- the number of blocks placed in the armour layer per unit of slope area covered. This should be presented both for the visible upper layer of blocks and for the total number of blocks.

Equation 9.9 gives the relation between the armour layer porosity (expressed as a fraction) of the visually accepted test panel and the relevant armour layer volumes.

$$n_{vp} = \left(1 - V_r / V_{bs}\right) \tag{9.9}$$

If there is less than a 2 per cent difference in value between n_{vp} and n_v assumed in the design (ideally also indicated in the contract), the panel is in every way acceptable as a construction benchmark to be followed for the contract.

If the difference is more than 2 per cent, another attempt might be made to construct nearer to the design armour layer porosity, without an unreasonably onerous burden being placed on the rate of build, given the classified placement method originally specified.

If after this rebuild the new surfaces surveyed fulfil tolerances and are visually accepted, but the test panel still has more than a 2 per cent difference, the contractor and engineer should agree that this panel becomes the benchmark for acceptable construction practices.

For those contracts where payment is based on a tonnage placed calculated from volume surveys, it is also an opportunity to validate and if necessary, revise the armour layer porosity assumption. If the contract states a pay rate for tonnage of armourstone placed in the works to be a tonnage calculated from surveyed bulk volume, assumed armour layer porosity and apparent rock density, then an appropriate basis for payment of the panel (see Equation 3.26, $V_r = V_b\ (1 - n_v)$) is given by Equation 9.10, an expression for the total mass of the armour, M_t.

$$M_t = \rho_{app} \cdot V_{bs}\left(1 - n_{vp}\right) \tag{9.10}$$

Placement workmanship at sample areas throughout the structure may be compared with the test panel(s) on visual criteria and also by comparing the number of blocks per unit area with results from the test panel(s). Major variations in block count results should be explained and removed by reworking if necessary. As the finished profiles of the entire works are normally checked for tolerances, the bulk-placed volumes of the entire armour layer in the completed structure can be similarly computed and bills for placed tonnages prepared accordingly. Precisely worded clauses usually exist to exclude liability for the client having to pay for armourstone determined by survey to be on average above an upper tolerance line.

Alternative simple schemes for payment based directly on tonnages placed exist. For example, contract payment for armour materials may be based on a rate per tonne delivered to site given satisfactory criteria for proof of delivery to site.

9.9 SURVEY AND MEASUREMENT TECHNIQUES

Because of the direct relationship between survey techniques and payments, all parties to a works contract should ensure that an accurate, fair and pragmatic approach to surveying is adopted that will lead to the correct method of payment for the work done. To suit the requirements of the works, tolerance levels should be practical, sensible, achievable and affordable. The various definitions of the term *tolerance* are set out in Section 9.3.7.

In addition to discussing the various survey techniques, this section also provides tables with information on achievable vertical tolerances for land-based and marine equipment, for both bulk and individually placed armourstone and concrete armour units.