PAVEMENT MATERIALS

Lecture 6

Sequence

- **SUBGRADE**

- Investigation
- Material Classification/Identification
- Material Evaluation
- Material Selection
- Construction of Subgrade
- QA/QC
- Post Construction Investigation

Subgrade Evaluation

- Strength
- Stiffness
  - Static
  - Dynamic
- Stability

Lecture 5

Stability ?

- ***Non-Load Induced Volume Change***
- **Expansion / Shrinkage**
- **Frost Susceptibility**

- **Moisture is culprit for reduction in Strength and Stiffness**
- **Moisture Change is responsible for Stability problems**

Stability Related Terminology

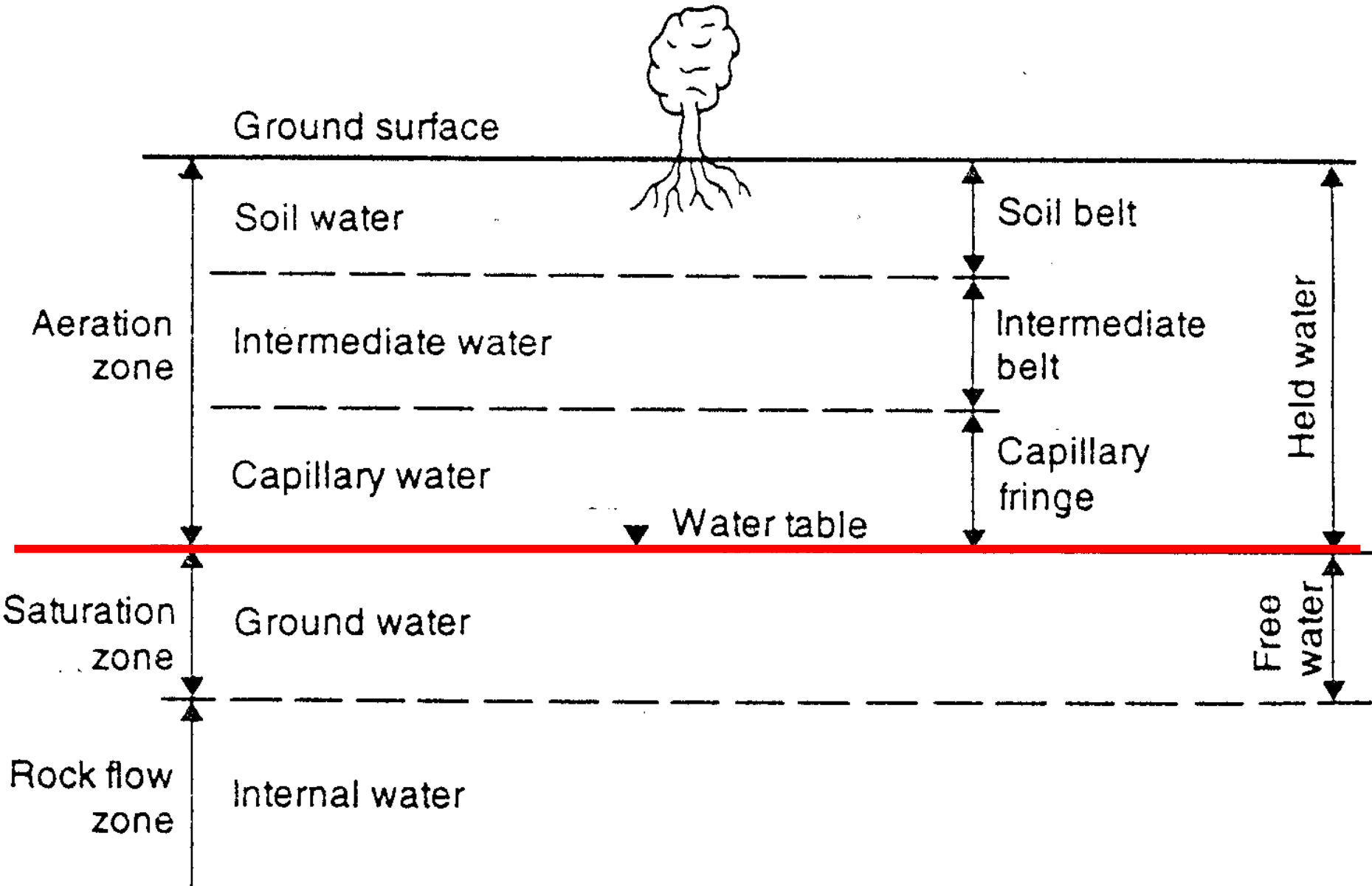
- Capillarity
- Soil Suction
- Equilibrium Moisture Content

Water in Soils

- Static Groundwater Table
- Zone fully saturated due to Capillarity
- Partial Saturation Zone
- Contact Moisture

} **Capillary Fringe**

Water in Soils



Capillarity

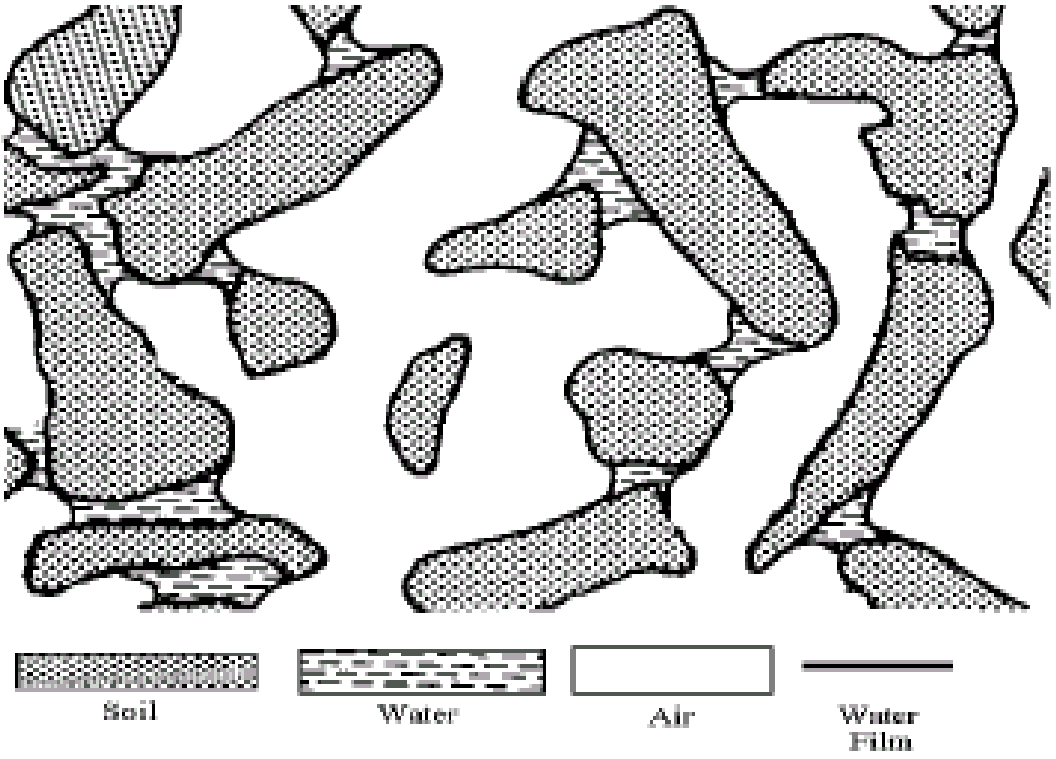
- Capillarity depends on
  - Diameter of Irregular Pore Spaces
  - Nature of Soil Grain Surfaces
  - History of Wetting of Soils
- Characteristics of Capillarity
  - Held by Soil Pores
  - Will not drain under Gravity
- Height of Capillarity Rise ?
  - Formulae
  - Estimate (Soil Type, Gradation)

Soil Suction

- **DEFINITION**
- The capacity of the Soil Mass to retain (or attract) water within its structure at a given water content is called Soil Suction.
- ***Range is 0 to 1,000,000 kPa, engineering range is 500 to 1500 kPa***
- Suction is related to

Soil Structure Properties

Water Properties



Equilibrium Water Content

- ***Competition of Water Intake***

- **Soil Suction**
- **Gravity**
- **Vegetation**
- **Overburden**

- Any change in the environment produces another unsteady system tending with time towards a new equilibrium.
- For example, paving over a clay soil alters the environment by reducing or eliminating ground surface evaporation and if the soil is susceptible to volume changes: ***it will swell or shrink, depending on the weight of the paving and the original seasonal condition of the soil, until a new equilibrium is reached.***

Equilibrium Moisture Content

- **Measurement of Equilibrium Water Content?**

- **Soils under existing adjacent pavements which can be used as indicators for the planned construction . Subgrade soils under pavements at least 3 years old are considered to have reached equilibrium moisture conditions .**
- ***(Caution : Use care in making assumptions regarding similarity of soil types, drainage, and topography).***

- **Importance?**

Table 12.2 Road Research Laboratory results.

	w (%) 0.3 m under grass verge	CBR	Required thickness (mm)	w (%) 0.3 m under road centre	CBR	Required thickness (mm)
Summer	10.5	32	150	17.0	6	380
Winter	20.5	2	690	16.8	6	380

Expansion / Shrinkage

- **Factors**
  - Type of Soil
  - Initial Water Content
  - Water Level Fluctuations
- **Acceptable Values**

Table 10.7. IS Classification (IS : 1494) of Expansive Soils (Ref. 19)

Liquid Limit (%)	*Plasticity Index*	*Shrinkage Index*	**Free Swell (%)*	*Degree of Expansion*	*Degree of Severity*
20-35	<12	< 15	< 50	Low	Non-critical
35-50	12-23	15-30	50-100	Medium	Marginal
50-70	23-32	30-60	100-200	High	Critical
70-90	> 32	> 60	> 200	Very High	Severe

*The free swell (Ref. 18) is measured by pouring two 10 gm ovendry soil samples (passing IS 425 micron sieve) in two 100-ml graduated cylinders. One cylinder is then filled with kerosene oil and the other with distilled water. The equilibrium volumes in the two cylinders are read. The free swell index (%) is calculated as under :

$$\text{Free swell index } (\%) = \frac{V_1 - V_2}{V_2} \times 100$$

Expansion / Shrinkage

- Laboratory
  - CBR Test
  - Free swell Test
  - Oedometer
- Assessment (Classification, Mineralogy)
  - Use: General Stability, Heave etc.

Frost Susceptibility

- Another aspect of soil suction is shown when soils or other porous materials are subjected to freezing conditions.
- When ice and water are present in a soil the soil suction experienced in the unfrozen water becomes dependent on the temperature alone and independent of water content.

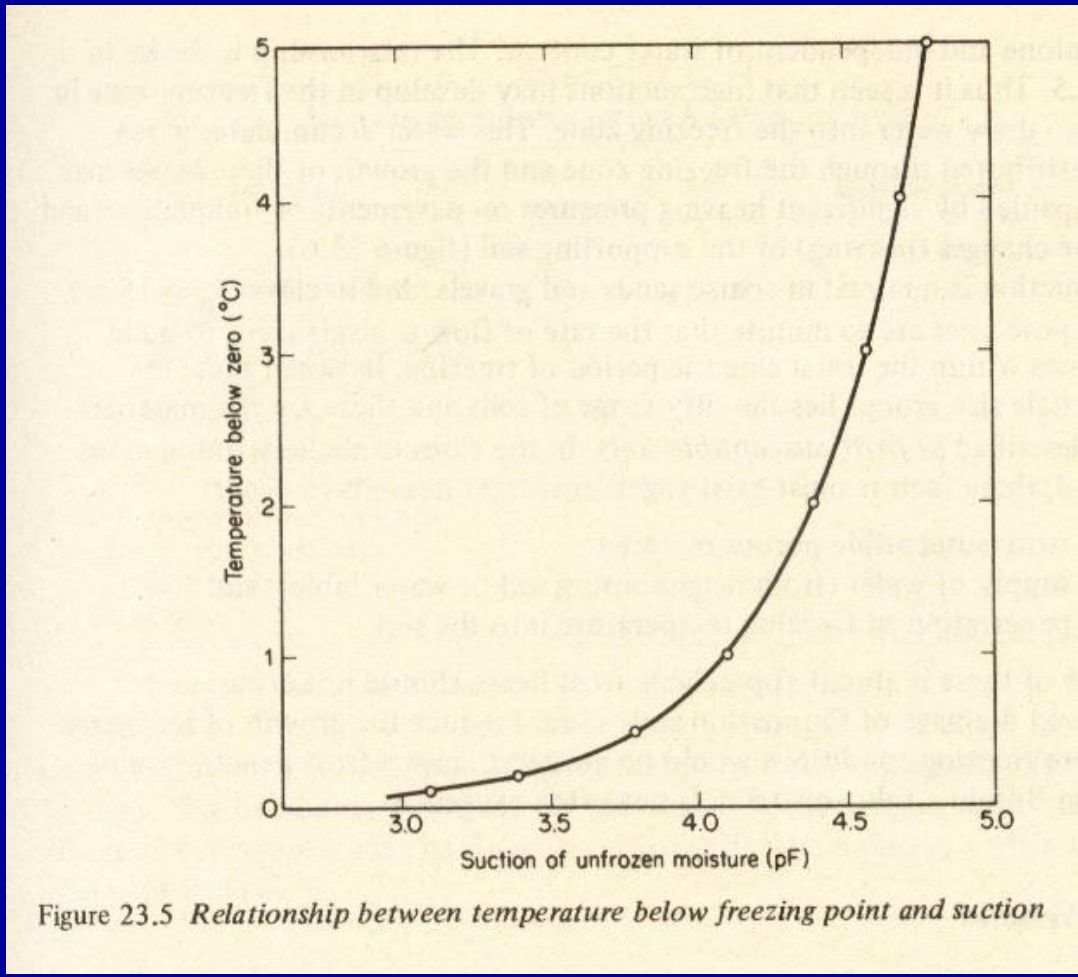
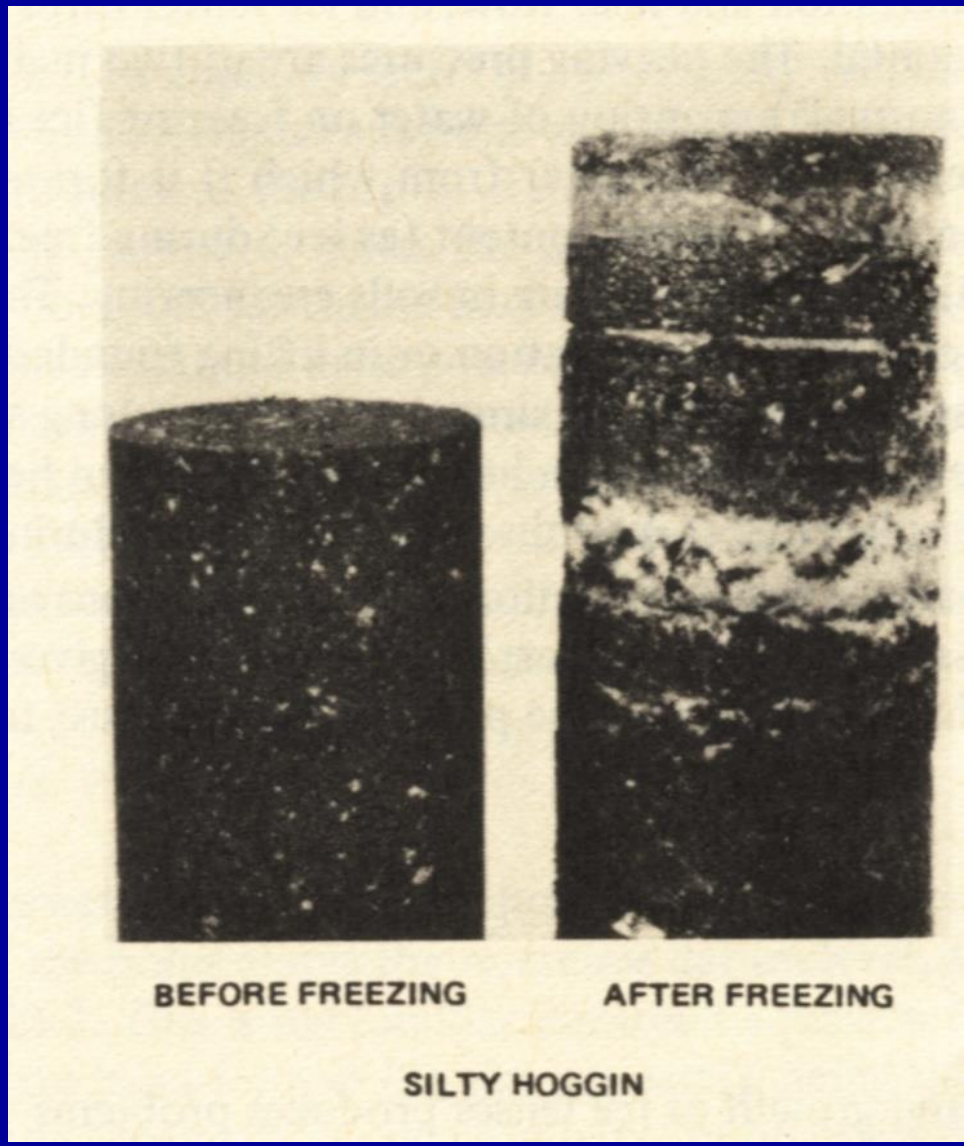


Figure 23.5 *Relationship between temperature below freezing point and suction*

Frost Susceptibility

- Thus it is seen that high suctions may develop in the freezing zone in soils and so draw water into the freezing zone. This water accumulates in ice lenses distributed through the freezing zone and the growth of these lenses may be accompanied by significant heaving pressures on pavements or foundations and by volume changes (heaving) of the supporting soil.
- Such suction is minimal in coarse sands and gravels, and in clays (Ip > 15 per cent) the pore sizes are so minute that the rate of flow is insufficient to build up ice lenses within the usual climatic period of freezing.
- *Between these extreme particle size groups lies the **silty range of soils** and these are the materials broadly described as frost-susceptible soils.*



Frost Susceptibility

- In the cases of shallow foundations, three factors must exist together if frost heave is to occur
- **(1) frost-susceptible porous material**
- **(2) supply of water (from neighboring soil or water table)**
- **(3) penetration of freezing temperature into the soil**
- If any one of these is absent appreciable frost heave should not occur.
- Improved drainage of foundation soils should reduce the growth of ice lenses.
- Very severe freezing conditions would be needed to give a frost penetration of **1m and usually a value of 0.5 m is not often exceeded.**

Heaving Pressures

- The heaving pressures are of two main types: those associated with the 'normal' expansion of water on freezing (ice having a volume about 9 per cent greater than the water from which it is formed), and those associated with the increase of water content (as ice) during freezing.
- Only the latter is regarded as the 'heaving' pressure in soils engineering.
- These maximum heaving pressures can be considerable and substantial heaving displacements may therefore take place during a prolonged cold spell.

Heaving Pressure

Heaving pressures exerted by freezing soils

Soil type	Heaving pressure p_i for $u = 0$ (kN m^{-2})
Coarse sands or coarser material only	0
Medium and fine sands or coarse silty sands	0 – 7.5
Medium silts or mixed soils with small amounts < 0.006 mm	7.5 – 15
Largely fine silts or silts with some clays	15 – 50
Silty clays	50 – 200
Clays	> 200

From Williams (1967)

Frost Susceptibility

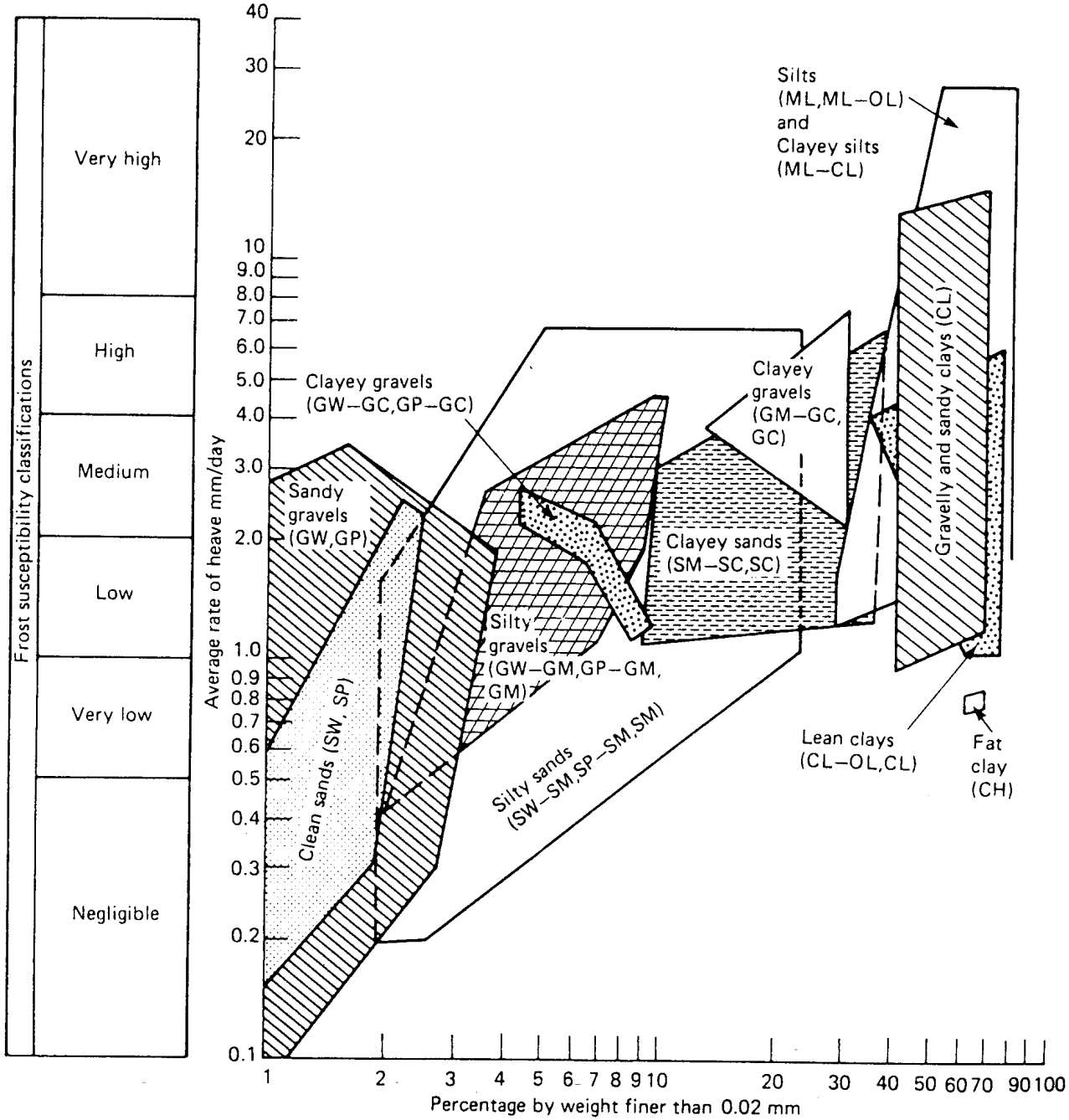
- **Thawing**
- **The intake of water and growth of ice lenses produces problems when the soil thaws.**
- **A Silty clay soil is broken up by the ice lenses to form a flaky structure and immediately after the thawing of the ice lenses the soil has a very high void ratio and water content and its strength is substantially reduced-**
- **Thawing will usually from the top downwards so the water is initially prevented from drainage.**
- **Till the drainage is allowed, the damage could be done by traffic.**

Frost Susceptibility

- **Assessment ??**

- **0.02mm sized particles are very critical**
  - **<1% (No Heave)**
  - **>3% (Considerable Heaving)**

Assessment


Frost susceptibility classifications
Very high
High
Medium
Low
Very low
Negligible
Average rate of heave mm/day
40
30
20
10
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
Silts (ML,ML–OL) and Clayey silts (ML–CL)
Clayey gravels (GW–GC,GP–GC)
Clayey gravels (GM–GC, GC)
Sandy gravels (GW,GP)
Clayey sands (SM–SC,SC)
Gravelly and sandy clays (CL)
Silty gravels (GW–GM,GP–GM, GM)
Clean sands (SW, SP)
Silty sands (SW–SM,SP–SM,SM)
Lean clays (CL–OL,CL)
Fat clay (CH)
1 2 3 4 5 6 7 8 9 10 20 30 40 50 60 70 90 100
Percentage by weight finer than 0.02 mm

Frost Susceptibility

- **Prevention**
  - Depth of Penetration
  - Remove and Replace the problem Soil
  - Addition of Chemicals (cohesive soils)
  - Addition of Cement, Bitumen (non-cohesive soils)
  - ***Drain the water from that layer***

Subgrade Selection

- **Selection Criteria**
- **Specifications**
  - Strength ?
  - Stiffness ?
  - Stability ?

- ***If not then what is the solution ?***
- ***Improve it !***
- ***How ?***
- ***Construction is one of the Solution !!***

THANK YOU