rate and the load that is needed to obtain that displacement rate is monitored.
- The load – displacement curve that is obtained in this way is compared to the load – displacement curve of a reference material and the CBR is calculated as shown in a side.
- The CBR design method results in thin asphalt layers which are mainly needed to provide a **smooth driving surface** and sufficient skid resistance