Box 3.14 *Calculation of mass density and water absorption during testing*

Masses of the test specimen, M_T, are determined by weighing, which is generally carried out at two extreme values of water content or degree of saturation, S_r:

- S_r = 0 or oven-dried state, OD; in that case $M_{T(Sr=0)} = M_M$ where M_M is the mineral mass (see Figure 3.8)
- S_r = 100 per cent or saturated surface dry state, SSD; in that case $M_{T(Sr=1)} = M_M + \rho_w \times V_p$, where V_p is the pore volume (see Figure 3.8).

The volume is either indirectly determined by hydrostatic weighing, V_{TH}, or directly (geometrically) measured on cores or cubes, V_{TG}, before carrying out other tests such as the compressive strength test.

a. Direct measure of the volume of the test specimen: If the volume is geometrically determined and its value is V_{TG}, then the apparent mass density is defined as:

$$\rho_{app(Sr=0)} = M_{T(Sr=0)}/V_{TG} \quad (3.51)$$

$$\rho_{app(Sr=1)} = M_{T(Sr=1)}/V_{TG} \quad (3.52)$$

b. Non-direct measure of the volume of the test specimen, V_{TH}: Hydrostatic weighing is a useful method for test specimens or aggregates with irregular shape. Equation 3.53 gives the relationship, based on:

- V_H is the volume of water displaced by the specimen; $V_H = V_M$
- M_H is the hydrostatic mass of the specimen determined by weighing while suspended in water

$$V_{TH} = [M_{T(Sr=1)} - M_{T(Sr=0)}]/\rho_w + V_H \quad (3.53)$$

Apparent mass densities are determined as follows:

$$\rho_{app(Sr=0)} = M_{T(Sr=0)}/V_{TG} \cong M_{T(Sr=0)}/V_{TH} \cong \rho_w \times M_{T(Sr=0)}/[M_{T(Sr=0)} - M_H] \quad (3.54)$$

$$\rho_{app(Sr=1)} = M_{T(Sr=1)}/V_{TG} \cong M_{T(Sr=1)}/V_{TH} \cong \rho_w \times M_{T(Sr=1)}/[M_{T(Sr=0)} - M_H] \quad (3.55)$$

In natural conditions on site, the actual apparent mass density of the rock depends on its actual water content as implied by the symbol $\rho_{app}(S_r)$. The designer should make the appropriate substitution of S_r in Equation 3.56 (see Section 3.3.3.3, and Table 3.17):

$$\rho_{app}(S_r) = \rho_{app(Sr=0)} \times (1\text{-}S_r) + \rho_{app(Sr=1)} \times S_r \quad (3.56)$$

The water absorption and porosity are given by:

$$WA = [M_{T(Sr=1)} - M_{T(Sr=0)}]/M_{T(Sr=0)} \quad (3.57)$$

$$p = [M_{T(Sr=1)} - M_{T(Sr=0)}]/[\rho_w \times V_{TG}] \quad \text{for geometric measurement of the volume} \quad (3.58)$$

$$p = [M_{T(Sr=1)} - M_{T(Sr=0)}]/[M_{T(Sr=1)} - M_H] \quad \text{for hydrostatic measurement of the volume} \quad (3.59)$$

3.8.3 Testing properties of individual pieces of armourstone

3.8.3.1 *Shape*

For shape specification compliance, factory production control in EN 13383 uses the test: determination of the percentage of pieces of armourstone with a length-to-thickness ratio *LT* greater than 3. The method to determine *l* and *d* uses two straight laths positioned parallel to each other at right-angles to the longest dimension *l* and then to the smallest dimension *d*. *l* and *d* are measured using a carpenter's rule, a tape measure or, to achieve greater accuracy, callipers (see Figure 3.82).

Shape indicators including length-to-thickness ratio, *LT*, cubicity, *(L+G)/2E*, and blockiness, *BLc*, are discussed in Section 3.8.4.

3.8.3.2 *Mass and size*

The mass of individual armourstone pieces is rarely determined alone but rather to determine:

- the mass distribution by combination of individual masses
- the input and output data for armourstone integrity tests that use destructive testing
- the blockiness index of armourstone pieces (relevant for individually placed armour layers).