ACCROPODE™ Design Guide Table

Unit Volume (m³)	V = 0,34H³		1.0	2.0	3.0	4.0	5.0	6.0	8.0	10.0	12.0	14.0	16.0	18.0	20.0	22.0	24.0	28.0
Unit Height (m)	H = (V/0.34)$^{(1/3)}$		1.43	1.81	2.07	2.27	2.45	2.60	2.87	3.09	3.28	3.45	3.61	3.75	3.89	4.01	4.13	4.35
Equivalent Cube Size (m)	Dn = V$^{1/3}$		1.00	1.26	1.44	1.59	1.71	1.82	2.00	2.15	2.29	2.41	2.52	2.62	2.71	2.80	2.88	3.04
Armour Thickness (m)	T = 1,29 Dn		1.29	1.63	1.86	2.05	2.21	2.34	2.58	2.78	2.95	3.11	3.25	3.38	3.50	3.61	3.72	3.92

Armour concrete consumption and coverage	Packing density Φ (-)		0.645	0.645	0.645	0.643	0.642	0.640	0.637	0.634	0.631	0.628	0.625	0.625	0.625	0.625	0.625	0.625
	Consumption (m³/m²)		0.645	0.813	0.930	1.021	1.098	1.164	1.275	1.366	1.445	1.514	1.575	1.638	1.697	1.751	1.803	1.898
	Number of units (u/m²)		0.645	0.406	0.310	0.255	0.220	0.194	0.159	0.137	0.120	0.108	0.098	0.091	0.085	0.080	0.075	0.068
	Porosity (%)		50.00	50.00	50.00	50.12	50.24	50.36	50.60	50.83	51.07	51.31	51.55	51.55	51.55	51.55	51.55	51.55

Filter stone underlayer - to meet the following requirement NUL/NLL < 3.0	NLL (tons)	Standard	0.17		0.34		0.50		0.67		0.84		1.01		1.34		1.68		2.02		2.35		2.69		3.02		3.36		3.70		4.03		4.70	
		Min/Max*	0.1	0.2	0.2	0.4	0.4	0.7	0.5	0.9	0.6	1.1	0.7	1.3	0.9	1.7	1.2	2.2	1.4	2.6	1.6	3.1	1.9	3.5	2.1	3.9	2.4	4.4	2.6	4.8	2.8	5.2	3.3	6.1
	NUL (tons)	Standard	0.34		0.67		1.01		1.34		1.68		2.02		2.69		3.36		4.03		4.70		5.38		6.05		6.72		7.39		8.06		9.41	
		Min/Max*	0.2	0.4	0.5	0.9	0.7	1.3	0.9	1.7	1.2	2.2	1.4	2.6	1.9	3.5	2.4	4.4	2.8	5.2	3.3	6.1	3.8	7.0	4.2	7.9	4.7	8.7	5.2	9.6	5.6	10.5	6.6	12.2
	Thickness (m) for standard NLL&NUL Specific density 2,6 t/m3	Kt=1,15	1.06		1.33		1.52		1.68		1.81		1.92		2.11		2.28		2.42		2.55		2.66		2.77		2.87		2.96		3.05		3.21	
		Kt=0.9*	0.83		1.04		1.19		1.31		1.41		1.50		1.65		1.78		1.89		1.99		2.08		2.17		2.24		2.32		2.38		2.51	

This table is to be used together with the note "Additional essential information regarding the tables" here appended.

: Geometrical characteristics of unit

: Recommended values for use at preliminary design stage

: (*)The information in this section is to be used with a compulsory analysis by a experienced coastal engineer even at preliminary stage - Ratio NUL/NLL should be kept between 2 and 3

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Graph 1-Relationship between the design wave height as a function of the armour unit volume.

This graph is valid for trunk section. For roundhead the unit volume should be increased by min 30%.

Graph 2-Relationship between the K_D stability coefficient and the seabed slope.

— Seabed slope 1%   — Seabed slope 2.5%
— Seabed slope 5%   — Seabed slope 10%
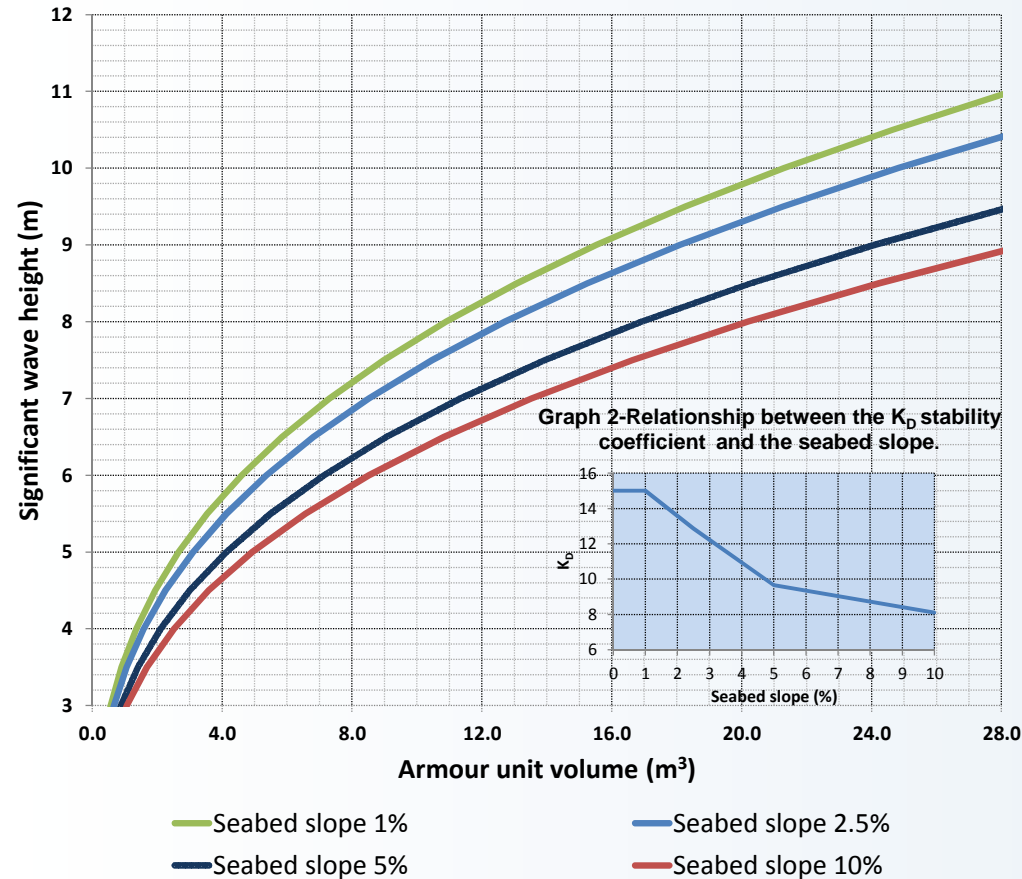
Sketch 1 : 3D view of the roudhead and transition with the trunk part

≥ 1.3 W

W
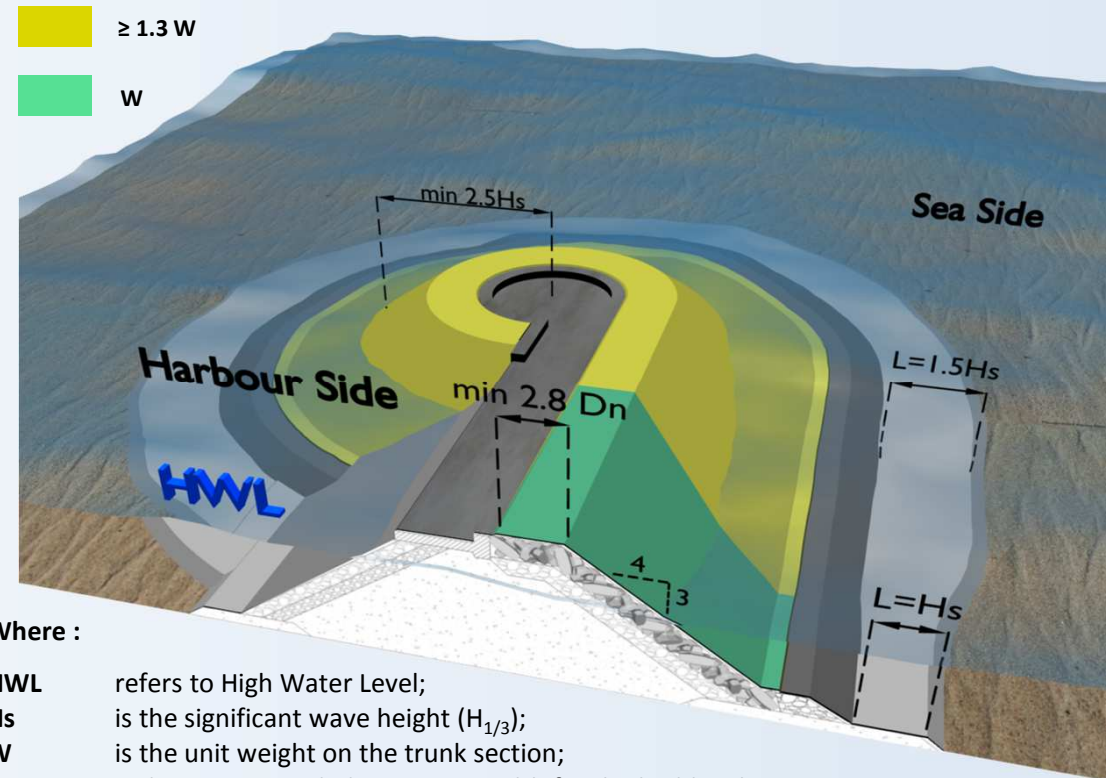
Where :

HWL	refers to High Water Level;
Hs	is the significant wave height ($H_{1/3}$);
W	is the unit weight on the trunk section;
L	is the recommended minimum width for the bedding layer ;

The transition between two sizes of armour unit, in this case the roundhead armour and the trunk armour, is to be built with an angle of 45° in the plane of the underlayer.

These preliminary guidelines for design shall be adpated case per case to projects. We recommend to contact CLI in order to share the expertise gained on many project completed worldwide and CLI updated knowledge. Please refer to the note "Additional essential information regarding the tables" here appended. A calculator is available on the CLI website.

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The proprietary information presented in this document is not a substitute for calculations undertaken by a professional engineer during the design of a breakwater. The information is only intended as guidance to assist the design engineer in completing preliminary calculations.

The final design of a breakwater may include consideration of many items including the seabed geotechnical conditions, the bathymetry of the seabed, the design wave conditions, the quality of concrete for the armour units, the availability of quarried rock, the required performance of the breakwater (such as overtopping) and may involve a physical model of the breakwater subjected to wave action.

The aim of this document is to provide additional information and preliminary recommendations regarding the parameters provided in the Design Guide Table.

First page

The following information is presented in each table:

Unit Volume

The CLI tables indicate some standard values of unit volume. However, other values can be used, notably the unit sizes already used in the past for which moulds are already available.

Armour unit volumes lower than 1.0m^3 are most of the time not cost-effective.

ACCROPODE™ units larger than 28 cubic meters should not be used without specific investigations.

Height of Armour Unit

The unit height of the armour unit is calculated using the shape coefficient, based on the following expression:

$$H = \left(\frac{V}{K_S}\right)^{\frac{1}{3}}$$

With the following coefficient value:

ACCROPODE™　　　　　　　　$K_S = 0.3400$

Equivalent Cube Size

This parameter is derived based on the following formula:

$$Dn = V^{\frac{1}{3}}$$

Armour Layer Thickness

The armour layer thickness is a theoretical value obtained by multiplying Dn by the thickness coefficient (K_t). The following K_t values are applicable for the different CLI concrete units:

ACCROPODE™　　　　　　　　$K_t = 1.29$

Coverage

Packing density : a non-dimensional parameter that characterizes placement density and allows comparison of the different types of armour units.

This parameter is derived based on the following formula:

$$N/_A = \emptyset \, V^{-\frac{2}{3}}$$

Consumption: concrete volume /m² of armour.

Number of units: number of units /m² of armour.

Porosity: percentage of voids in the armour taking into consideration the theoretical armour thickness.

Underlayer

The underlayer rock categories presented in the tables give standard Nominal Lower Limit (NLL) and Nominal Upper Limit (NUL) (respectively 7% and 14% of the armour unit mass) of the underlayer filter stone. These values have been calculated assuming a concrete specific gravity of 2.4 t/m³ and a rock specific gravity of 2.6 t/m³.

An extension of 30% below (NLL) and above (NUL) has been successfully used in projects and is acceptable in most standard cases and the values Min/Max indicate the maximum possible extension of NLL and NUL if NUL/NLL remains less than 3.0.

It remains the design engineer's to determine the most suitable underlayer stone categories for underlayers on his specific project. Meeting the underlayer rock grading limits for use under the CLI armour units is only a part of the issues. Stability of the underlayer profile during works is to be carefully considered.

The thickness of the underlayer presented in the tables is calculated using thickness coefficients (K_t) of 1.15 and 0.9. The value 1.15 is considered by CLI to be appropriate in any site condition for preliminary calculations. It is noted that the CIRIA rock manual (CIRIA 2007) recommends a thickness coefficient around 0.9, varying in function of rock shape. Such low thickness coefficient should only be used in controlled conditions during works.

Second page

The following notes describe the information that can be obtained from the graphs.

Graph 1 and 2 illustrate the possible influence of the seabed slope on the armour stability.

Graph 1

Graph 1 presents armour unit volume (**V**) as a function of wave height (Hs = $H_{1/3}$) for different seabed slopes (1, 2.5, 5 and 10%). The calculation is based on the Hudson formula:

$$V = \frac{H_S^3}{K_D \times \Delta^3 \times \cot \propto}$$

- K_D is the stability coefficient (please refer to § Graph 2 and Sketch 1).
- Δ is the relative buoyant density of the material.
- $\cot\alpha$ is the armour slope. Note that with the CLI single layer units, gravity has a significant influence on the interlocking of the units and the stability of the armour layer. Flatter slopes do not result in an increase in stability. In the preliminary design phase, CLI recommends that slopes of 4/3 or 3/2 be used. CLI does not recommend a slope flatter than 3/2

These graphs are valid only for permeable core and permeable underlayer.

Graph 2

Graph 2 presents the value of the stability coefficient K_D as a function of seabed slope. This curve is appropriate for structures located in the breaking zone. For non-breaking wave conditions, the K_D value for the 1% seabed slope can be used.

Sketch 1

Sketch 1 illustrates several design aspects and provides some preliminary information to assist the designer.

The roundhead of the breakwater requires extra protection. CLI recommends that the armour unit size at the roundhead be increased by 30% over the size calculated for the trunk section.

CLI also recommends a minimum distance of 2.5 Hs between the central point of the roundhead and the high water level on the armour layer. This is equivalent to a radius of 2.5 Hs, as illustrated in the sketch. This minimum radius is recommended to achieve the required interlocking between the armour units.

The transition between two different sizes of CLI armour units, or between ACCROPODE™ units and rock armour, should be achieved with a 45° slope in the plane of the underlayer.

References

Denechere, M. Thomson, I. (1999). "Experience with single-layer breakwater armour". Proceedings of COPEDEC'99, Cape Town, South Africa.

CIRIA, CUR, CETMEF (2007). "The Rock Manual. The use of rock in hydraulic engineering (2nd edition)". C683, CIRIA, London.

CLI ACCROPODE™, ACCROPODE™ II / ECOPODE™ and CORE-LOC™ brochures and tables.

Web site Computing tool.

Contact

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