

properties, the type of placements assigned to granular materials in the works, are classified as:

- random placement
- standard placement
- dense placement
- specific placement.

These terms are described in detail in Section 9.8.1. All bulk-placed materials are designated random placement, whereas any type may be appropriate for stones placed individually into armour layers. In principle, for armour layers, there are two distinct calculations adopted to obtain bulk volumes (ie rock volume, V_r (m³), plus void volume) in a panel. $V_{b,d}$ (m³) is the design bulk volume assumed before construction and $V_{b,s}$ (m³) the surveyed bulk volume after construction. V_b (m³) is the bulk volume referring to either method. By following guidance in Boxes 3.7 and 3.8 their differences should be minimised. The Equations 3.23–3.28 (see also Figure 3.25) define the geometry and related properties of armour layers.

$$\text{Designed bulk volume (m}^3\text{):} \quad V_{b,d} = A t_d \quad (3.23)$$

$$\text{Surveyed bulk volume (m}^3\text{):} \quad V_{b,s} = A_{cs} L \quad (3.24)$$

$$\text{Theoretical orthogonal thickness (m):} \quad t_d = n k_t D_{n50} \quad (3.25)$$

$$\text{Volume of rock (m}^3\text{):} \quad V_r = V_b (1-n_v) \quad (3.26)$$

$$\text{Total number of stones in panel (-):} \quad N_a = n A k_t (1-n_v)/D_{n50}^2 \quad (3.27)$$

$$\text{Bulk (or placed packing) density (t/m}^3\text{):} \quad \rho_b = (1-n_v) \rho_{app} \quad (3.28)$$

where:

A	=	total surface area (m ²) of the armour layer panel parallel to the local slope
A_{cs}	=	cross-sectional area (m ²)
L	=	panel chainage length (m)
n	=	number of layers (-)
n_v	=	(volumetric) layer porosity (-)
k_t	=	layer thickness coefficient (-)
ρ_{app}	=	apparent density of the armourstone (t/m ³) (see Section 3.3.3).

NOTE: The volume of rock, V_r , should not be confused with the volume of armourstone, which is V_b . The only practical possible use of V_r is as an input to determine the mass of rock, $M_r = \rho_{app} \times V_r$, which is also the total mass of armourstone.

The placed packing density or **bulk density**, ρ_b (t/m³), can be predicted from Equation 3.28 or, if the mass of armour placed into a panel is known, it may be determined directly from the surveyed bulk volume. When dealing with wider gradings, a better prediction for the number of blocks, N_a (-), will result if D_{n50} in Equation 3.27 is replaced by the nominal size calculated from the average mass, M_{em} .