PORT OF DURBAN

ISLAND VIEW SEAWALLS UPGRADE

TENDER NUMBER: TBC

VOLUME III: CONTRACT DOCUMENT

ANNEXURE E2

GENERIC SPECIFICATIONS

ROCK

TABLE OF CONTENTS

PAGE NO.

E2 ROCK FOR RUBBLE MOUND STRUCTURES

1. SCOPE

This specification provides definitions and requirements for the production, testing, transport, placement and survey of rock materials for use in the construction of marine rubble mound structures. These structures may include but are not limited to breakwaters, revetments, scour protection and groynes.

The rock must be sourced from a quarry licensed by the Department of Mineral Resources and Energy within the Durban area. It shall be the responsibility of the Contractor to satisfy itself that the intended quarry (or quarries) is (are) capable of supplying rock of the grading, quality, quantity and rate required to complete the works in time.

2. INTERPRETATIONS

For the purposes of this specification the following definitions will apply:

Rock: Broken natural rock sourced from a quarry.

Armour Stone/ Armour Rock: Rock used as primary protection against waves or currents.

Graded Rock: Rock which is graded by sieve sizes or by weight of the rock.

Coarse-Graded Rock: A grading which is determined with the aid of sieve sizes.

Light-Graded Rock: A rock grading which is determined by weight or size of rock for mean weights less than 300 kg per rock.

Heavy-Graded Rock: A rock grading which is determined by weight for rocks of mean weight of at least 300 kg.

Rock Fragment: A piece of rock in a grading with a lesser weight or size than the extreme lower class limit (ELL) for that particular grading class.

Effective Mean Weight W_{EM}: The arithmetic average weight of all blocks in a sample excluding any rock fragments.

Nominal Rock Diameter D_n: The nominal rock diameter, D_n, is calculated as the cube root of the volume of the rock. The volume is calculated by dividing the mass of the rock by the saturated surface dry density. Where a numbered subscript is given to D_n, this refers to the percentage by weight of rocks in the grading having a smaller nominal rock diameter.

Load of Rock: The quantity of rock per unit of transport.

Class Limits: The size (or weight) defined for each rock grading together with the allowable percentage of a sample that can lie beyond that limit, as follows:

- Extreme lower limit (ELL)
- Nominal Lower Limit (NLL)
- Nominal Upper Limit (NUL)
- Extreme Upper Limit (EUL)

3. MATERIALS

Full quality control of rock as referred to in Section 7 shall be carried out at the site of the quarry. However, with regard to temporary stockpiling of quarry material further visual inspections shall be carried by the Contractor at the construction site on a regular basis during deliveries.

In his quality control plan the Contractor shall provide for continuous visual inspection of rock during supply from the quarry. These inspections shall comprise not less than the following:

- Verification of origin of the material (agreed section/face of the quarry); indicators are petrography, colour, grain size
- Mass distribution: carried out by a trained inspector; in case of doubt, the Supervisor may require an "alternative" mass distribution test to be carried out; this will involve the weighing and plotting of the weight distribution of 25 rocks from an agreed sample
- Check on breakage
- Check on cleanliness, absence of soil or quarry dust

3.1 Standard rock gradings

EN 13383 divides rock gradings into:

- Heavy gradings for larger sizes appropriate for amour layers – normally handled individually
- Light gradings appropriate for armour layers, underlayers and filter layers – produced in bulk, usually by crusher opening and grid bar separations
- Coarse gradings often used for filter layers – of such a size that all pieces can be processed by production screens with square openings (i.e. typically less than 200 mm).

Standard gradings according to EN 13383 are specified in TABLE 0-1.

TABLE 0-1: HEAVY, LIGHT AND COARSE STANDARD GRADING REQUIREMENTS ACCORDING TO EN 13383

Heavy	**Class designation**	**ELL**	**NLL**	**NUL**	**EUL**	**M_{em+} (kg)**	
	Passing Requirements kg	**<5% kg**	**<10% kg**	**>70% kg**	**>97% kg**	**Lower limit**	**Upper limit**
	10 000 – 15 000	6 500	10 000	15 000	22 500	12 000	13 000
	6 000 – 10 000	4 000	6 000	10 000	15 000	7 500	8 500
	3 000 – 6 000	2 000	3 000	6 000	9 000	4 200	4 800
	1 000 – 3 000	700	1 000	3 000	4 500	1 700	2 100
	300- 1 000	200	300	1 000	1 500	540	690
Light	**Class designation**	**ELL**	**NLL**	**NUL**	**EUL**	**M_{em+} (kg)**	
	Passing Requirements kg	**<5% kg**	**<10% kg**	**>70% kg**	**>97% kg**	**Lower limit**	**Upper limit**
	60 – 300	30	60	300	450	130	190
	10 – 60	2	10	60	120	20	35
	40 – 200	15	40	200	300	80	120
	5 – 40	1.5	5	40	80	10	20
	15 – 300*	3	15	300	450	45	135
Coarse	**Class designation**	**ELL**	**NLL**	**NUL**	**EUL**	**M_{em+} (mm)**	
	Passing Requirements mm	**<5% mm**	**<10% mm**	**>70% mm**	**>97% mm**	**< 50% mm**	
	45/125	22.4	45	125	180	63	
	63/180	31.5	63	180	250	90	
	90/250	45	90	250	360	125	
	45/180**	22.4	45	180	250	63	
	90/180***	45	90***	180***	250	NA	

Notes:

* = wide light grading, ** = wide coarse grading, *** = gabion grading, NLL = 20% and NUL

= 80%.

$^{+}$ Mean effective mass

3.2 Shape

The quarry rock sample shall not contain more than 5% of rocks with length to thickness ratio (l/d) greater than 3, where the length, l, is defined as the greatest distance between two points on the rock and the thickness, d, as the minimum distance between two parallel straight lines through which the rock can just pass.

3.3 Rock quality requirements

3.3.1 General

All results for rock quality tests shall refer to samples taken in accordance with Section 7.2.

3.3.2 Density

The average density of rock used for armour or core must be at least 2 650 kg/m^3 with 90% of the rocks having a density of at least 2 600 kg/m^3. For sampling, testing and reporting in accordance with Section 7.2.8, ten density determinations shall be made, each determination being carried out on a different randomly selected rock which shall have a volume of at least 50 ml. If any rock is too large, a representative part of at least 50 ml shall be taken.

3.3.3 Water absorption

For sampling, testing and reporting in accordance with Section 7.2.9, ten water absorption determinations shall be made, each determination being carried out on a different randomly selected rock which must have a volume between 50 and 150 ml. If any rock is larger than 150 ml, a representative part of between 50 and 150 ml shall be taken. The average water absorption of rock must be less than 2% and the water absorption of nine of the individual rocks less than 2.5%.

3.3.4 Resistance to impact and mineral fabric breakage

The average point load index (in the planar direction of the most pronounced layering should any visible anisotropy exist) done in accordance with ISRM 1985 "Suggested Methods for Determining Point Load Strength", recommended method for sampling, testing and reporting shall be at least 4.0 MPa with the average minus the standard deviation of the point load index being at least 3.0 MPa.

The average and standard deviation shall be calculated from at least ten valid results obtained from pieces of randomly selected rocks after the largest and smallest valid test results have been excluded from the calculation. In practice this will mean that at least twelve test results will be required.

3.3.5 Block integrity

Blocks from heavy gradings must be free from visually observable cracks, veins, fissures, shale layers, styolite seams, laminations, foliation planes, cleavage planes, unit contacts or other such flaws which could lead to breakage during loading, unloading or placing.

In addition, the drop test breakage index calculated based on appropriate sampling and testing as described in Section 7.2.10, must be less than 5%.

3.4 Impurities

Rock must not contain visually observable or chemically detectable impurities or foreign matters in such quantities that these are damaging for the constructive application of the rock or for the environment in which the rock is applied.

4. EQUIPMENT

4.1 General

The Contractor shall provide for all the necessary equipment to produce the specified rock quality and gradings, transport the rock to the site and place in the Works as shown in the drawings to the required tolerances. Suitable equipment shall be provided for the accurate control of placing the rock in the structure and for surveying the seabed and the profiles of the sub-components of the structure to prove compliance with the relevant tolerances.

The requirements of SANS 1200D (clause 4.3) apply to all vehicles that are required to operate on or over any public road. Spillage of materials, generation of dust, or contamination of public roads with mud from the site shall be controlled. The Contractor shall be responsible for cleaning the haul route of any spilled material from its vehicles at its own expense.

Audible reversing warning signals shall be provided for all transport vehicles exceeding 3 ton GVM.

4.2 Lifting machinery

All cranes and gantries together with all slings, ropes and hooks, to be used on the site of the works shall be tested and certified as required by legislation.

Cranes must be equipped with load measuring devices, and must be provided with a means to monitor the location of the crane hook in three degrees of freedom whether in air or underwater.

4.3 Marine equipment

All marine equipment to be used in the Works is subject to the safety, environmental and legal requirements as specified in Volume II – Part II Specification. The Contractor is also referred to the Project Health and Safety Management Plan.

5. CONSTRUCTION

5.1 Precautions

5.1.1 Safety

Over and above the general safety requirements as specified elsewhere, the Contractor's Safety Management Plan shall take cognisance of the following specific risks:

- The Contractor shall at all times remain responsible for preventing public access to the site of the Works.
- Construction equipment shall only be operated by personnel who are suitably trained, licensed and qualified for the particular item of equipment.
- Stockpiles of rock shall each be monitored and controlled by an experienced Engineer to ensure that they present no danger to personnel working in the vicinity.
- Storm management plan (storm warnings, secure equipment)
- Emergency sea rescue plan

5.1.2 Stormwater and groundwater

The provisions of clause 5.1.3 of SANS 1200 D shall apply insofar as they are relevant to haulage and stockpiling of rock and concrete rubble. This includes the provision and maintenance for the duration of the contract of suitable flood control structures to protect the site from stormwater damage and protection from potential flooding.

5.1.3 Nuisance and environmental control

In addition to the requirements of clause 5.1.4 of SABS 1200 D, the Contractor shall comply with the environmental controls specified in Volume II Part II Specification (refer to Environmental Management Requirements).

5.2 On-site inspections

The Contractor shall provide all facilities required for any on-site inspection, categorisation, and/or approval/rejection activities.

5.3 Transportation, handling and stockpiling

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

- Obtain the acceptance of the Project Manager and the approval of the appropriate Authorities before using the public highway.
- Avoid damage to public or private roads and shall repair any damage that does occur due to the transport of rock.
- Make a photographic record of the state of the public and/or private road to be used for transporting rock prior to the start of the works
- Trucks used to transport rock shall be of a type specifically constructed for hauling rock and must have tail boards or scow-ends. If transporting heavy armour stone, adequate chains and slings must be used and verified before the truck leaves the quarry to ensure optimum security. No other mode of rock transportation may be employed unless first accepted by the Project Manager and approved by the relevant Authorities.
- 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 shall have an emergency procedure in place should there be an imminent threat of sea and wind conditions beyond the safe mooring design conditions.

Subject to the acceptance of the Project Manager, the Contractor may be permitted to stockpile rock at or near the site of the permanent works. Separate stockpiles must be made and identified for different rock grades. The stockpiles must be formed so that they do not constitute a hazard; the location, side slopes and heights and other factors affecting safety shall be as accepted by the Project Manager.

The Contractor shall make a risk assessment for the transportation to and handling of rock on site, and implement a strict risk control plan and maintain good operational practice throughout the period of supply and installation for the construction of the rubble mound structures. A stockpile plan must be drawn up which is commensurate with the overall project planning, giving due regard to the quarry output capacity and production lead-in time. Stockpiles on site must be sized, taking into considerations the type of grading, access, weight limitations, manoeuvring and handling requirements (tipping or tipping and stacking) and risk of cross contamination (no overlaps of grades). If possible, a one-way rotation system should be instituted for controlling traffic. The stockpile area must be checked for services to avoid risk of damages. The Contractor shall prevent unauthorized pedestrian access, keep

stockpile areas well lit during night operation, maintain equipment in adequate working condition, and keep suitable backup equipment nearby.

5.4 Rock placement

5.4.1 General

Before commencement of the construction work the Contractor shall submit to the Project Manager for his acceptance full details of his proposed method of forming the works to the profiles indicated on the drawings (to be prepared after the preconstruction survey).

The Contractor shall not commence any permanent works until the Project Manager has accepted in writing the Contractor's working method for forming the works. During the course of the works, the sequential placing of individual core material, filter and cover layer armour stone 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 acceptance by the Project Manager of the previous front.

Rock that will be placed in the Works in bulk shall be transported and handled in such a manner as to minimise segregation of the rock.

5.4.2 Temporary haul roads

Any temporary haul road or track to be created within or on the rubble mound structure, must be constructed of free-draining local material if available and suitable for this purpose, or of other free-draining material accepted by the Project Manager. 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 rocks laid to facilitate haul road construction that do not comply with the requirements shall be removed and replaced as necessary.

5.4.3 Underlayer and core

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

Core material shall be placed to the position and slopes indicated on the drawings and in accordance with the method and sequence of construction accepted by the Project Manager.

Underlayer and core material shall be placed to achieve a dense underlayer or core but must not be compacted.

Underlayer and core material shall be placed carefully to avoid damage to the surface below or to the geotextile if used.

Underlayer and core material shall be placed to achieve an even distribution of stone sizes without concentration of smaller stones.

Rocks shall be placed to achieve a layer porosity in the range of 35-40 per cent. The rocks must 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 stones for underlayer from vehicle, or bulldozing or dumping from hoppers or barges into final position, is not permitted without the prior acceptance of the Project Manager. Such permission may only be given following placing trials. Placing trials shall be executed if required by the Project Manager, at no additional cost to the Employer.

Placing stones for underlayer 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.

Placing core material with a split hopper or 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 material are placed within the required lines and levels.

5.4.4 Cover layer armourstone

Armourstone shall be 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 placed in such a way that they obtain their stability from interlocking and frictional resistance, and not from friction on one plane alone.

Armourstone shall be deposited carefully to minimise disturbance to any alreadyplaced rock and to avoid damage to any existing structures. This may require stones to be lowered into place individually.

Armourstone shall be placed to achieve a minimum "three-point support" and be stable to the lines and levels shown on the drawings.

Unless otherwise stated, the surface of the armoured slope must 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.

Pieces of armourstone broken during handling or placing shall be removed immediately at the Contractor's expense. Subject to the Project Manager's acceptance, broken pieces of armourstone may be included in smaller gradings.

Any void below the finished profile level in excess of the $0.75D_{n50}$ size of the armour rock, must be filled with an appropriate rock or rocks. Determination of the acceptability of any void shall be by means of a test sphere of diameter $0.75D_{n50}$.

The rocks must be deposited carefully to minimise disturbance of any already-placed rock and to avoid damage to geotextiles and any existing structures. The rocks must be placed to achieve an even distribution of stone size without concentrations of smaller stones.

5.5 Protection of placed materials

Each placed layer must be protected by the subsequent layer (as indicated on the drawings) as soon as possible after placement in order to minimise damage due to currents or due to waves in the event of storms during the construction period. Placing of materials shall be one continuous operation, to ensure that none of the underlying layers are left unprotected over a distance or for a duration greater than that proposed by the Contractor and accepted by the Project Manager. If the operation has to be interrupted, temporary protection of the underlying layers must be provided with the same material as to be used for the final construction.

5.6 Disturbance to previously placed materials

Material eroded by wave action or other cause must be made good before placing the appropriate protective layer. However, in respect of core material, if accepted by the Project Manager, the core may be built up to the dimensions shown on the drawings with the material specified for the next layer 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 due to dropping or other potentially disturbing placing methods.

6. TOLERANCES

6.1 Tolerances in rock grading

Tolerances on rock grading shall be determined in accordance with the Tables in Section 3.1. The system for defining heavy, light and coarse gradings requirements is based on setting limit values with an associated percentage passing by mass. A set of nominal limits corresponds to the target size of the armourstone. A set of extreme limits corresponds to tolerances. The standard grading requirements and associated passing values are summarised in TABLE 0-1.

The associated limits are:

- ELL (Extreme Lower Limit) – the mass below which no more than 5 per cent passing by mass is permitted.

- NLL (Nominal Lower Limit) – the mass below which no more than 10 per cent passing by mass is permitted.
- NUL (Nominal Upper Limit) – the mass below which no less than 70 per cent passing by mass is permitted.
- EUL (Extreme Upper Limit) – the mass below which no less than 97 per cent passing by mass is permitted.

In

TABLE 0-1 limits for M_{em} are also given, defined as effective mean mass, i.e. the average mass of a sample of stones without fragments (those below the ELL-value of the grading).

6.2 Tolerances on placed rock levels

6.2.1 Cover layer armourstone

Rock material must be placed to levels, dimensions and slopes shown on the drawings and, when the surface profile is measured using the techniques specified in Section 8.2, shall comply with the vertical placing tolerances in accordance with TABLE 0-1.

TABLE 0-1: VERTICAL PLACING TOLERANCES FOR PLACING ROCK 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:

- The tolerance on two consecutive mean actual profiles must not be negative.
- Notwithstanding any accumulation of positive tolerances on underlying layers, the thickness of the layer must not be less than 80 per cent of the nominal thickness when calculated using mean actual profiles. Where an accumulation of positive tolerances arises and is acceptable to the Project Manager, the position of the design profiles will need to be adjusted to suit.

The Contractor shall, at its own expense, remove rock outside the specified profiles irrespective of whether the excess is due to faulty placing or due to displacement of the rock by sea action.

6.2.2 Underlayer and core

Rock material for underlayers and core must be placed to levels, dimensions and slopes shown on the drawings and, when the surface profile is measured using the techniques specified in Section 8.2, must comply with the following vertical tolerances:

The vertical placing tolerance of individually-placed underlayers consisting of heavy grading must be the same as the tolerances for placing rock in armour layers give in Clause 6.2.1.

The vertical tolerance of underlayers and core consisting of bulk placed quarried rock must be in accordance with TABLE 0-2 below.

TABLE 0-2: 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}

7. TESTING

7.1 Inspection

The requirements of Section 3 apply to inspections at or near the site.

For inspections carried out at the quarry, the interpretation of inspection results shall take into account the possible influence of storage, loading, transporting and unloading on the quality requirements.

7.2 Sampling

7.2.1 General

The samples of the grading of rock to be inspected shall be taken at random and must be representative. The sampling, transport and transfer of the samples shall be carried out in a careful manner so that breakage is limited to a minimum.

The pieces of one rock which, according to observation, were broken during sampling, will be considered to comprise one rock at the inspection.

7.2.2 Homogeneity of the batch

When, on the basis of visual judgement of the quarried rock batch to be inspected, non-homogeneity or possible non-homogeneity of the batch is considered to exist with regard to one or more of the relevant qualities, that batch has to be divided into parts considered to be homogeneous. Sampling for those qualities must then be carried out on the supposedly homogeneous parts.

When one of the parts does not satisfy the requirements, the whole batch of quarried rock shall be considered unsatisfactory.

If separation of the divided part(s), which does (do) not satisfy the requirements, is possible without difficulty, it can be agreed to regard the remaining part of the batch as a separate batch.

7.2.3 Size and composition of samples

7.2.3.1 Samples for Determining Particle Distribution

For the determination of the particle distribution of a coarse-graded quarry rock, at least six sub-samples shall be taken if the sampling takes place from a stockpile or a ship's load. In all other cases the number of sub-samples has to be at least three.

The numerical value of the weight in kilograms of each sub-sample must be at least equal to the numerical value of the upper limit in millimetres of the designation of the grading concerned if that upper limit is less than or equal to 100 mm. The numerical value of the weight of each sub-sample in kilograms must be at least twice the numerical value of the upper limit in millimetres of the grading designation if the upper limit is greater than 100 mm.

7.2.3.2 Samples for Determining Weight Distribution

For the determination of the weight distribution of the light or heavy graded quarry rock, at least six sub-samples shall be taken if the sampling takes place from a stockpile or a ship's load. In all other cases the number shall be at least three.

The sub-samples including all the rock fragments together constitute one sample. This sample must contain at least 200 pieces of rock heavier than the extreme lower class limit of the designated grading class.

When the determination of the weight distribution concerns a ship's load containing less than 200 pieces of rock, the whole load is taken to be one sample.

7.2.3.3 Samples for Determining Shape and Rock Quality

The sample must contain at least 50 pieces taken at random from above the ELL weight.

The rocks would normally be chosen at random from the sub-samples which have been taken for the particle and weight distributions. Where such samples are not available, the rocks shall be taken at random from the batch to be inspected. If the chosen pieces of rock are too large for the test descriptions in force, it will be necessary to break from each rock a representative piece of the required dimensions.

7.2.3.4 Samples for Determining Grading Designated by Size and Average Weight

At least four sub-samples shall be taken if sampling is from a ship's load or from a stockpile. In all other cases, the number must be at least two.

The sub-samples, including all rock fragments, together constitute one sample. This sample must contain at least 100 pieces of rock retained on the L square hole of size 500 mm x 500 mm for Light Grading class.

7.2.4 Method of operation

7.2.4.1 General

Sampling methods shall be according to the specifications in EN 13383-2:2002 Clause 4. The Contractor shall ensure that during sampling the degree of filling of the grab or other extraction equipment does not adversely affect the representativeness of the sample taken.

7.2.4.2 Sampling from a Belt Conveyor

Prior to sampling material on the belt conveyor, let the belt transport for a period sufficient to ensure that deviations from the composition of the material possibly present due to the starting up of the installation will not be shown in the sample. For sampling from a belt conveyor a sample of a sufficient quantity of material should be taken by catching it from the end of the belt or by stopping the belt and then taking material from the belt. Catch the material from the end of the belt in a manner to ensure that, from the cross-section of the material flow, material is taken from each point for equal for equal periods of time.

Take the required number of sub-samples at approximately equal intervals along the whole batch.

7.2.4.3 Sampling from a Silo

When sampling from a silo, take a sample by catching a sufficient quantity of material discharging from the silo. When sampling from a silo, account must be taken of the fact that particle size reduction and segregation can occur due to the methods of filling and extraction from the silo. Take the required number of sub-samples at approximately equal intervals from the whole batch to be sampled.

If during the sampling, segregation is observed, the number of samples should be adjusted accordingly.

7.2.4.4 Sampling from a Stockpile

When sampling from a segregated stockpile, take a sample of sufficient quantity from the material which is being taken from the stockpile. Take, for this purpose, the contents of one or more loads of a wheel loader, lorry or any other transport or transfer method employed.

Simulate the removal of material from the segregated stockpile if, at the instance of sampling, no material is undergoing routine removal. Before taking the sample, make several extractions of material from the stockpile so as not to distort the sample contents with segregation effects associated with initiation of stockpile extraction.

When sampling from a non-segregated stockpile, take a sample as indicated for a segregated stockpile or take a sufficient quantity of material from a random location which is easily reached with the equipment available.

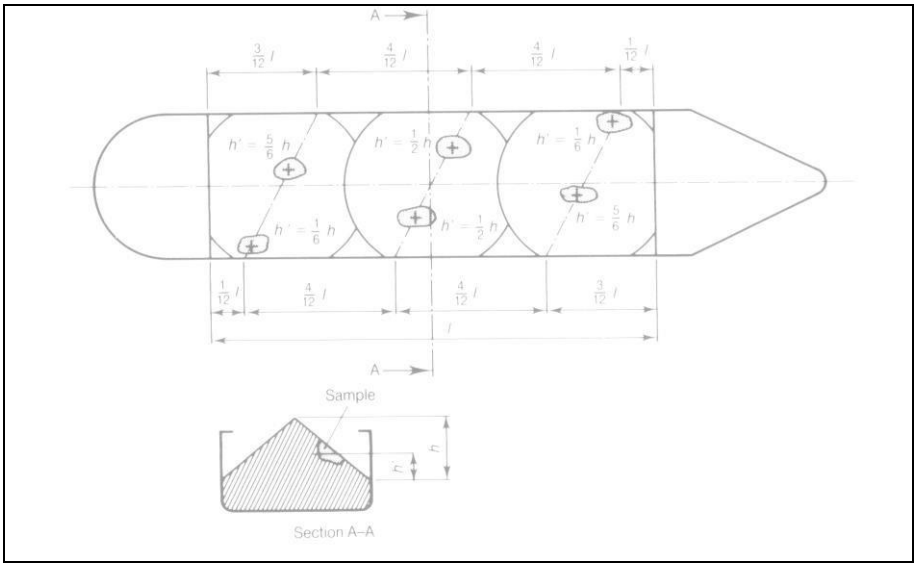
7.2.4.5 Sampling from Floating Equipment

For sampling prior to the unloading of the segregated load, take adequate quantities of material from the locations shown in FIGURE 0-1 at the surface of the load, with the aid of the unloading equipment. For the sampling of a non-segregated load the samples must be taken as indicated for a segregated load or by taking an adequate quantity of material at random or evenly distributed locations on the surface of the load, with the aid of the unloading equipment.

When sampling during the unloading, take for each sample an adequate quantity of material with the aid of the unloading equipment. Take the required number of subsamples at approximately equal intervals from the whole of the load to be sampled.

FIGURE 0-1: SAMPLING LOCATIONS IN THE LOAD ON FLOATING

EQUIPMENT



7.2.4.6 Sampling from Wheeled Transport

For the sampling of a load of rock, let the load be tipped out partially or completely in a manner which produces an evenly distributed long pile. Take the required number of sub-samples from across that pile by removing at random or at equally distributed locations an adequate quantity of material, while avoiding the possible segregated material at the start and finish of the pile. Take the material in long strips over the full width of the pile or in equal numbers of half strips from the left – and right-hand side of the centre line of the pile.

7.2.4.7 Splitting of Samples of Light and Fine Gradings

If the collected sample to be inspected for compliance with the requirements in Section 3.3 is too large, reduce the size of the sample according to one of the methods described below.

FIGURE 0-2: SAMPLING LOCATIONS IN A NON-SEGREGATED LOAD ON FLOATING EQUIPMENT

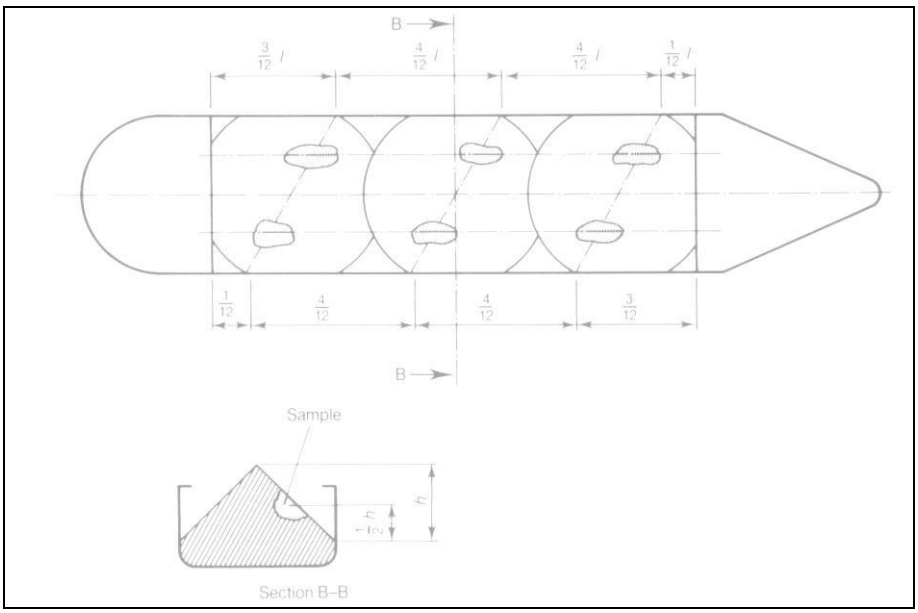
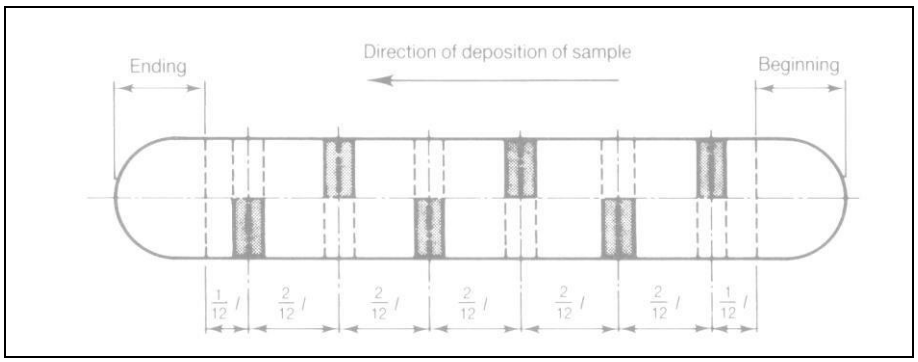


FIGURE 0-3: SAMPLING LOCATIONS IN A SPREAD DUMPED LOAD



When depositing a sample, take into account the splitting to be carried out by spreading the sample appropriately. Dump the sample to be deposited and to be split into one or more buckets in a manner which limits segregation as far as possible. When dumping material from a wheel loader bucket, catch all the material from an imagined cross-sectional width of the bucket content in the sample bucket(s). The diameter of the (sample) buckets must be twice the sieve dimensions of the largest piece of rock.

If so desired dump the sample, which is to be deposited and to be split, over one or two vertically set plates, which will create separation planes. Proceed further in accordance with the work methods presented in the following description, utilising wires representing the imaginary vertical separation surfaces. Stretch a wire as a separation line over the sample already deposited to indicate the desired demarcation into two approximately equal parts. Where segregation has taken place in one direction of the deposited sample, place the wire in the same direction. Remove all material where all pieces of rock or the majority are placed to one side of the imagined vertical plane projected by the wire.

When, for division of the deposited sample, less than half of the total sample is required, stretch two parallel wires as dividing lines over the sample, so that the desired part of the sample lies between the two separation lines. If the complete sample has been segregated in one direction, stretch the wires in the same direction. Take all the material from the strip between the imaginary two vertical planes between the wires, with all pieces of rock which are completely or for the largest part between the two planes. If so desired, where no segregation of material has taken place, material to be taken can be limited to half the separated strip.

Take a sample, which consists of a not too large number of rocks, by a random collection of the necessary number of rocks. Take the rock pieces at random by choosing them blindfolded by lottery numbers or by selecting rocks at pre-determined but irregular intervals.

FIGURE 0-4: HALVING A SAMPLE BY MEANS OF A SEPARATION PLANE

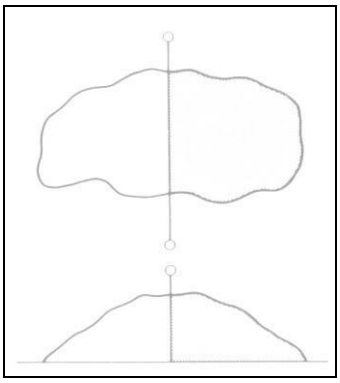
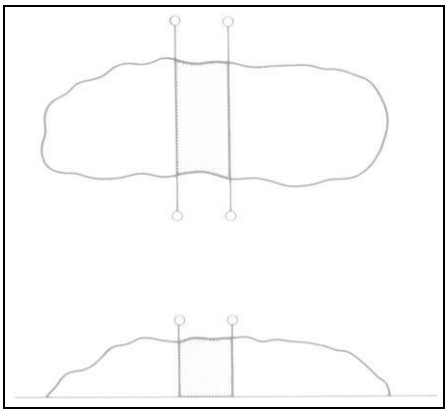


FIGURE 0-5: DIVIDING A SAMPLE WITH TWO SEPARATION PLANES



7.2.4.8 Transport and Identification of the Samples

For the transport of a sample, precautions shall be taken so that no material is broken or lost and that the sample is not contaminated. A sample shall be accompanied by a

certificate drawn up by the person responsible for taking the sample. The certificate shall include the following information:

1. A reference to this specification;
2. The name of the producer and location of the quarry or other source where the broken rock is produced;
3. The description and class designation of the grading;
4. The number of rock pieces in the sample;
5. Details about location and method of sampling, including the date when the sampling took place;
6. The name of the sample taker.

7.2.5 Testing procedure

7.2.5.1 General

Quality control shall take place during production of the rock and should routinely be performed by the producer. Part of the quality control consists of ensuring that the rock is coming from the areas designated in the extraction plan as suitable for rock. Significant variation within the rock source is detected by quality control that focuses on petrography, density, porosity and discontinuity content. The production method shall also be considered to determine the optimum quality control , e.g. quality control of gradings should be more frequent for eye-selected than for mechanically produced rock. The frequency of testing shall be selected to be representative of homogeneous batches of production. It shall be selected by considering the potential range of variability of the properties.

Testing for rock quality is therefore described in this chapter and guidance on the frequency of testing armour stone properties during deliveries is given in TABLE 7-1 below.

TABLE 0-3: GUIDANCE ON FREQUENCY OF TESTING ROCK PROPERTIES DURING DELIVERIES

Property considered	Frequency for mechanically sorted armourstone	Frequency for individually selected armourstone
Size – coarse gradings	every 3000–5000 t	N/A
Mass – light gradings	every 3000–5000 t	N/A
Mass – heavy gradings	every 3000–5000 t	every 1500 – 2500 tonnes
Core material – mass	every 10 000–25 000 t	N/A
Shape – coarse and light gradings	As for size/mass grading testing (see above), but take into account the type of use, ie armour or underlayer	
Shape – heavy gradings	Visual inspection of 50 per cent of the stones	
Integrity	Visual inspection of all stones for heavy gradings; further quality control may be required for borderline blocks or poor integrity	
Rock density, water absorption, durability, strength (using point load at the quarry)	Adapt based on known variability of the source and the risk of further weathering: at least every 20 000 t	

Note: N/A = not applicable

7.2.6 Determination of the weight distribution of quarried rock

7.2.6.1 Equipment and Other Aids

Weighing equipment, accurate to 2% of the NLL

Lifting equipment and lifting aids for pieces that cannot be moved manually.

7.2.6.2 Weighing

Weigh each rock heavier than the ELL separately (W_i), and all pieces lighter than the ELL (the rock fragments) together (W_s), accurate to 2% of the NLL. Record the total weights falling in each weight fraction together with the total number of rocks (n), heavier than the ELL.

7.2.6.3 Calculation

Calculate the total weight $\square W_i$, of pieces equal to or heavier than the ELL.

To obtain the cumulative curve where W_y is the weight for which the fraction y is lighter, calculate the successive points on the curve at weight intervals given in TABLE 0-4.

TABLE 0-4: WEIGHT INTERVALS FOR THE CUMULATIVE WEIGHT PLOT

NLL of grading class (kg)	**Weight interval** (kg)
10-60	5
60-300	25
300-1000	50
1000-3000	200
3000 or greater	500

To obtain only those values of y for which a requirement has been set, i.e. the fractions corresponding to W_y at the ELL, NLL, NUL and EUL, calculate the total weight W_n, for W_y corresponding to each of the four class limits, with the formula:

$$y = \frac{100 W_n}{W_S + \Sigma W_i}$$

where

W_n = the total weight of rocks lighter than W_y (kg).

ΣW_i = the total weight of all pieces heavier than the ELL (kg).

W_s = the total weight of pieces lighter than the ELL (kg).

Calculate the effective mean weight, W_{em}, to the nearest kilogram, using the formula:

$$W_{em} = \frac{\Sigma W_i}{n}$$

where:

W_{em} = the effective mean weight of the rock sample which equals the average weight of rocks heavier than the ELL. n = the number of rocks heavier than the ELL.

7.2.6.4 Report

The following data shall be included in the report:

a) The measured cumulative percentage by weight passing the ELL, NLL, NUL and EUL holes;

b) The average weight of pieces not passing the L hole;

c) The rock density tested according to Section 7.2.8;

d) A reference to this specification;

e) A description of the sample; including its weight;

f) The source of the sample;

g) The date of the inspection.

7.2.7 Determination of shape

7.2.7.1 Subject and Area of Applicability

This test method is used to determine the content of rocks with a length to thickness ratio greater than 3 and 2. It is used to verify the requirement given in Section 3.2. For heavy gradings only, the weighing procedure is unnecessary, as only the number per cent of rocks with length to thickness ratios of greater than 2 and 3 is required.

7.2.7.2 Sample for Analysis

At least 50 pieces shall be taken at random from rocks greater in weight than the ELL.

7.2.7.3 Equipment and Other Aids

Measurement apparatus for the determination of length and thickness of rocks with an accuracy of 3% or better.

Weighing equipment, accurate to within 2% of the lightest piece to be weighed.

7.2.7.4 Execution

Measure the length of each rock as the maximum distance between two points on the rock to within 3% accuracy. Measure the thickness of each rock defined as the minimum distance between two parallel straight lines through which the rock can just pass to within 3% accuracy. Weight the total weight (W_3), of the rocks with a lengthto-thickness ratio of greater than 3 to within 2% accuracy. Determine the total weight (W_t), of the rocks accurately to within 2%. Determine the number of rocks with length-to-thickness ratio greater than 3 (n_3), and the number of rocks with length-to-thickness ratio greater than 2 (n_2). Count the total number of rocks, n.

7.2.7.5 Calculations

Calculate the weight per cent rounded to the nearest 1% of rocks with length-tothickness ration of greater than 3 using the formula:

$$C_{W3} = \frac{100W_3}{W_t}$$

Calculate the number per cent of rocks with length-to-thickness ratio greater than 3 and 2 using the formulae:

$$C_{n3} = \frac{100n_3}{n}$$

$$C_{n2} = \frac{100n_2}{n}$$

7.2.7.6 Report

The report shall provide the following data:

a) The measured weight per cent of rocks with length-to-thickness ratio greater than 3;

b) The measured number per cent of rocks with length-to-thickness ratio greater than 3, and greater than 2;

c) A reference to this specification.

d) A description of the sample, including the weight and the number of rocks;

e) The source of the sample;

f) The date of the test.

7.2.8 Determination of rock density

7.2.8.1 Subject and area of application

This method is for the determination of the density of a natural rock and rock-type materials with a volume of at least 50 ml.

7.2.8.2 Sample for Analysis

The rock shall have a volume of at least 50 ml. If the rocks are very large, a representative part can be used, subject to the minimum volume required.

7.2.8.3 Equipment and other aids

a) Drying oven or other appropriate, adjustable to (110±5)°C.

b) Weighing scales, accurate to 0.05% of the rock weight, suitable for weighing in air and under water.

c) Water-bath, filled with tap water at room temperature and suitable for weighing rocks under water.

d) Thermometers, suitable for recording temperature in the water bath, accurate to 1°C.

e) Moist chamois leather.

7.2.8.4 Execution

Remove all loose parts and brush the rock clean with water. Measure the water temperature in the water-bath to 1°C accuracy. Keep the rock submerged in the tap water at room temperature for at least 5 min and then weigh it submerged (m_1) with an accuracy of 0.05% of the rock's weight.

Take the rock out of the bath, dry it with the moist chamois leather to the point that no shiny-wet surface remains and then weigh the rock (m_2) again with 0.05% accuracy.

Dry the rock in the oven to a constant (steady) weight, which is reached when two consecutive weightings with a 24-hour interval show less than 0.05% loss of total weight.

Weigh the rock again after cooling to room temperature (m_3) with 0.5% accuracy.

7.2.8.5 Calculation

Calculate the density of the rock in kg/m^3 and rounded to 1 kg/m^3 with the aid of the formula:

$$\rho_r = \frac{m_3 \cdot \rho_w}{m_2 - m_1}$$

where ρ_r = the density of the rock.

ρ_w = water density (g/ml) at the test temperature of the water-bath.

m_1 = apparent weight of the rock submerged (g).

m_2 = weight of the damp rock (g).

m_3 = weight of the dry rock (g).

7.2.8.6 Report

The report shall supply the following data:

a) The density of the rock;

b) Reference to this specification;

c) A description, including the weight of the rock and of the part of the rock that is used;

d) Source of the rock; and

e) Date of testing.

7.2.9 Determination of water absorption at atmospheric pressure

7.2.9.1 Subject and Area of Application

This method determines the water absorption at atmospheric pressure of a natural rock or other rock material with a volume of at least 50ml.

7.2.9.2 Sample for Analysis

This rock must have a volume of at least 50ml. If it has a volume in excess of 150 ml, break a part off to leave a volume under 150ml.

7.2.9.3 Equipment and Other Aids

Drying oven or other appropriate apparatus, adjustable to $(110 \pm 5)^0$C.

Weighing scales, accurate to 0.05% of the weight of the rock.

Water-bath filled with tap water at room temperature.

Moist chamois leather.

7.2.9.4 Method of Operation

Remove loose parts and clean the rock by brushing with water. Place the rock submerged in the water-bath. Leave the rock submerged until the weight over a period of 24 hours does not increase more than 0.1%.

Take the rock from the bath, dry it with the moist chamois leather until it leaves a dull surface and weigh it (m_1) to within an accuracy of 0.05%. Dry the rock in the oven to a constant weight (m_2), which is reached when the rock's weight over an interval of 24 hours does not reduce more than 0.05%.

7.2.9.5 Calculation

Calculate the water absorption of the rock in percentage and rounded to 0.1% with the aid of the formula:

$$c = \frac{m_1 - m_2}{m_2} \cdot 100$$

where: c = water absorption at atmospheric pressure. m_1 = weight of a moist rock after absorption (g). m_2 = weight of a dry rock (g).

7.2.9.6 Report

The report must contain the following data:

a) The water absorption at atmospheric pressure;

b) Reference to this specification;

c) A description of the rock with its weight and, if used , of the part rock;

d) Source of the rock;

e) Date of testing.

7.2.10 Determination of the drop test breakage index

7.2.10.1 Subject and Area of Application

This method is used to determine the percentage of rock loss from heavy gradings of rock in a standard drop test, the percentage being described as the Drop Test Breakage Index.

7.2.10.2 Sample for Analysis

The sample shall contain at least 50 pieces taken at random from the ELL weight of the grading class in question.

7.2.10.3 Equipment and Other Aids

a) Suitable hydraulic grab (e.g. orange-peel type).

b) Weighing equipment, accurate to within 2% of the lightest piece to be weighed.

c) Bed of rocks of same grading as the sample to be tested.

d) Sufficient volume of crushed rock aggregate to give a 0.5 m thick layer covering an area to support the bed of rocks.

7.2.10.4 Execution

Determine the individual weights of the rock sample prior to the test in accordance with Clause 7.2.6. Prepare the bed of rocks by laying them out in a single compact layer on a 0.5 ± 0.05 m thick, layer of crushed rock aggregates. Subject each block in the test sample, in turn, to a drop of fall height 3 m ± 0.1m onto the bed of rocks. Record the result of each drop, such record to include the number and type of visible flaws in blocks and the number and type of blocks resulting.

Remove the block, or broken parts thereof, from the bed of rocks. Set aside all resulting pieces whose weight is greater than the ELL weight, or whose weight is assessed to be close to the ELL weight, for further weightings. Clear all rock fragments from the bed of rocks, leaving clean surfaces prior to dropping the next block in the test sample.

Individually weigh each rock piece in the test sample heavier than the ELL on completion of drop testing accurate to within 2% of the NLL weight. Record the total weights in each weight fraction.

7.2.10.5 Calculation

Calculate the cumulative weight distribution curves for the sample prior to drop testing and after drop testing for all pieces heavier than the ELL and calculate the median sample weight before testing (W_{50i}) and after testing (W_{50f}), all in accordance with Clause 7.2.6.3. Calculate the drop test breakage index, I_d, as

$$I_d = [(W_{50i} – W_{50f})/W_{50i}] * 100\%$$

7.2.10.6 Report

The following data shall be included in the report:

a) The Drop Test Breakage Index;

b) A reference to this specification;

c) A description of the sample, including its weight;

d) The source of the sample;

e) The date of the testing.

If agreed beforehand, the cumulative weight distributions before and after testing shall be provided and it is recommended that this be on a single graph.

8. SURVEY

8.1 General requirements

Breakwater profiles shall be plotted at a scale of 1:100 and provided in digital CAD format. Survey points shall be recorded with a horizontal accuracy of 500 mm and a vertical accuracy of 100 mm. This tolerance applies to the bottom of the survey staff or probe and any inclination of the staff or probe shall be accurately accounted for in the survey method.

8.2 Survey of rock layers

Measurements shall be carried out using a probe connected to a rigid stem with a rigid connection between stem and special spherical end of diameter $0.5D_{n50}$ unless for reasons such as health and safety, an alternative method is deemed necessary e.g. 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 Project Manager for acceptance. The Contractor may propose alternative measurement methods using multi beam sonar below water level and conventional survey methods above.

Measurements shall be carried out at 2 m intervals (measured horizontally) across the measurement profile, and 1 m at toe and benches.

Measurement profiles shall be at intervals along the length of the structure proposed by the Contractor and accepted by the Project Manager. The survey intervals shall be not less than 10 m, but shall be more frequent as directed by the Project Manager where the profile is changing rapidly or on tight-radius curves.

The Contractor shall provide and maintain chainage markers at the accepted measurement intervals along the lines of the parts of the Works that involve armourstone. Chainage markers shall be visible from both the land and seaward side of the structure. Surveyed sections shall extend to a distance of 5 m beyond the asconstructed 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 accepted by the Project Manager.

The *Project* Manager may order the *Contractor* to perform a post storm re-survey of the rock layers at no additional cost to the Employer in areas where in the *Supervisor* considers storm damage may have occurred, before covering with a subsequent layer.