3.6.4 Principles of degradation modelling

In simple terms, a degradation model is the application of mechanics consisting of:

- material **properties + loadings** (and boundary conditions) = deformation or damage **response**

or:

- evolution of material **properties** + history **of loadings applied** = history of damage **response**

or:

- average material **properties** + average **loading intensity** = average **rate of degradation**.

Degradation models use armourstone **properties** representative of the armourstone consignment at the point of leaving the quarry. This may be measured by a specific material property, such as armourstone integrity or abrasion resistance, or an overall quality index, such as *AQD*.

The model then predicts the **response** to future **loading intensity** of the rock armour with such properties. These may be short-term loads or long-term in-service loads. The model output gives the change in the performance parameter (such as M_{50}, or the complete mass distribution) for any number of handling events or storm/flood events or, alternatively, for the number of years in service including the design life of the structure.

The **loading intensity** or **project site aggressiveness** can be assessed in terms of:

- **attrition** loading intensity: a function of waterborne attrition agents, rocking, sliding and rolling loads (affected by stone size, wave energy, mobility in design, interlock due to shape and grading)
- **breakage** loading intensity: a function of rocking and rolling loads (affected by stone size, wave energy, mobility in design, interlock due to shape and grading)
- **physiochemical climatic** loading intensity: a function of zone on structure, meteorological climate, slope angle.

For static armour designs, mass loss is by both fast and imperceptibly slow or subcritical opening of cracks, spalling, rounding and by accelerated loss of interlock from wear. A comprehensively averaged model is currently considered most appropriate in such cases where wear is the dominant mechanism (see Section 3.6.5).

For a dynamic design, attrition and breakage loading intensity will be considerably higher than climatic loading intensity – a breakage model calibrated using armourstone integrity, mineral fabric strength and/or resistance to wear properties may be more useful.

Degradation models focusing specifically on wear mechanisms (Tomassicchio *et al*, 2003) and breakage mechanisms (Tørum and Krogh, 2000; Dupray *et al*, 2004) have also been proposed. Such models consider progressive mass reduction associated with repeated storm events where storm loading exceeds a threshold energy for start of damage, or where armour movement velocity is above a threshold value. Such models attempt to deal with mass loss by specific wear or breakage mechanisms that ignore climatic weathering intensity effects. The fewer the degradation mechanisms considered in a model, the more rigorous the model calibration approaches can be, but the less widely applicable is the model to long-term service life prediction.

Probabilistic methods have been proposed to assess accumulated structural damage (eroded profile area) due to probability of exceedance of the design condition (see Takahashi *et al*, 2003). Such design approaches also require an estimate of the reduction in M_{50} of the armourstone due to rock material degradation. The degradation model tools described here may be tentatively applied to estimate changes in M_{50} for such purposes.