



Appendices

A1 Model construction specification

NOTES:

- *Guidance on material specification is given in Chapter 3. Section 3.7 covers rock and Section 3.16 covers geotextiles.*
- *Model specifications are given as normal font text, whereas general guidance and information is given as italic font text; references to sections of this manual are therefore given as “The Rock Manual” in model specification text, and as “Section X of this manual” or alternatively as “Section X” only in accompanying guidance text.*

A1.1 ACCESS TO THE WORKS

If the Client or Designer has special or necessary requirements these should be stated here. These requirements might cover issues such as:

- *restraints on access routes*
- *working areas*
- *fencing/security of the site and public safety requirements*
- *modes of delivery (eg road vs rail vs sea)*
- *times and/or rates of delivery*
- *hours of working and delivery*
- *pre- and post-construction surveys of properties or infrastructure outside the site that may be affected by the works*
- *noise and vibration and associated surveys.*

For example, it is often the case that local residents, or indeed the local authorities, may not wish for 24 hour unloading of barges or night time working and this will have a considerable effect on cost. It is therefore important that these issues and potential conflicts are identified before tender stage and resolved such that the tender documents and specification reflects this.

As identified in Section 9.5 of this manual, working in the marine environment is risk-prone. The specification and associated works information should therefore include as much as is known about winds, waves, currents and tidal water levels, along with any surveys of bathymetry, soil or geological conditions and conditions of existing structures within the site. A particular issue is beach and seabed level fluctuations as a result of wave and current action; a warning about this should be given together with any available historical information.

Specific bathymetric, tidal range and/or other environmental constraints need to be identified together with any requirements by local or national legislative bodies. These may include:

- *requirements to maintain access for other users to certain land or water areas at specific times*
- *specific health and safety requirements.*

A1.2 TRANSPORTATION AND STOCKPILING OF ARMOURSTONE

Armourstone shall be transported to the site of the permanent works along an approved route. The Contractor shall:

1. Obtain the approval of the Engineer¹ and the appropriate Authorities before using the public highway.
2. Avoid damage to public or private roads and shall repair any damage that does occur due to the transport of armourstone.
3. Trucks used to transport armourstone for this Project shall be of a type specifically constructed for hauling armourstone and shall have tail boards or scow-ends. If transporting heavy armourstone on flat top wagon, adequate chains and slings shall be used and verified before it leaves the quarry to ensure optimum security. No other mode of armourstone transportation may be employed unless first approved by the Engineer and the relevant Authorities.
4. If sea transportation is used, ensure all barges are seaworthy and have the necessary safety certificates and insurance issued by the relevant Authorities. Permission for safe mooring of sea transport vessels shall be obtained from the relevant Authorities. The Contractor (or supplier if armourstone delivery is sub-contracted to a supplier) shall have an emergency procedure in place should there be an imminent threat of sea and wind conditions beyond the safe mooring design conditions.
5. If river transportation is used, ensure that the barges and vessels have the necessary safety certificates and insurance issued by the relevant Authorities.

Subject to the approval of the Engineer, the Contractor may be permitted to stockpile armourstone at or near the site of the permanent works. Separate stockpiles shall be made and identified for different grades of armourstone. Stored materials shall not obstruct normal access to the beach by pedestrians and boat users, to public footpaths by pedestrians, and for emergency access. The stockpiles shall be formed so that they do not constitute a hazard; the locations, side slopes and heights and other factors affecting safety shall be as approved by the Engineer.

A1.3 TEMPORARY HAUL ROADS

Where the Contractor wishes, or the Engineer requires, that a temporary haul road or track be created within or on the structure, it shall be constructed of free-draining local material if available and suitable for this purpose, or of other free-draining material approved by the Engineer. Such material shall be removed before placing subsequent layers. The haul road material shall be sufficiently removed to expose between one third and one half of the depth of the upper layer of stones of the permanent works upon which the haul road material is placed, when measured from the highest points. Any armour stones laid to facilitate haul road construction that do not comply with the requirements of Section A1.6 shall be removed and replaced as necessary.

Note

1. In this specification, the term “Engineer” should be read as the relevant person responsible for technical and/or financial approvals under the form of contract adopted for the construction of the part of the project that involves armourstone. The wording should be changed to suit the particular form of contract, noting that more than one person or role may need to be referenced. For example (notably, under the UK ICE Engineering and Construction Contract) some references will be to the Project Manager and others to the Supervisor.

A1.4 ON-SITE INSPECTION

The Contractor shall provide all necessary facilities for any on-site inspection, categorisation, and approval/rejection activities on materials

The required facilities should be listed here.

NOTE: *Within Europe quality control of armourstone is largely a matter of compliance with EN 13383 and associated legal obligations on the supplier to provide compliant materials and to declare its compliance. Outside Europe a different regime exists and on site facilities are likely to be essential.*

A1.5 PLACING ARMOURSTONE – GENERAL

At least 30 days before commencement of the construction work the Contractor shall submit to the Engineer for his approval full details of his proposed method of forming the Works to the profiles indicated on the Drawings (to be prepared after the pre-construction survey).

The Contractor shall not commence any Permanent Works until the Engineer has approved in writing the Contractors working method for forming the Works. During the course of the Works, the sequential placing of individual core material, filter and cover layer armourstone shall proceed as closely-spaced defined fronts in only one grade of material as required at each front location. At each location, construction with material associated with the placing of the next front is only permitted to proceed upon approval by the Engineer of the previous front. The maximum spacing of working fronts is specified in Section A1.5.3.

Placing of materials shall be one continuous operation, to ensure that none of the underlying layers is left unprotected over a distance greater than agreed or for a duration greater than agreed between the Contractor and the Engineer. If the operation has to be interrupted, temporary protection of the underlying layers shall be provided with the same material as to be used for the final construction.

A1.5.1 Survey

Before placing armourstone the Contractor shall:

1. Submit to the Engineer for approval, details of the survey methods to be adopted to ensure accurate setting out, alignment, level and cross-sectional control during construction of all parts of the Works that involve armourstone.
2. Carry out initial ground, beach and sea bed survey lines at 10 metre centres, or other closer spacing if required, extending for at least 10 metres outside the intended toes or other edges of the parts of the Works that involve armourstone. A land-based survey shall be carried out with a staff fitted with a foot plate of at least 50 cm². The under water survey shall be carried out with a narrow beam echosounder.

Measurements of armourstone layers and other structures containing armourstone shall be carried out using a probe with a spherical foot of diameter $0.5D_{n50}$ unless for reasons such as health and safety, an alternative method is deemed necessary eg for certain gradings of heavy armourstone. If the Contractor intends to use an alternative method to the spherical foot probe, the alternative method for obtaining individual armourstone surface heights across the profile shall be submitted to the Engineer for approval. This submission shall include the conversion factor to be used to relate the reference levels in the design drawings (these assume a spherical foot probe survey) to levels that would be measured by the alternative method.

NOTE: Table 9.9 of the Rock Manual provides recommended factors for orthogonal thickness corrections using two alternative survey systems for double armourstone layers. For a land-based survey the probe will generally be connected to a staff or EDM target; for an underwater survey it will generally be a weighted ball on the end of a sounding chain. At greater water depths survey control shall be carried out with a narrow-beam, a multi-beam or a side scan echosounder (for information see Section 9.9.8.2 of the Rock Manual).

In this specification, D_{n50} is the nominal stone diameter for the median armourstone size for the grading (m), and shall be calculated as the cube root of the total volume of the stone, V_T (m^3). The volume shall be calculated by dividing the mass of the median stone, M_{50} (kg), by the apparent mass density of the stone, ρ_{app} (kg/m^3). For the purposes of calculations in this construction specification only, the mass of the median stone may be assumed to be close to the average of the nominal upper and lower limits of the grading: $M_{50} = (NUL + NLL)/2$. Stone density values for zero saturation are applicable for such mass values.

When above water survey measurements are based on fixed interval methods, measurements shall be carried out at the following intervals across the measurement profile:

- coarse and light grading: 1 m to 2 m
- heavy grading: $0.75 D_{n50}$.

Measurement profiles shall be at intervals along the length of the structure (breakwater, seawall, revetment etc) approved by the Engineer. These will generally be every 10 m, but may need to be more frequent where the profile is changing rapidly or on tight-radius curves; for example, on breakwater roundheads, radial sections at every 15 degrees from the centre of the roundhead shall be taken. The Contractor shall provide and maintain chainage markers at the approved measurement intervals along the lines of the parts of the Works that involve armourstone. Chainage markers should be visible from both the land and seaward side of the structure.

Surveyed sections shall extend to a distance of 5 m beyond the as-constructed toe and 2 m for the other edges.

No layer shall be covered by a subsequent layer until the profile of the former layer has been approved by the Engineer. The Contractor shall give an agreed minimum period prior notice of survey to the Engineer and shall provide facilities for his attendance during surveys. The minimum period shall take into account the working method, sea state and current conditions.

Further details of survey techniques are given in Section 9.9.8 of this manual. For underwater surveying of large breakwaters where very thick armour layers are used as part of optimal use of quarry output, survey control using narrow-beam echosounders may provide adequate control.

A1.5.2 Test panel or test section

As explained in Section 9.8.4 of this manual, test panels or test sections are a very useful way of testing and reaching agreement on the form of construction (including placing, packing and the resulting surface profiles). This section of the specification should be used if such panels or sections are adopted in the contract.

At the commencement of constructing each new section of works that involve armourstone, the Contractor shall as required by the Engineer, construct a test panel or test section of structure, which shall be used to demonstrate the quality of placing of armourstone for all layers including the core, scour protection, under layer(s) and armour layer, for approval by the Engineer. For structures or parts of structures above water, a 10 m length (commonly

designated as the “test panel”) may be adequate. For reasons of constructability, when a substantial part is under water the total test section of core, apron and under layers shall be considerably longer. The Contractor shall obtain approval of each layer or element prior to commencing subsequent elements and shall make any adjustments necessary to obtain the Engineer’s approval.

For each approved test panel or test section, the Contractor shall record accurately for agreement:

1. The grading of each type of armourstone used.
2. The quantity (tonnes) and volume (m³) of material used of each armourstone type.
3. In addition, for cover layer, the slope area covered and the number of pieces of armourstone placed.

The significance of these quantities is explained in Section 9.8.4 of the Rock Manual.

During the progress of the Works, the Contractor may, from time to time, be required to demonstrate that the placed packing density being achieved is in accordance with the approved test panel for that particular section of the Works. The visual quality achieved in test panels shall be maintained throughout the remainder of the Works. Areas of placed armourstone that show an appearance distinguishably different from the agreed test panel in terms of quality of the construction finish, may be rejected. Block counting methods (see Section 9.8.2 of the Rock Manual) may be used to further substantiate grounds for rejection or acceptance by the Engineer. Rejected panels shall be reworked until test panel quality is achieved.

A1.5.3 Working in the water environment

Subject to complying with the general survey requirements above, each placed layer shall be protected by the subsequent layer (as indicated on the drawings) as soon as possible after placement. A maximum length of each material of [...] metres and a maximum height of [...] metres should be left unprotected, in order to minimise wave damage in the event of storms during the construction period.

The designer should insert the lengths and heights in the above clause to reflect:

- *any constraints in Section A1.1 or elsewhere on the overall method of working (eg seasonal exclusions)*
- *wave and current exposure at the (expected) time of placing*
- *the size of the armourstone in relation to the exposure. Generally the core and smaller underlayer materials will be more vulnerable to erosion and damage.*

The Contractor shall make good any location where material has been eroded by wave and/or current action or removed by other cause before placing the appropriate material for the overlying (protective) layer. However, in respect of core material, the Contractor may, if authorised in writing by the Engineer, build up the core up to the dimensions shown on the drawings with the material specified for the layer next overlying the core and in accordance with the method for this overlying layer.

Notwithstanding the above, the Contractor shall take all reasonable care to avoid disturbing a previously placed layer by avoiding dropping armourstone or any other potentially disturbing placing methods.

Preference will be given by the Engineer to methods of working that progress from upstream/updrift to downstream/downdrift and thereby reduce undesirable siltation in the work area prior to stone dumping/placing.

For work above low-tide level, sufficient fine material on the surface of already placed stones (including stones within the layer being placed) shall be removed from those areas where surface contact will arise between the stone being placed and those already placed to ensure sound bearing and interlock between stones. The Contractor shall make due allowance for the removal of such fine material.

A1.6 PLACING OF COVER LAYER ARMOURSTONE

Armourstone placing for the cover layer shall comply with the following requirements:

1. Heavy armourstone defined in EN 13383-1 or with a $NLL > 300$ kg shall be individually placed to achieve a dense, fully interlocked armoured slope so that each armour stone is securely held in place by its neighbours. Placing shall commence at the toe and proceed upwards towards the crest. Stones shall be lowered into place individually. Stones shall be placed in such a way that they obtain their stability from interlocking and frictional resistance, and not from friction on one plane alone. Light armourstone (as defined in EN 13383-1 or with a $NUL < 300$ kg) may be placed with several stones at a time.
2. Tipping of armourstone from vehicles, or bulldozing or dumping from hoppers or barges into final position shall not be permitted without the prior approval of the Engineer. Such permission may only be given following placing trials.
3. Armourstone shall be placed according to one of four recognised placement methods described in the Rock Manual - Section 9.8.1.1 and as summarised in Box A1.1 to achieve a minimum “three-point support” and be stable to the lines and levels shown on the drawings.

Box A1.1 Recognised armourstone placement methods

Random placement is without control of orientation and should not be assumed to be any tighter than would be expected if the stones were placed out of view underwater by single cable release from a crane using a spatial positioning grid.

Standard placement is where minimum orientation control is applied so that the block attitude is effectively governed by its orientation in the stockpile before lifting. However, a minimum of three points of contact within the layer being placed should be ensured, ie excluding stones effectively beneath.

Dense placement involves the rotation of stones until the orientation achieved is expected to give the maximum number of point contacts and minimum voids. Individual stones are removed and replaced if necessary.

Specific placement is used when the procedures coupled with stone shape constraints are specified to be other than random, standard or dense.

4. Unless otherwise stated, the surface of the armoured slope shall present an angular uneven face to the water to achieve the desired energy dissipation of waves. Pieces of armourstone smaller than the equivalent of the ELL value of the grading shall not be used to fill interstices, or to prop larger stones in order to achieve the required profile.
5. Pieces of armourstone broken during handling or placing shall be removed immediately at the Contractor's expense. Subject to the Engineer's approval, broken pieces of armourstone may be included in smaller gradings.
6. Any void below the finished profile level as shown on the drawings (but modified according to survey technique as set out in Section A1.5 above) in excess of $0.75D_{n50}$ shall be filled with an appropriate stone or stones. Determination of the acceptability of any void shall be by means of use of the survey probe or other a test sphere or cage of diameter $0.75D_{n50}$.

In some cases the requirement to fill voids in point 6 above may not be required – this clause may therefore, be adapted accordingly.

Vertical achievable placing tolerances for armourstone shall be in accordance with Table A1.1. Measurement shall be in accordance with Section A1.5.1 of this Appendix with profiles taken at 10 m intervals along the length of the structure.

Table A1.1 Vertical placing tolerances for placing armourstone in armour layers

	Dry, ie above low water, placed using land-based plant	Below low water placed using land-based plant	Below low water, placed by water-borne equipment
Maximum allowable deviations based on individual measurements (m)	$\pm 0.3 D_{n50}$	$\pm 0.5 D_{n50}$	$\pm 0.8 D_{n50}$

Notwithstanding the above tolerances, the following criteria shall apply to the armourstone cover layer:

1. The tolerances on two consecutive mean actual profiles shall not be negative.
2. Notwithstanding any accumulation of positive tolerances on underlying layers, the thickness of the layer shall not be less than 80 per cent of the nominal thickness when calculated using mean actual profiles.

A1.7 PLACING OF ARMOURSTONE IN UNDERLAYER AND CORE

Placing of underlayer and core material (including scour protection material, where provided) shall comply with the following requirements:

1. Core material shall be placed to the positions and slopes indicated on the drawings and in accordance with the method and sequence of construction approved by the Engineer.
2. Underlayer and core material shall be placed to achieve a dense underlayer or core but shall not be compacted.
3. Underlayer and core material shall be placed carefully to avoid damage to the surface below or to the geotextile if used.
4. Underlayer and core material shall be placed to achieve an even distribution of stone sizes without concentrations of smaller stones.
5. Armourstone shall be placed to achieve a layer porosity in the range of 35–40 per cent. The stones shall be placed in such a way that they do not obtain their stability on a plane by frictional resistance alone, but also by interlocking. The Contractor shall take measures to ensure this prior to placing further stones. Tipping of armourstone for underlayers from vehicles, or bulldozing or dumping from hoppers or barges into final position, shall not be permitted without the prior approval of the Engineer. Such permission may only be given following placing trials.
6. Placing armourstone for underlayers with a side stone dumping vessel is permitted provided that the position of the vessel and the rate of dumping can be controlled in such a way that the materials are placed according to the required lines and levels.
7. Placing core material with a split-hopper and a flat-top barge is permitted provided that the position of the vessel and the dumping can be controlled in such a way that the materials are placed within the required lines and levels.

Armourstone for underlayers and core material shall be placed to the following tolerances:

1. The vertical placing tolerance of individually-placed underlayers consisting of heavy grading shall be the same as the tolerances for placing armourstone in armour layers given in Section A1.6 of this appendix.
2. The vertical tolerance of underlayers and core consisting of bulk placed quarried rock shall be in accordance with Table A1.2 below.

Table A1.2 Vertical placing tolerances for bulk-placed material in underlayers and core

Depth of placing	Coarse gradings and core	Light gradings (NUL < 300kg)	Heavy gradings (NLL > 300kg)
Placed with land-based plant above low water	+0.1 m to -0.1 m	+0.2 m to -0.2 m	+0.4 m to -0.2 m
Placed with land-based plant up 5 m below low water	+0.15 m to -0.15 m	+0.5 m to -0.3 m	+0.8 m to -0.3 m
Placed with land-based plant between 5 and 15 m below low water	+0.2 m to -0.2 m	+0.5 m to -0.3 m	+1.2 m to -0.4 m
Placed with land-based plant below -15 m	+0.2 m to -0.2 m	+0.5 m to -0.3 m	+1.5 m to -0.5 m
Placed with water-borne plant below low water	+0.2 m to -0.2 m	+1.0 D_{n50} to -1.0 D_{n50}	+1.0 D_{n50} to -1.0 D_{n50}

A1.8 PLACEMENT OF CONCRETE ARMOUR UNITS

In preparing a specification for placing concrete armour units the technical advice and recommendations provided by the proprietary manufacturers should be taken into account. However much of the good practice set out herein (for example general items, approaches to and tolerances for survey) are still likely to apply.

A1.9 PREPARATION OF ARMOURSTONE SURFACE FOR CROWN WALLS AND CONCRETE STRUCTURES

Where the drawings indicate that the structure involving armourstone is to have a crown wall or other reinforced or mass concrete structure cast upon it, the interstices between the stones directly under the concrete structure shall be filled with selected material to form an effective seal against leakage of concrete, leaving natural key projections of not less than $0.25D_{n50}$ between the irregular surface of the secondary layer and the concrete structure.

If settlement of the surface on which the concrete structure is to be cast has taken place, the use of a layer of small stones to bring it to the correct level will not be permitted. In such circumstances the thickness of concrete placed shall be increased to ensure that the correct surface levels of the concrete structure are attained.

A1.10 DISPOSAL OF SURPLUS MATERIAL

It shall be the Contractor's responsibility to remove from the site of the works all surplus material, rubbish, debris and material unsuitable for inclusion in the works and dispose thereof at an approved location.

A1.11 SETTLEMENT

The Contractor shall make good any parts of the Works that has been subject to any settlement within the structure that is beyond the specified allowable limits and that may occur up to one year after completion of the works. Making good of settlement shall be with materials and in a manner approved by the Engineer.

NOTE: Settlement due to sub-soil deformation is generally outside the Contractor's responsibility, being a design issue. This does, however, not necessarily apply to all contracts; an example of such an exception in this respect may be a Design and Construct contract. The responsibility should be defined unambiguously.

A1.12 GEOTEXTILE FILTERS

Geotextile filters shall be delivered to site in packaging that will protect the rolls from ultra-violet light degradation. The labelling of the rolls shall clearly identify the product supplied in accordance with EN 10320:1999. Geotextiles shall be protected at all times against physical or chemical damage. Geotextiles shall be kept in the protective wrappings provided by the manufacturer until required for use in the works.

The rolls of geotextile shall be stored on level ground and stacked not more than five rolls high and no other materials shall be stacked on top of the geotextiles.

The Contractor shall ensure that filter fabric is not exposed to direct sunlight for more than the number of days written in the geotextile CE certificate in accordance with EN 13253:2000 Annex B, or a maximum of one day if not tested.

The Contractor shall ensure that the geotextile complies with the requirements set out in the specification, in particular regarding the appropriate functional characteristics, that the geotextile is sufficiently robust to withstand, without being damaged, the working method of placing the geotextile and the subsequent placing of the armourstone layer on top, and that it is durable for the lifetime of the project, specified elsewhere in the specification. The geotextile filters shall be laid on prepared surfaces in accordance with the manufacturer's recommendations. On sloping surfaces, the fabric shall be laid with its longitudinal axis down the slope. The geotextile shall be installed in the positions and to the lines and levels described on the drawings. Folds shall be avoided to obtain the best contact between the geotextile and the material beneath to be filtered. Material that may be in contact with the geotextile shall not have protrusions, which are likely to damage the geotextile during installation or in service. Construction plant shall not operate directly on the geotextile.

Overlapping widths between adjacent sheets/rolls shall be adapted to compensate the risk of soil uncovering during its installation or during armourstone placement. Filter fabric shall be laid with minimum 1000 mm overlaps unless detailed or specified otherwise. Where fabric is laid under water and visibility is poor, ie the fabric cannot be seen clearly from the surface, then overlaps shall be increased to 2000 mm, unless the Contractor has other means of guaranteeing the minimum 1000 mm overlap. On sloping surfaces, the geotextile filter shall be laid to have overlaps parallel to the slope. The stitching of adjacent sheets in accordance with the manufacturer's instructions may be considered by the Engineer, as an alternative to overlapping.

Armourstone shall be placed on the geotextile filter from the bottom to the top of the slope. The placing method shall comply with the requirements of Sections A1.6 and A1.7 of this specification. The Contractor shall adopt such placing method that moving of stones over the geotextile filter is prevented. The thickness of the armourstone layer shall be such that the geotextile filter is protected against direct UV exposure.

