Soil Rebound

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When a remoulded soil is laterally confined in a consolidometer, and the consolidation test data are plotted in ***e*** vs. $\log \overline{\sigma}$, the straight line portion of the virgin compression curve can be expressed by the following empirical relationship given by Terzaghi (1943),

$$e = e_0 - C_c \log \frac{\overline{\sigma}_0 + \Delta\overline{\sigma}_0}{\overline{\sigma}_0} \qquad \ldots \qquad \ldots \qquad (1.17)$$

where e_0 = initial void ratio corresponding to initial pressure $\overline{\sigma}_0$

e = void ratio at increased pressure $\left(\overline{\sigma}_0 + \Delta\overline{\sigma}_0\right)$.

The expansion curve is also a fairly straight line on the semi-log plot and is expressed by

$$e_0 = e + C_s \log \frac{\overline{\sigma}_0 + \Delta\overline{\sigma}_0}{\overline{\sigma}_0} \qquad \ldots \qquad \ldots \qquad (1.18)$$

where C_s = expansion or swelling index. It is a measure of the volume increase due to the removal of pressure [Terzaghi, 1943]. The phenomenon of swelling or rebound is explained below.

After full consolidation has occurred, if the vertical load is released, the soil sample will rebound, which will also depend upon time. The soil compression and rebound curve will be as shown in Fig. 1.21. It is evident from this figure that the deformation in soil during consolidation is not completely recoverable. Only a part of it is recoverable. This is due to the fact that during consolidation there is structural rearrangement of soil particles when reduction in void space occurs. Upon release of load the rearranged soil particles do not spring back to their initial arrangement.

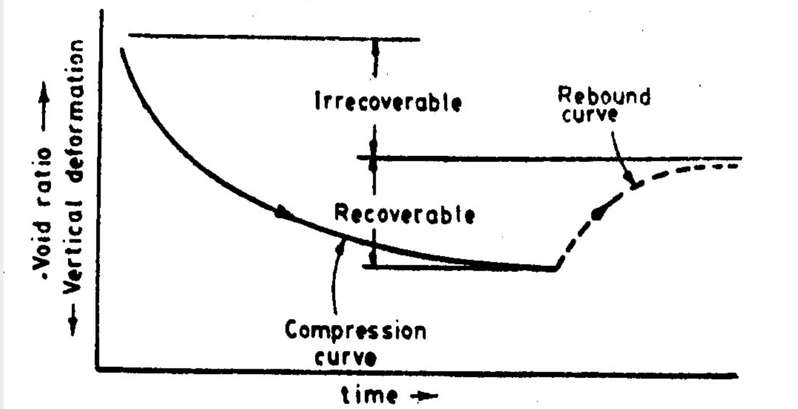

Figure 1.21: Compression and rebound curves

Let the consolidation test be carried out in the following manner:

1. first the sample is successively loaded.
2. at some stress level it is partially unloaded,
3. after rebound the sample is reloaded.

The $e - \log \overline{\sigma}$ curve plotted for the experiment carried out in this manner will be as shown in Fig. 1.22. The behaviour during unloading of the soil sample represented by portion *BC* of the curve can be used to define the swelling characteristics of the soil. The slope of this line defines the swelling index.

Swelling index, $$C_s = \frac{e_i - e_f}{\log \overline{\sigma_i} - \log \overline{\sigma_f}} \quad \ldots \quad (1.19)$$

e_i, e_f, $\overline{\sigma_i}$ and $\overline{\sigma_f}$ are explained in Fig. 1.22.

Some of the important points about C_s are:

1. Numerically C_s is much smaller than C_c ($C_s \ll C_c$) as is evident in Fig. 1.22.
2. C_s is more or less same for all stages of unloading [Fig. 1.20]. It means that we can evaluate C_s at any stress level in consolidation test. However, it must be done when the stress level has reached the straight-line portion of $e - \log \overline{\sigma}$ curve.
3. The slope of the recompression curve (*CD* in Fig. 1.22) is nearly same as C_s. That is, on reloading the change in void ratio of soil is very small till the stress level reaches the previous maximum level before unloading.

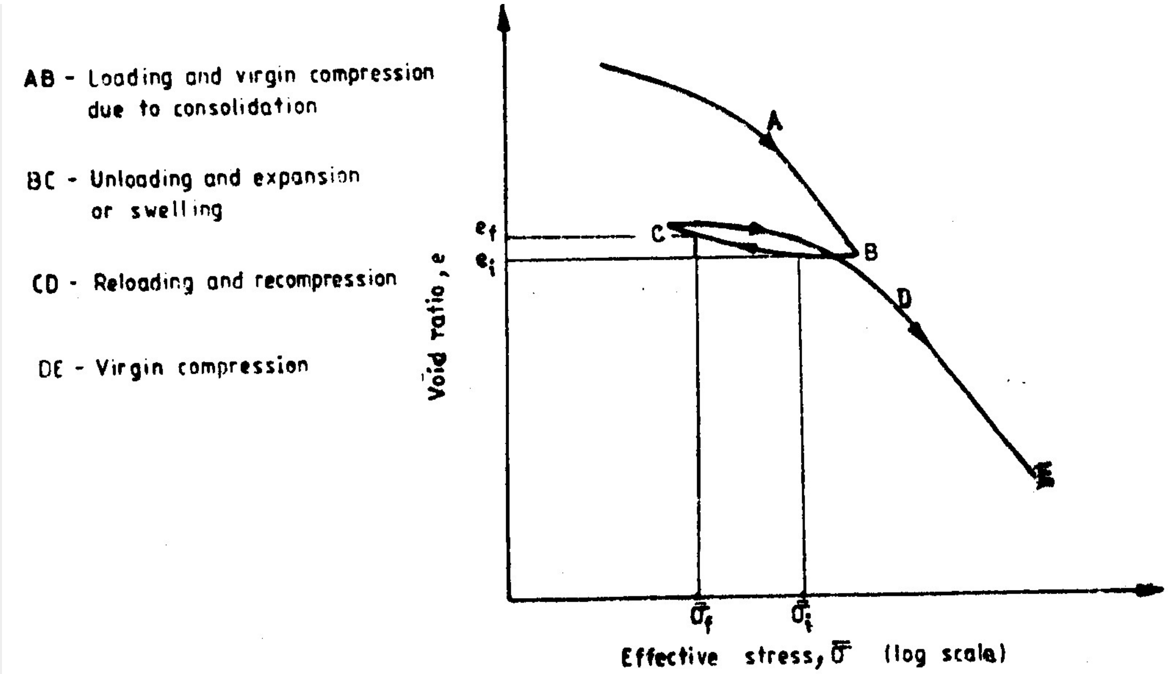

Figure 1.22: $e - \log \overline{\sigma}$ curve for loading – unloading – reloading cycle.

4. C_s increases with increasing liquid limit. Variation of C_s with liquid limit is shown in Fig. 1.23.

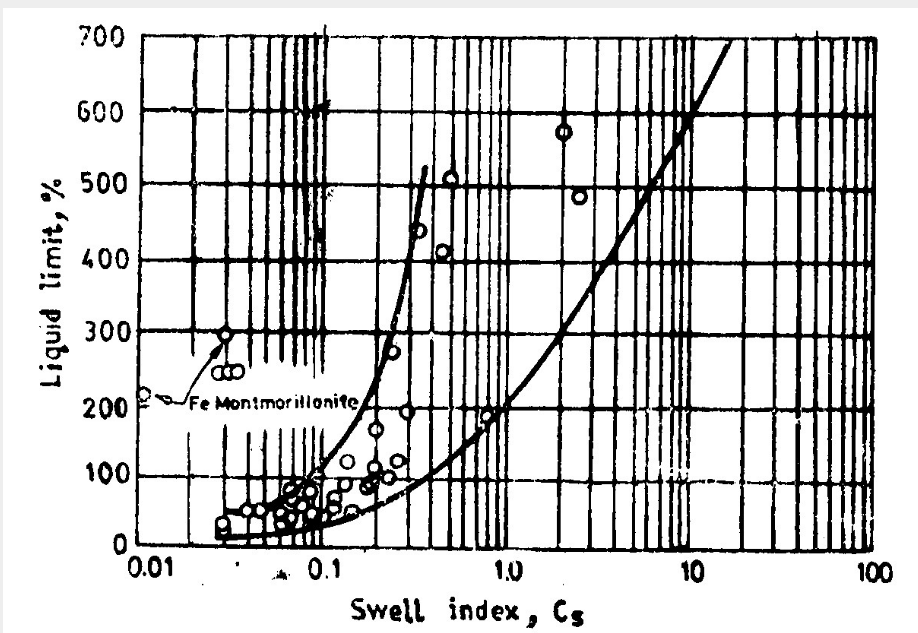

Figure 1.23: Variation of swelling index with liquid limit (after Lambe and Whitman, 1979)

The added effective pressure increment $\Delta\bar{\sigma}_0$ may be produced by a structural building or by reducing water pressures by pumping. Consequently, land subsidence takes place when the effective stresses are increased due to pumping or other causes. In the case of land subsidence due to pumping, the reduction in water pressure and, consequently, the increase in $\Delta\bar{\sigma}$ is continuous over time, whereas in structural loading, $\Delta\bar{\sigma}$ has one value (the stress due to structure).

2.1.3.4 *REBOUND*

The equations for calculating subsidence can also be used for calculating rebound if P_i decreases, due, for instance, to rising water tables or piezometric levels. In that case, the values of E, C_c, or C_u must be evaluated from the appropriate rebound portions of e-vs.-P_i relationships (as shown, for example, in Figure 2.3) (Figure 2.3 is not included in this White Paper). For the sand curves in Figure 2.3, E for rebound was 2 to 10 times E for compression, depending on P_i . For the Boston blue clay, E for rebound was about 50 percent of E for compression at low values of P_i , but 3 times E for compression at P_i = 2 kg/cm^2. Gambolati et al. (1974) found that E of the silt and clay layers below Venice, Italy, was 7 to 10 times larger for rebound than for compression. For the Boston blue clay (Figure 2.4), C_c was 0.08 for rebound and 0.40 for compression [Taylor, 1958].

The relation between compression and rebound parameters for granular materials may also be influenced by the time that the material has been under compression. Whereas complete rebound has been observed after short-term (5 to 30 min.) pumping of wells [Davis et al., 1969], rebound of the land surface after prolonged subsidence may be only a fraction of the original subsidence [Gambolati et al., 1974; Mayuga and Allen, 1969].