ACS1330 Rock Armour

Contents

ACS1330.1 Scope

This Specification sets out the material requirements for Rock Armour in Coastal Environments, comprising rock used for armour and underlayers in the construction of breakwaters, groynes, revetments and other types of coastal works in Auckland Council-family projects (see ACS1330.4).

This Specification specifically excludes:

- Rock used as core and filter material within breakwaters and groynes, which should be specified in accordance with Auckland Council Standard Specification ACS510 Earthworks.
- Rock used for wire gabion baskets and mattresses, which should be specified in accordance with Auckland Council Standard Specification ACS1340 Gabions and Reno Mattresses.
- Construction aspects of structures incorporating Rock Armour.

ACS1330.2 Interpretation

Where other standards, specifications and guidelines are referenced herein (see ACS1330.3) the latest edition shall always be used.

In the event of any conflict or inconsistency between this Specification and other Auckland Council standard specifications, the provisions of this Specification shall prevail for the stated scope.

ACS1330.3 Referenced standards, specifications and guidelines

The following Standards and Specifications are referenced by this Specification:

NZS 4407	Methods of sampling and testing road aggregates.
NZS 3111	Methods of test for water and aggregate for concrete.
AS2758.6	Aggregates and rock for engineering purposes - Guidelines for the specification of armourstone.
AS1141.24	Methods for sampling and testing aggregates – Aggregate soundness: Evaluation by exposure to sodium sulphate solution.
CIRIA, CUR, CETMEF	The Rock Manual: The use of rock in hydraulic engineering (2nd edition).
ACS510	Auckland Council Standard Specification for Earthworks.

ACS1330.4 Terms, definitions, symbols and abbreviations

ACS1330.4.1 Terms and definitions

For the purposes of this document, the following terms and definitions apply:

Term	Definition
Contract Works Specification	A definitive document detailing the technical requirements, materials, and procedures for a specific construction project, which forms a key part of the contractual agreement between involved parties that may include departures from this Specification.
Rock Armour	Coarse rock used in hydraulic structures and other civil engineering works to protect land or structures from erosion.
Rock Armour grading	Distribution defined by grading limits, with regard to size or mass of individual rocks.
Slope	The inclined face of a cutting or embankment. In the context of coastal structures, it refers to the sloped surface of groynes, revetments, or breakwaters.
Source	The specific location and geological formation from which rock is extracted. Each new face within a quarry shall be considered a new source.
Square opening sieve size	The smallest square sieve size through which a rock can pass.

ACS1330.4.2 Symbols and abbreviations

For the purposes of this document, the following symbols and abbreviations apply:

Symbol/Acronym	Definition	Unit
D	The smallest square sieve size through which a rock can pass.	(m)
d	The minimum distance between two parallel lines through which the rock can pass.	(m)
D_{50}	The median rock diameter, where 50% of the total number of rocks in the sample is made up of smaller rocks, and 50% is made up of larger rocks.	(m)
D_n	The nominal diameter, defined as the edge length of a cube with the same volume as the rock.	(m)
ELL	Extreme lower limit is the mass or sieve size below which 0% of rocks are permitted to pass, based on rock count.	(kg) or (m)
EUL	Extreme upper limit is the mass or sieve size below which 100% of rocks must pass, based on rock count.	(kg) or (m)
F	A force applied to rock samples to induce deformation or failure.	(kN)
L	The greatest distance between any two points on the rock.	(m)
L/d	Length-to-thickness ratio.	
NLL	Nominal lower limit is the mass or sieve size below which no more than 10% of rocks are permitted to pass, based on rock count.	(kg) or (m)
NUL	Nominal upper limit is the mass or sieve size below which no less than 70% of rocks are permitted to pass, based on rock count.	(kg) or (m)
M_{50}	The median rock mass, where 50% of the total number of rocks in the sample is made up of lighter rocks, and 50% is made up of heavier rocks.	(kg)
ρ	Material density, typically measured as the mass of a substance per unit volume.	(kg/m^3)

V	Volume, a physical quantity expressing the amount of three-dimensional space an object occupies.	(m^3)

ACS1330.5 Source materials

The nominated source materials shall comprise natural rock of igneous, or high-grade thermal metamorphic origin. Generally, quarried good-quality basalt, andesite, or greywacke are considered acceptable. Complying site-won, river-sourced or paddock rock may also be considered acceptable. Sedimentary rocks such as shales, mudstones, claystones, bedded sandstones, or slates are deemed unsuitable.

The nominated source material/s shall be sound, uniform in consistency and quality, and free from contaminants, signs of Sonnenbrand, or impurities in such quantities that could compromise structural performance or lead to the release of silt, sediment, or pollutants harmful to the coastal marine environment.

Rock Armour shall not be sourced from sites or structures listed on the Ministry for the Environment (MfE) Hazardous Activities and Industries List (HAIL)[1].

Specific source material properties are specified in ACS1330.9.2.

ACS1330.6 Stockpiles

Rock Armour of different grading classes shall be stockpiled separately to prevent cross-contamination and to facilitate quality assurance. Additionally, Rock Armour from different sources shall be stockpiled separately.

All stockpiles shall be managed to prevent material segregation or breakdown, with clear separation from water courses to mitigate risks of clay/silt contamination, in accordance with Auckland Council Standard Specification ACS510 Earthworks.

ACS1330.7 Sampling and testing

Representative samples of Rock Armour shall be taken from the conveyor belt, bin, stockpile, barge, or truck, in accordance with NZS 4407, Part 2. Sampling for the specified source and production properties shall follow the sampling rates outlined in ACS1330.9.3 and ACS1330.10.3.

[1] The current edition of the HAIL shall always be used. Refer to the MfE website for the latest version.

All source property testing per ACS1330.9.2 shall be conducted by a laboratory with current IANZ accreditation for the specified tests, unless explicitly noted otherwise. For such testing, smaller rock fragments may be used if they are naturally occurring or produced by crushing Rock Armour from the same source. Where the maximum aggregate size exceeds NZS 4407: Part 2, Clause 2.3, a minimum field sample mass of 150 kg is required.

Production property testing per ACS1330.10.2 shall be conducted at the quarry by a suitably qualified and experienced person only after confirming source property conformance.

ACS1330.8 Compliance

Rock Armour that does not comply with this Specification shall be deemed non-conforming.

ACS1330.9 Source property tests

ACS1330.9.1 General

The suitability of the nominated source material/s for use as Rock Armour shall first be demonstrated by the source property tests in ACS1330.9.2 and ACS1330.9.3.

The source property testing shall be completed on samples of the source material/s to be used for Rock Armour.

For Rock Armour comprising materials from more than one source, the requirements of ACS1330.9.2 and ACS1330.9.3 shall apply to each individual source material.

ACS1330.9.2 Durability and quality

ACS1330.9.2.1 Mass density

When tested in accordance with NZS 4407 Test 3.7.2, the mass density of the rock intended for use as Rock Armour shall exceed 2650 kg/m^3.

ACS1330.9.2.2 Crushing resistance

The crushing resistance of rock shall be tested in accordance with NZS 4407, Test 3.10 or NZS 3111, Section 14. The minimum crushing resistance shall not be less than 130kN when the rock is crushed to produce 10% fines.

ACS1330.9.2.3 Rock integrity

Rock integrity shall be confirmed through visual assessment by a suitably qualified and experienced person; IANZ-accredited laboratory testing is not required. Rock Armour shall be free from visually observable cracks, veins, fissures, laminations, unit contacts, cleavage

planes, or other such flaws that could cause breakage during handling or placement. Rock damaged to the extent it no longer meets ACS1330.10.2.3 shall be rejected and removed.

If more than five handlings are required between the source and final placement or as specified in the Contract Work Specification, a Drop Test shall be conducted on-site, as per Section 3.8.5.2 of the Rock Manual (CIRIA, 2007). Individual rocks, selected according to the sampling rates in ACS1330.9.3, shall be weighed, dropped from a height of 3 m onto a bed of similarly sized rocks, and then re-weighed to determine the mass of the largest remaining piece.

The breakage index shall be determined by subtracting the cumulative mass of the largest remaining pieces from the total initial mass of the tested rocks, then dividing the result by the total initial mass of the tested rocks. The resultant breakage index for Rock Armour shall be less than 5%.

ACS1330.9.2.4 Weathering resistance

The weathering resistance of rock shall be tested in accordance with NZS 4407, Test 3.11 or NZS 3111, Section 15. Rock Armour shall achieve a quality index of AA, AB, or BA.

ACS1330.9.2.5 Abrasion resistance

The abrasion resistance of rock shall be tested using the Los Angeles Abrasion Test in NZS 4407, Test 3.12. The mass loss after 500 revolutions shall not exceed 25% for Rock Armour.

ACS1330.9.2.6 Water absorption

The water absorption of rock shall be tested in accordance with NZS 3111, Section 12. The water absorption for Rock Armour shall not exceed 1.5%.

ACS1330.9.2.7 Soundness

If water absorption exceeds 0.5% as determined in ACS1330.9.2.6 , a sodium sulphate soundness test shall be conducted in accordance with AS 1141.24. The percentage loss determined shall be less than 6%.

ACS1330.9.3 Compliance

Table 1 specifies the required sampling rates for source property testing and summarizes the acceptance criteria for each test as discussed in ACS1330.9.2.

Table 1: Minimum sampling rate for source property tests

Section	Property	Test method	Frequency of testing	Acceptance criteria
ACS1330.9.2.1	Mass density	NZS 4407, Test 3.7.2 or NZS 3111, Section 14: Solid density of aggregate particles - immersion in water method for coarse aggregate.	Five per source [1]	Refer ACS1330.9.2.1
ACS1330.9.2.2	Crushing resistance	NZS 4407 Test 3.10: The crushing resistance of coarse aggregate under a specified load.	One per source[1]	> 130kN, < 10% fines
ACS1330.9.2.3	Rock integrity	Rock Manual (CIRIA, 2007), Section 3.8.5.2: Drop Test	Once per source[1] where more than 5 handlings required (at least 20 rocks)	BI < 5%
ACS1330.9.2.4	Weathering resistance	NZS 4407, Test 3.11 or NZS 3111, Section 15: The weathering quality index of coarse aggregate.	One per source [1]	AA, AB or BA
ACS1330.9.2.5	Abrasion resistance	NZS 4407, Test 3.12: The abrasion resistance of aggregate by the use of the Los Angeles machine.	One per source [1]	< 25% loss after 500 revolutions
ACS1330.9.2.6	Water absorption	NZS 3111 Section 12: Method for determining the density and absorption of coarse aggregate.	One per source [1]	< 1.5%
ACS1330.9.2.7	Soundness	Sodium Sulphate Soundness Test, AS1141.24 Aggregate soundness - Evaluation by exposure to sodium sulphate solution	One per source[1], if required, depending on result of ACS1330.9.2.6	< 6%

Note:

[1] Each source shall be sampled and tested for every 10,000 m^3 produced (measured loose in stockpile), or at least once per year, whichever occurs first (NZTA M04: 2024).

ACS1330.10 Production property tests

ACS1330.10.1 General

The suitability of the Rock Armour shall be demonstrated through sampling and testing as specified in ACS1330.10.2 and ACS1330.10.3.

The production property testing shall be conducted prior to delivery.

ACS1330.10.2 Geometric requirements

ACS1330.10.2.1 Rock angularity

All Rock Armour shall be angular and blocky, with surfaces bounded by sharp edges and corners, and shall have an equant and/or irregular shape with relatively flat faces. Rounded rocks, without clear edges and corners, shall be deemed non-conforming.

The angularity of the Rock Armour shall be determined based on visual inspection. Examples of angular, blocky, semi-rounded and fully rounded rock according to Bradbury et al. (1988)[2] are shown in Appendix A.

ACS1330.10.2.2 Rock shape

All Rock Armour shall be equi-dimensional, with elongated or thin slabs deemed unacceptable. The length-to-thickness (L/d) ratio of rock shall be assessed in accordance with the methodology and apparatus specified in EN 13383-2, Clause 7, and the sampling rates specified in ACS1330.10.3. No individual rock shall have a ratio exceeding 3.

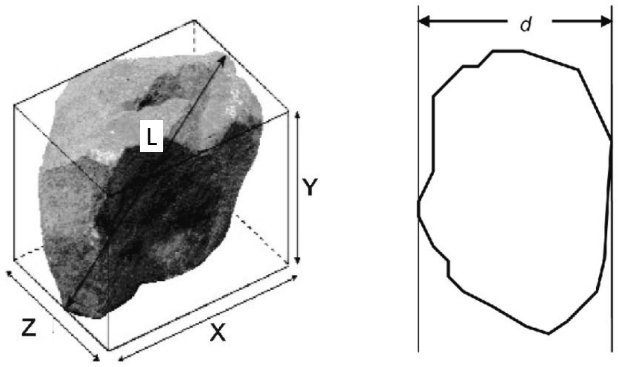

Figure 10.1: Illustration of armour rock shape measurements (CIRIA, 2007).

[2] Bradbury, A. P., Allsop, N. W. H., Latham, J.-P., Mannion, M., & Poole, A. B. (1988). *Rock armour for rubble mound breakwaters, sea walls, and revetments: Recent progress* (Report SR 150). Hydraulics Research, Wallingford.

Length (L) is defined as the greatest distance between any two points on the rock, and thickness (d) as the minimum distance between two parallel lines through which the rock can pass (Figure 10.1). The orientation of length and thickness is independent.

ACS1330.10.2.3 Rock grading

All Rock Armour shall be well graded, conforming to the standard gradings in Table 2. Poorly or gap-graded rock shall not be permitted. Grading checks shall be undertaken during production in accordance with the sampling rates in ACS1330.10.3.

Table 2: Standard Rock Armour grading classes for use in the Auckland Region

Class	Percentage passing	ELL	NLL	NUL	EUL	Acceptable M50	
		0%	< 10%	> 70%	100%	Lower limit	Upper limit
1	Rock mass M (kg)	2000	2400	5500	9000	3800	4600
	Indicative 'square opening sieve size' D (m) [1]	1.10	1.15	1.50	1.80	1.35	1.45
2	Rock mass M (kg)	700	800	2400	4500	1500	1800
	Indicative 'square opening sieve size' D (m) [1]	0.75	0.80	1.15	1.40	0.95	1.05
3	Rock mass M (kg)	200	230	800	1500	450	550
	Indicative 'square opening sieve size' D (m) [1]	0.50	0.55	0.80	1.00	0.65	0.75
4	Rock mass M (kg)	30	50	230	450	100	120
	Indicative 'square opening sieve size' D (m) [1]	0.25	0.30	0.55	0.65	0.38	0.42
5	Rock mass M (kg)	8	10	50	125	25	35
	Indicative 'square opening sieve size' D (m) [1]	0.15	0.20	0.30	0.45	0.25	0.28

Note:

[1] Indicative square opening sieve size is based on an assumed rock density of $\rho = 2650 kg/m^3$ and assumption of mass = $\rho (0.84D)^3$, (values rounded).

Where a calibrated load cell (or equivalent) is available, or rocks can be weighed by construction plant, the rock mass shall be used to determine grading compliance. Rocks shall be weighed individually, with its mass recorded in a grading table and marked on the rock.

If weighing equipment is not available, compliance shall be determined by estimating the smallest equivalent ‘square opening sieve size’ through which the rock could pass. This is calculated by measuring the maximum (X), intermediate (Y), and minimum (Z) dimensions of the smallest hypothetical box enclosing the rock, as shown in Figure 10.2. The dimensions X, Y, and Z shall be recorded, with Y representing the 'square opening sieve size’.

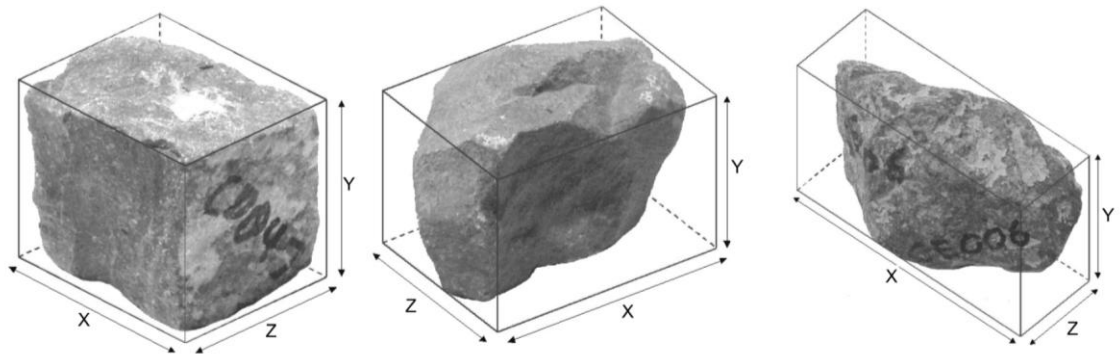

Figure 10.2: Measurement of hypothetical rectangular box that encapsulates the rock being measured (CIRIA, 2007).

To facilitate stockpile sorting during production, the quarry shall establish reference rocks adjacent to each stockpile after the grading check. Three rocks representing the ELL, three at the median, and three at the EUL shall be selected, spray-painted with their mass or square sieve size, and kept separate but adjacent to the stockpile area. These reference rocks shall remain with the stockpile for the duration of the works and shall not be incorporated in the structure.

ACS1330.10.3 Compliance

Table 3 specifies sampling rates and acceptance criteria for production property testing.

Table 3: Minimum sampling rate for production property tests

Section	Test	Test method	Frequency of testing	Acceptance criteria
ACS1330.10.2.1	Rock angularity	Visual inspection	Initial 50 rock check per source[1]	Refer ACS1330.10.2.1
ACS1330.10.2.2	Rock shape	Length-to-thickness ratio	Initial 20 rock check per source [1], followed by a record of at least 1 test (20 rocks) per 1,000 m^3 produced	L/d < 3
ACS1330.10.2.3	Rock grading	Percentage passing by rock count.	Initial 50 rock check per source [1], followed by a record of at least 1 test	Refer ACS1330.10.2.3

Section	Test	Test method	Frequency of testing	Acceptance criteria
			(20 rocks) per 1,000 m^3 produced	

Note:

[1] Each source shall be sampled and tested for every 10,000 m^3 produced (measured loose in stockpile), or at least once per year, whichever occurs first (NZTA M04: 2024).

Appendix A Visual Indicators of Rock Angularity

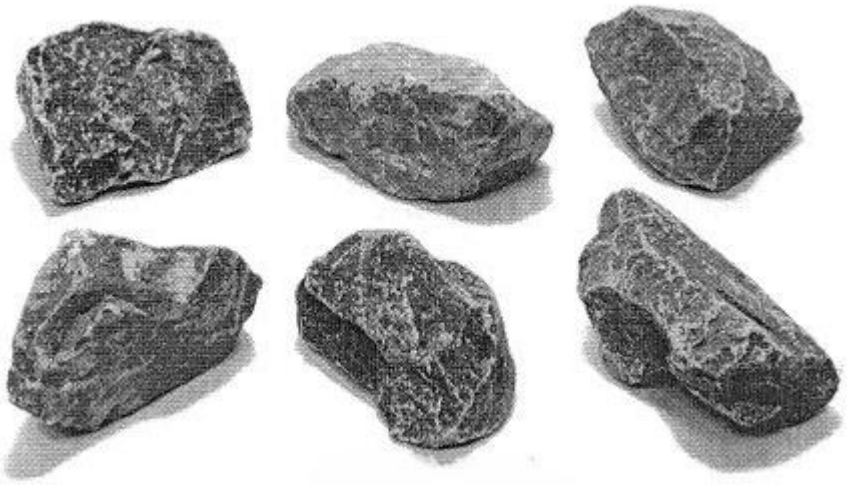

Figure A.1: Angular rock (Source: Bradbury et al. 1988).

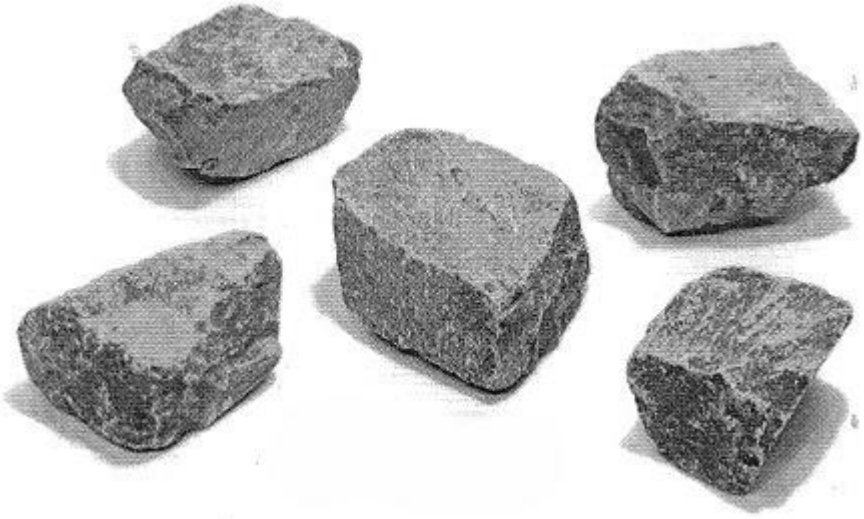

Figure A.2: Blocky rock (Source: Bradbury et al. 1988).

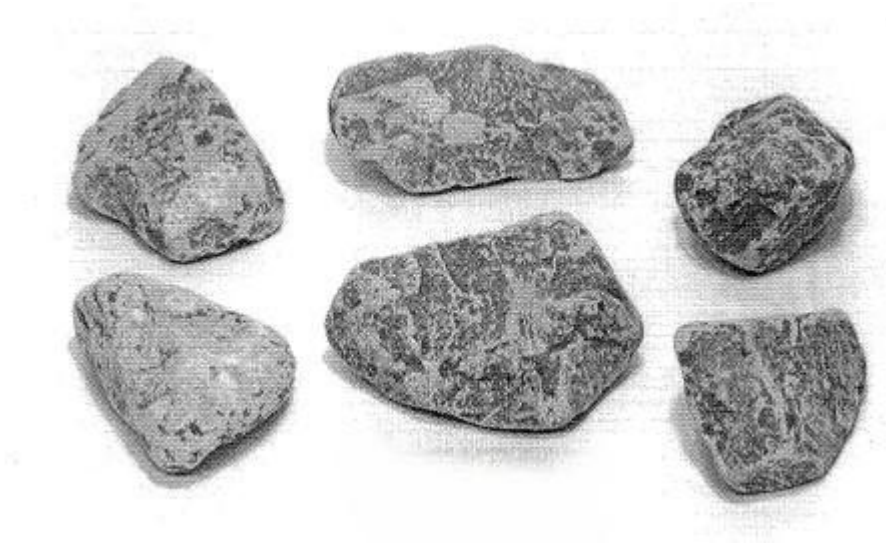

Figure A.3: Semi-rounded rock (Source: Bradbury et al. 1988).

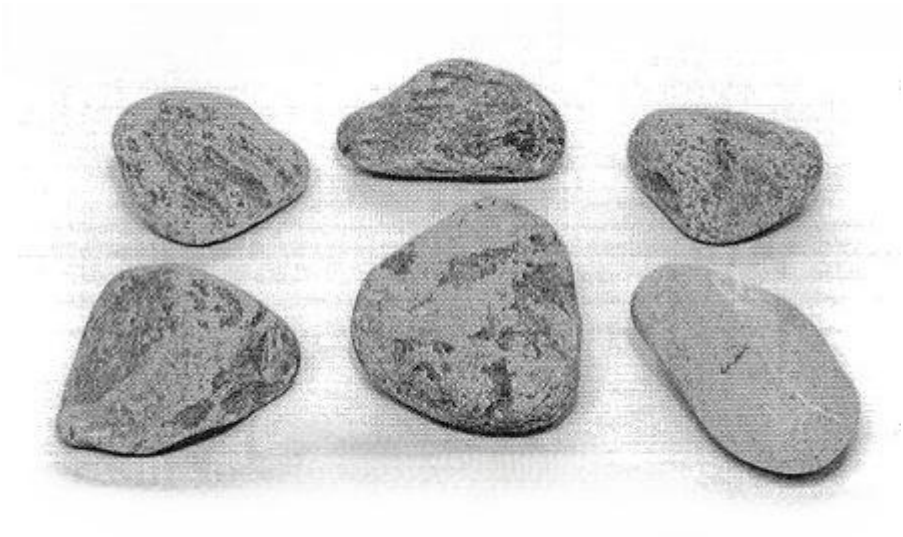

Figure A.4: Rounded rock (Source: Bradbury et al. 1988).

Appendix B Rock Armour Grading Worksheet

Rock Armour Class: _____ **Source:** _____

Client: _____ **Date:** _____

Rock #	X (m)	Y (m)	Z (m)	Mass (kg)
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
21				
22				
23				
24				
25				
26				
27				

Rock #	X (m)	Y (m)	Z (m)	Mass (kg)
28				
29				
30				
31				
32				
33				
34				
35				
36				
37				
38				
39				
40				
41				
42				
43				
44				
45				
46				
47				
48				
49				
50				
Minimum				
10th percentile				
Median				
70th percentile				
Maximum				