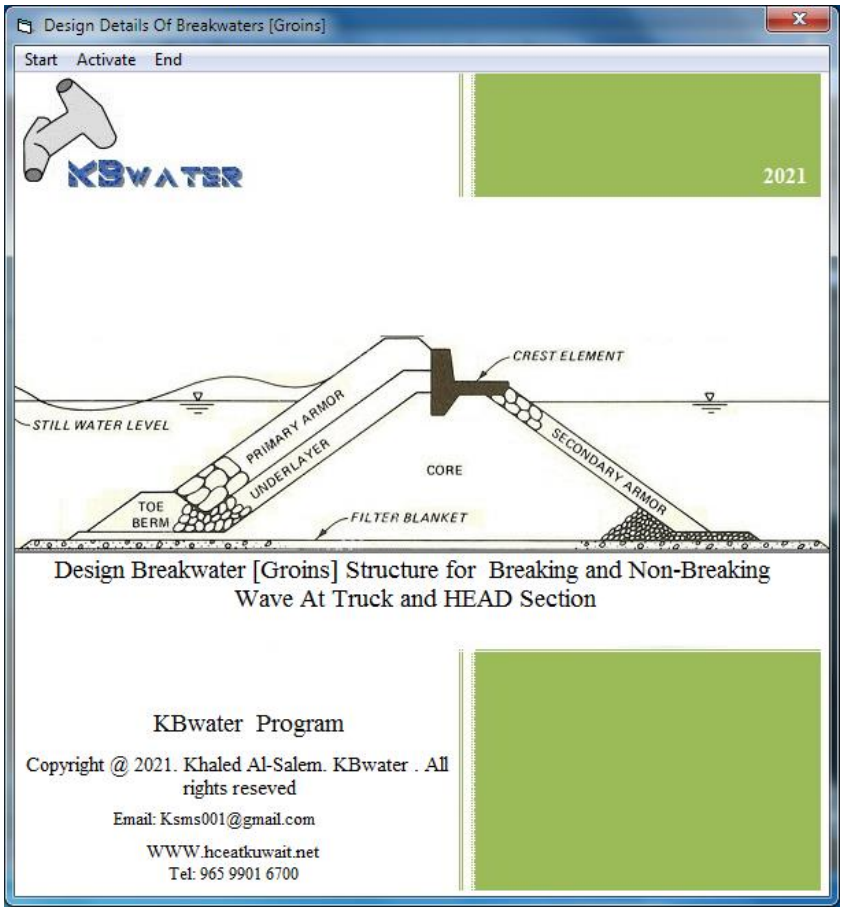
Technical Report



DETAILES DESIGN PRINCIPLES OF BREAKWATERS

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Introduction

Breakwaters are structures constructed on coasts as part of coastal management or to protect an anchorage from the effects of both weather and longshore. Breakwater is the oldest coastal structure used by human being. A thorough knowledge of the basics of the dynamics of waves, currents, tides, cyclones, storm surges and its influence on the breakwater in terms of disturbing actions, scours and response are essential for a successful deign of breakwater.

Breakwaters are basically classified as

- Rubble mound Breakwaters and Vertical breakwaters
- Composite Breakwaters (Horizontally composite and Vertically Composite)
- Floating breakwaters and Special type of breakwaters.

Rubble mound breakwaters are built using natural rubbles *Figure 1* and they are good energy dissipaters.

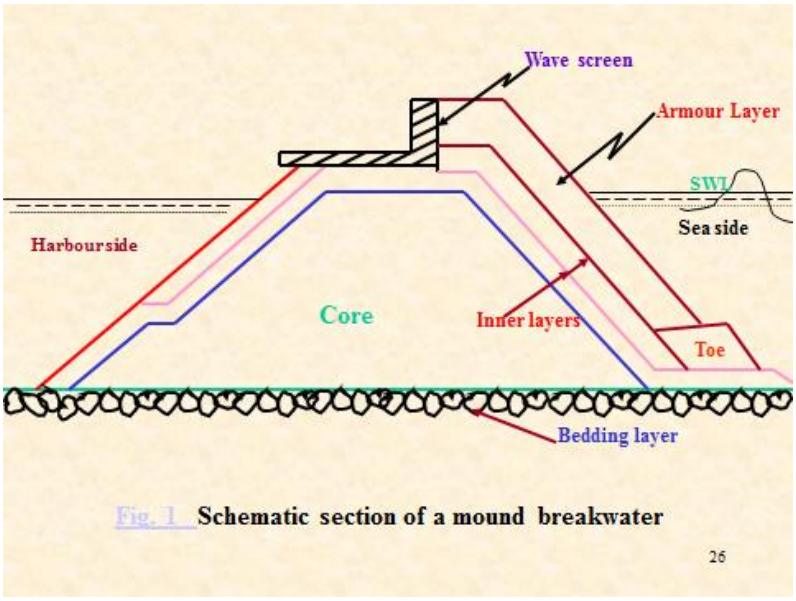

Figure 1. Schematic section of a rubble mound breakwater.

Many different concrete shapes have been developed as armor units for rubble structures. The major advantage of concrete armor units is that they usually have a higher stability coefficient value and thus permit the use of steeper slopes or a lighter weight of armor unit. This advantage has particular value when quarrystone of the required size is not available. Some of the prominent concrete armor units are shown in *Figure.2* including rubble in Fig. 5a.

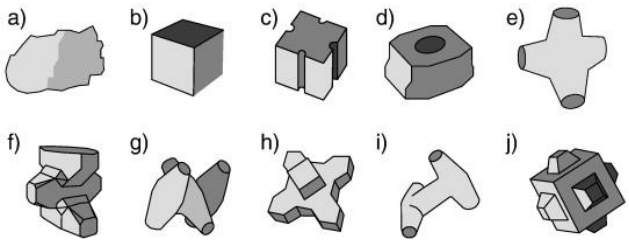

Figure 2. Some artificial armor units (b. Cube; c. Antifer; d. HaroR; e.Tetrapod; f. Accropode; g. Core-loc; h. XblocR; i. Dolos; and j. CubipodR.

The rubble structure is normally composed of a bedding layer and a core of quarry run stone covered by one or more layers of large stones and an exterior layer or layers of quarrystone (armor) or concrete armor units. Typical rubble mound cross sections are shown in *Figure 3* (Source: Shore Protection Manual, 1984). This breakwater is exposed to wave actions on one side (Seaside) and intended to allow minimal wave to the lee-side. Breakwaters of this type are usually designed with crests elevated such that overtopping occurs only in very severe storms.

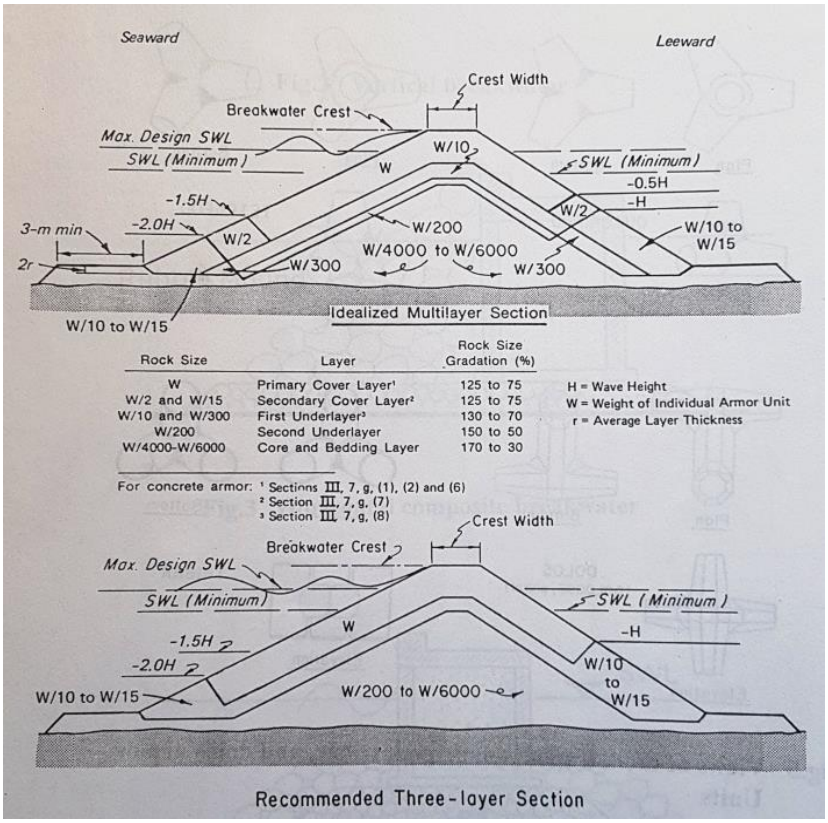

Figure 3.Rubble mound Section for save wave exposure with zero tp moderate overtopping Conditions

Methodology of design breakwaters [groins] structure

The rubble structure is normally composed of a bedding layer and a core of quarry run stone covered by one or more layers of large stones and an exterior layer or layers of quarrystone (armor) or concrete armor units. This breakwater is exposed to wave actions on one side (Seaside) and intended to allow minimal wave to the lee-side. Breakwaters of this type are usually designed with crests elevated such that overtopping occurs only in very severe storms. If it is exposed for substantial wave action from both sides (Example: outer portions of jetties). The recommended cross section takes into account some of the practical problems involved in constructing submerged features. According to this principle, the size of pore at any layer must be smaller than the size of the inner material so that the inner material should not be finding its way to escape out due to the dynamic activity of the waves.

WEIGHT OF THE PRIMARY LAYER

The stable weight of the armor stone, W is estimated by using Hudson formula.

$$W = w_r H^3 / (K_D (S_r - 1)^3 \cot \theta) \quad (1)$$

Where

w_r : *unit weight of armor unit (N/m^3)*

H : *design wave height at the structure (m)*

K_D : *Stability Coefficient*
(Varies with the shape of the armor units, roughness of the armor unit surface, sharpness of edges, degree of interlocking obtained in placement) (Refer Table 1)

S_r : *Specific gravity of the armor unit, relative to the water at the structure (w_r / w_w)*

W_w : *Unit weight of water (N/m^3)*

θ : *Angle of structure slope measured from horizontal in Degrees*

Eqn.1. is intended for conditions when the crest of the structure is high enough to prevent major overtopping. The slope of the cover layer can be partly determined on the basis of stone sizes economically available. Cover layer slopes steeper than 1 V: 1.5 H is not recommended. Eqn.1 determines the weight of armor unit of nearly uniform size. For graded riprap armor stone, the eqn. is modified as

$$W_{50} = w_r H^3 / (K_{RR} (S_r - 1)^3 \cot \theta) \quad (2)$$

Where W_{50} is the weight of the 50% size in the gradation. The maximum weight of graded rock is 4.0 W_{50} and the minimum is 0.125 W_{50}. K_{RR} is a stability coefficient for angular, graded riprap and is shown in Table 1. These values allow for 5% damage as shown in Table 2. Use of graded riprap cover layers is generally more applicable to revetments than to breakwaters or jetties. A limitation for the use of graded riprap is that the design wave height should be less than about 1.5 m. For waves higher than 1.5 m, it is usually more economical to use uniform-size armor units as specified by eqn.1.

WEIGHT OF THE FIRST UNDERLAYER AND SECONDARY COVER LAYER

= W/10 to W/15

WEIGHT OF CORE AND BEDDING LAYER

= W/200 to W/6000

Gradation Layers Details Table shown in Table 3

CREST ELEVATION

Select the crest elevation such that overtopping of water is allowed only 2% of the time during a storm.

$Ru_{2\%} / H_s = 0.83 \xi_p$ for $\xi_p < 2$

Consider H_s = Maximum wave height / (2% of 90%)

= 0.78 X Hs/(1.8)

ξ_p = Surf Similarity parameter

= $\tan \theta / (H_s / L_{0p})^{1/2}$

As a first approximation, run-up height can be predicted using the above eqn.

$Ru_{2\%}$ = 0.83 X ξ_p X Hs

Which mean that crest elevation of the structure is at $Ru_{2\%}$ (m), then only 2% of the waves during a storm will overtop the breakwater.

CREST WIDTH

The minimum crest width, B should be equal to the combined width of three armor units (n=3).

i.e. $B = n\, k_\Delta (W/w_r)^{1/3}$

Where

B = Crest width (m)

n = No. of stones (n=3 is recommended minimum)

k_Δ = layer coefficient (1.02 from Table 4)

Use crest width of B m in order to facilitate movements of machines and trucks during construction recommend (B <= 4m)

ARMOUR LAYER THICKNESS, r

$R = n\, k_\Delta (W/w_r)^{1/3}$

Where

n = No. of stones (n=2 is recommended)

k_Δ = layer coefficient (1.02 from Table 4)

W = Weight of armor unit in primary cover layer, Tons

w_r = Unit weight of armor unit, Ton/m^3

TOE BERM FOR COVER LAYER STABILITY

Weight of the stone = W/10

Width of the toe Berm = 3 r,

Where : r = $k_\Delta (W/w_r)^{1/3}$

Height of the Berm = 2r

UNDERLAYER THICKNESS

Thickness of the under layer = 2 r,

Where: r = $k_\Delta (W/w_r)^{1/3}$

Table 1. Suggested K_D values for use in determining armor unit weight (Shore Protection Manual)

No- Damage Criteria and Minor Overtopping							
Armor Units	N [III]	Placement	Structure Trunk K_D [II]		Structure Head K_D		Slope
			BW	NBW	BW	NBW	Cot θ
QUARRYSTONE							
Smooth rounded	2	Random	1.2	2.4	1.1	1.9	1.5-3
Smooth rounded	>3	Random	1.6	3.2	1.4	2.3	V
Rough angular	1	Random [IV]	IV	2.9	IV	2.3	V
Rough Angular	2	Random	2.0	4.0	1.9	3.2	1.5
					1.6	2.8	2.0
					1.3	2.3	3.0
Rough Angular	>3	Random	2.2	4.5	2.1	4.2	V
Rough Angular	2	Special [VI]	5.8	7.0	5.3	6.4	V
Parallelepiped [VII]	2	Special [I]	7.0 – 20.0	8.5 – 24.0	---	---	
TETRAPOD & QUADRIPOD	2	Random	7.0	8.0	*5.0*	6.0	1.5
					4.5	5.5	2.0
					3.5	4.0	3.0
TRIBAR	2	Random	9.0	10.0	*8.3*	9.0	1.5
					7.8	8.5	2.0
					6.0	6.5	3.0
DOLOS	2	Random	15.8 [VIII]	31.8 [VIII]	*8.0*	*16.0*	2.0 [IX]
					7.0	*14.0*	3.0
MODIFIED CUBE	2	Random	6.5	7.5	---	*5.0*	V
HEXAPOD	2	Random	*8.0*	9.5	*5.0*	*7.0*	V
TOSKANE	2	Random	11.0	22.0	---	---	V
TRIBAR	1	Uniform	12.0	15.0	*7.5*	*9.5*	V
QUARRYSTONE ((K_{RR}) Graded Angular	---	Random	2.2	2.5	---	---	

BW : Breaking Wave
NBW : Non Breaking Wave

Table 2. $H/H_{D=0}$ as a function of cover-layer damage and type of armor unit [I].

Unit		Damage (D) in Percent						
		0 - 5	5 -10	10-15	15-20	20-30	30-40	40-50
Quarrystone (Smooth)	$H/H_{D=0}$	1.00	1.08	1.14	1.20	1.29	1.41	1.54
Quarrystone (Rough)	$H/H_{D=0}$	1.00	1.08	1.19	1.27	1.37	1.47	*1.56*[II]
Tetrapods & Quadripods	$H/H_{D=0}$	1.00	1.09	1.17[III]	1.24[III]	1.32[III]	1.41[III]	1.50[III]
Tribar	$H/H_{D=0}$	1.00	1.11	1.25[III]	1.36[III]	1.50[III]	1.59[III]	*1.64*[III]
Dolos	$H/H_{D=0}$	1.00	1.10	*1.14*[III]	*1.17*[III]	1.20[III]	*1.24*[III]	*1.27*[III]

[I] *Breakwater Trunk, n=2, random placed armor units, non breaking waves, and no overtopping conditions*
[II] *Values in italics are interpolated or extrapolated.*
[III] *Caution: Tests did not include possible effects of unit breakage. Waves exceeding the design wave height conditions by more than 10% may result in considerably more damage than the values tabulated.*

Table.3. Rock-size gradation as a percent of the rock size

LAYER	ROCK SIZE	GRADATION (%)
Primary Cover Layer	W	75 to 125
Secondary Cover Layer	W/2 and W/15	75 to 125
First Under layer	W/10 and W/300	70 to 130
Second Under layer	W/200	50 to 150
Core and Bedding Layer	W/4000 to W/6000	30 to 170

Table 4.Layer Coefficient and Porosity for various armor units

Armor Unit	n	Placement	Layer Coefficient k_Δ	Porosity (P) in %
Quarrystone (Smooth)	2	Random	1.02	38
Quarrystone (Rough)	2	Random	1.15	37
Quarrystone (Rough)	>3	Random	1.10	40
Cube (modified)	2	Random	1.10	47
Tetrapod	2	Random	1.04	50
Quadripod	2	Random	0.95	49
Hexapod	2	Random	1.15	47
Tribar	2	Random	1.02	54
Dolos	2	Random	1.00	63
Tribar	1	Uniform	1.13	47
Quarrystone	graded	Random	----	37

KBwater Model Demonstration
Internet Version
Website: WWW.hceatkuwait.net\KBwater\kbw.aspx

User must login to website address at: *WWW.hceatkuwait.net\KBwater\kbw.aspx*
Then Figure 4 will display the main KBwater website page on internet as follows:

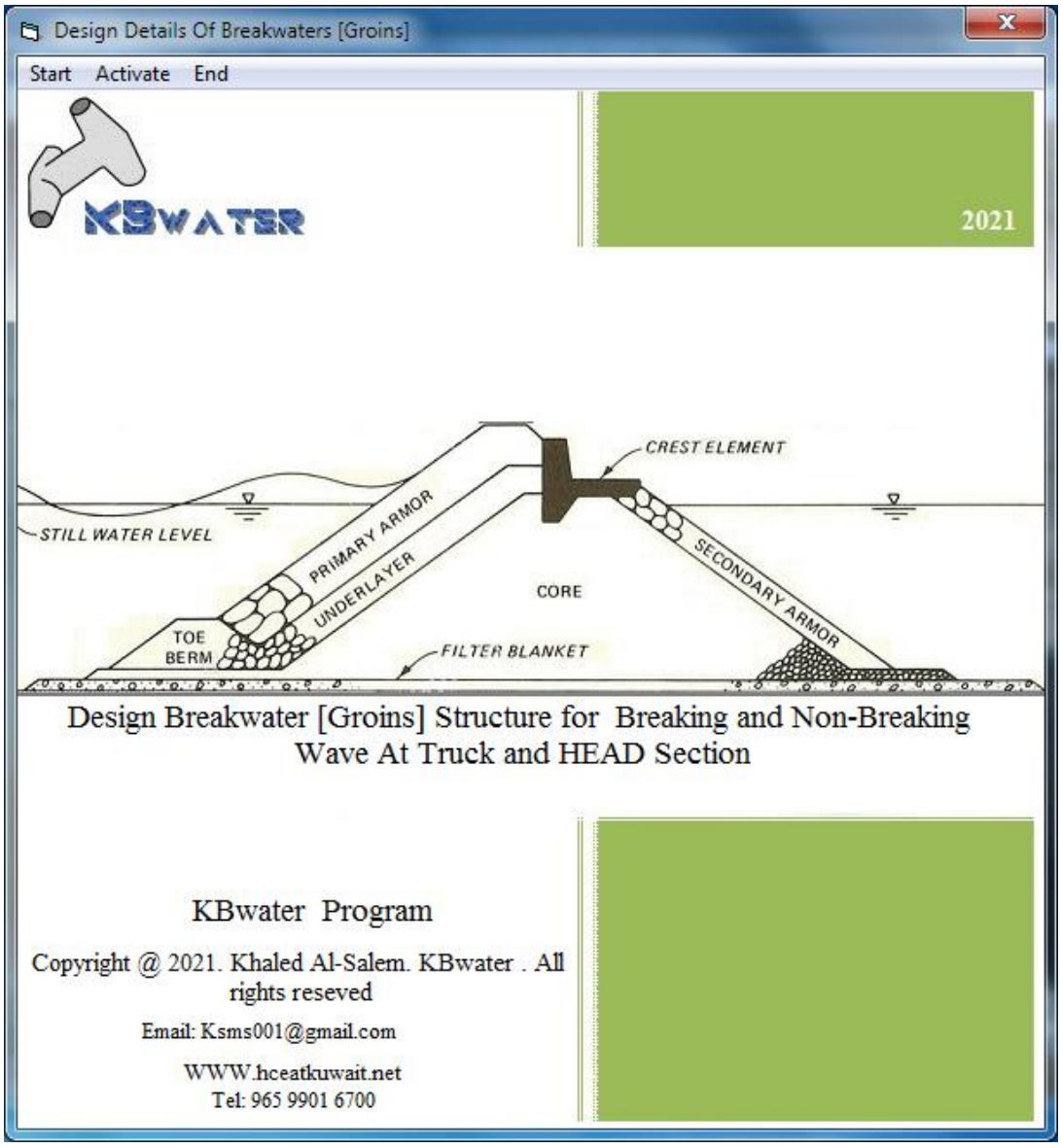

Figure 4

User must select [ ] to start the model for new project. Figure 5 will display for new project setup.

Figure 5 display for user to setup structural design for breakwater for the following Section

1- Design Breakwater section
   - Trunk Section of Breakwater as shown in Figure 10 [On the Right Of Figure 5]
   - Head Section of Breakwater as shown in Figure 10 [On Left of Figure 5]

2- Type of wave to design
   - Breaking Wave
   - Non-Breaking Wave

User must enter the following Parameter of the design as

1. Design Depth [m] D
2. Design Wave Height [m] [Extreme wave height] Hs
3. Design Corresponding wave periods [sec] Pr
   The from these model will decided the design based on [Breaking and NON-breaking] as followings:
   Hs > 0.78D [Breaking wave design]
   as shown in Figure 6 after user select [*Press-Check Case*].
4. Select Armor type [From Drop list]
5. Select Layer Coefficient [Ka] by two ways:
   - From Armor type selection
   - From select [*Table Ka*] manual enter value.
6. Armor units weight [KN/m3 Or Tons]
7. Select structure trunk[Kd] by select [*Table Kd*] manual enter value
8. Select Breakwater Slop as V-vertical direction and H Horizontal direction

HEAD SECTION SAME WAY OF DATA PARAMETER INPUTS

When all Data input for Trunk and Head section of breakwater are done user must enter [An ACESS CODE].
User can get ACESS CODE from Developer at [Ksms001@Gmail.com].

Figure 7 will display for user a complete structural design of the breakwater.
From Figure 7 user can display the Cross section of breakwater structural design detail in graphically by select the [check box] next to each section the design?

Then select map icon [] to display the cross section of the breakwater as shown in:
   - Figure 8 TRUNK Cross section of breakwater
   - Figure 9 HEAD Cross section of breakwater

A sample project Report display at the end for user by Selecting from Figure 7 Icon[

].

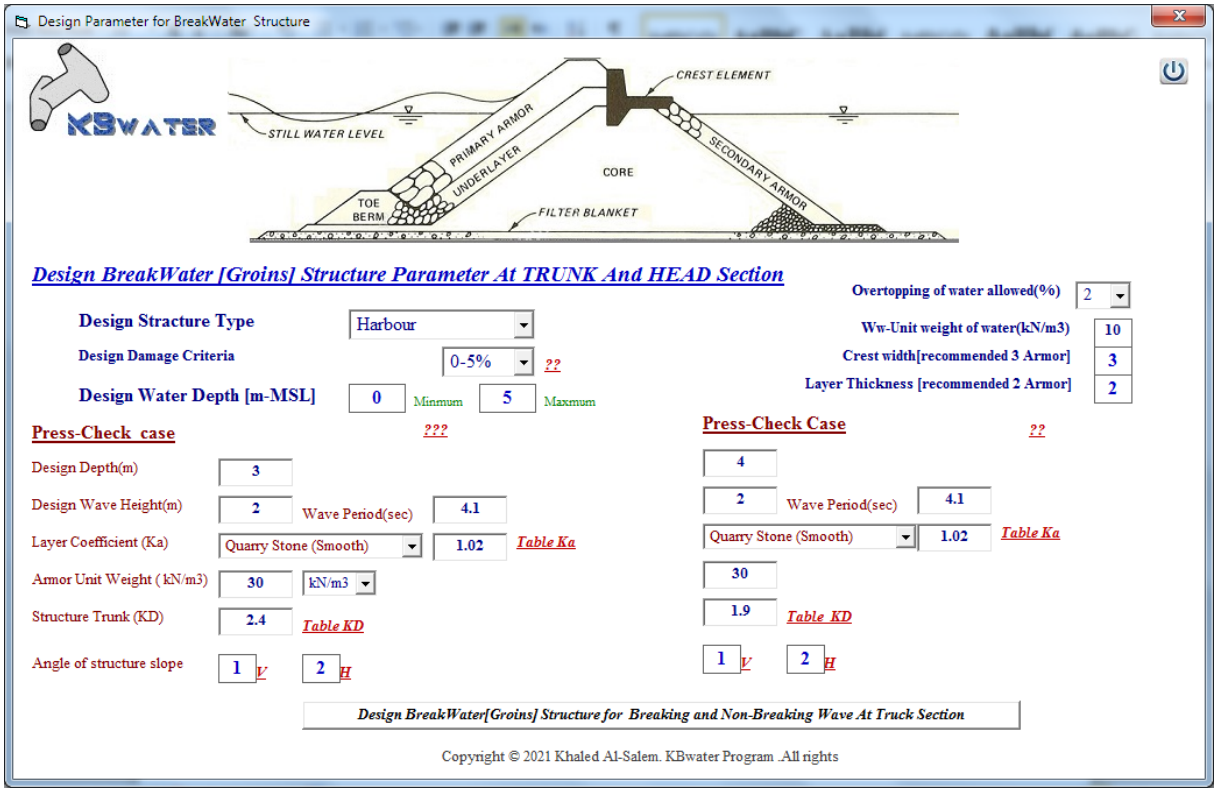

Figure 5

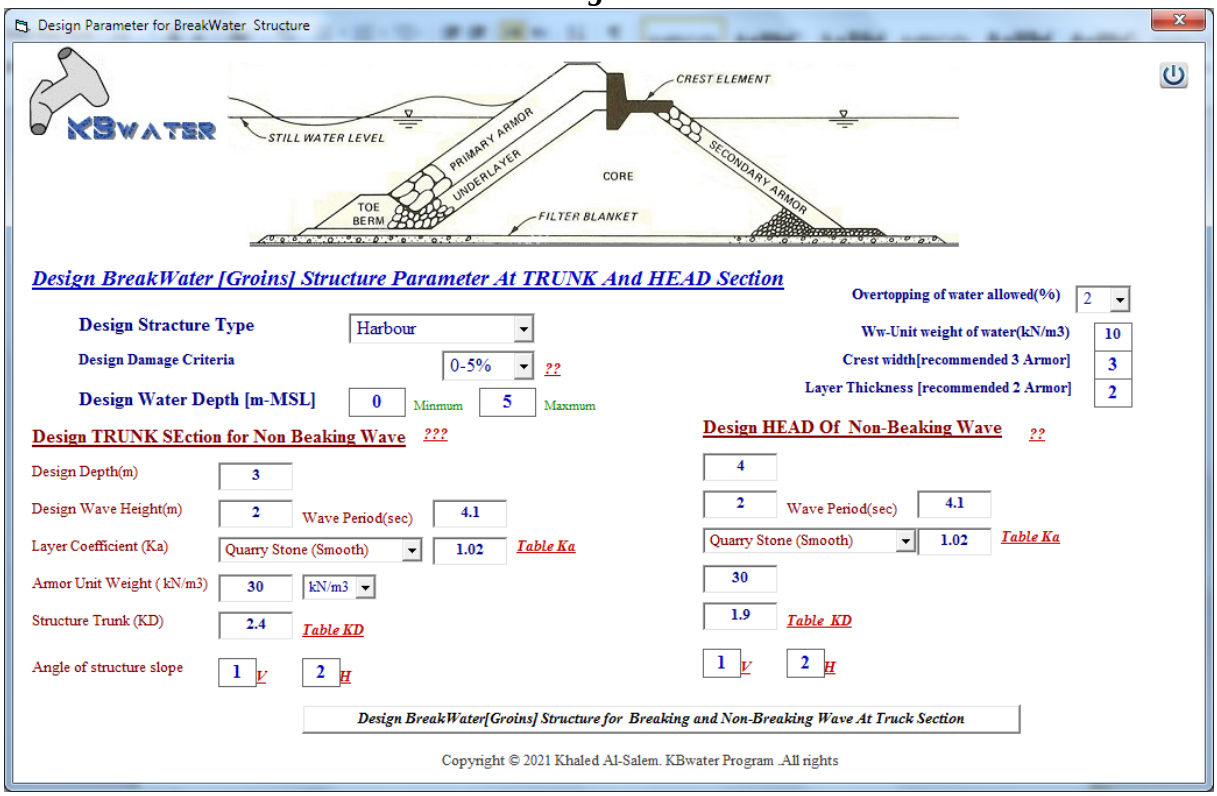

Figure 6


Design Sheet for WEIGHT OF ARMOR UNIT at Structure Trunk of BreakWater
KBWATER
Design Details Sheet
For BreakWater [Groins] Structure at Trunk Section
REPORT
WEIGHT OF ARMOR UNIT for Breakwater Trunck Section
Design Armor Units weight (K-Tons) 6
Weight of the First UnderLayer and Secondary Cover Layer W/10 to W15 0.6 .4 (K-Tons)
Weight of Core and Bedding Layer W/200 to W/6000 0.03 .001 (K-Tons)
WEIGHT OF ARMOR UNIT Breakwater HEAD Section
8
0.8 .5333 (K-Tons)
0.04 .0013 (K-Tons)
Armour Details
GRADATION DETAILS ??
Layer | Rock Size (K-Tons) | GRADATION (%)
Primary Cover Layer | W 6 | 125 To 75% 7.5 to 4.5
Secondary cover Layer , First under Layer | W/10 To W/15 .6 To .4 | 130 To 70% .78 to .28
Core and Bedding Layer | W/200 To W/6000 .03 To .001 | 170 To 30% .051 to .0003
GRADATION DETAILS ??
Layer | Rock Size (K-Tons) | GRADATION (%)
Primary Cover Layer | W 8 | 125 To 75% 10 to 6
Secondary cover Layer , First under Layer | W/10 To W/15 .8 To .5333 | 130 To 70% 1.04 to .37331
Core and Bedding Layer | W/200 To W/6000 .04 To .0013 | 170 To 30% .068 to .00039
BreakWater Details
Crest Elevation [r-m] 2 only 2% of the waves during a storm will overtop the breakwater.
Crest Width [B-m] 2 Armour units Recommend used (n=3) for facilitate movements of machines
Armour Layer Thickness 1 r-(m) Recommended # Armour unit n=2
TOE BERM FOR COVER LAYER STABILITY
Stone Weight [Kn] 0.6 Width Toe Berm [m] 2 Height of the Berm [m] 1.255
Underlayer Thickness [r-(m)] 1.255
Design Damge Wave = 2m Damge Criteria = 0-5%
BreakWater Details
Crest Elevation [r-m] 3 only 2% of the waves during a storm will overtop the breakwater.
Crest Width [B-m] 2 Armour units Recommend used (n=3) for facilitate movements of machines
Armour Layer Thickness 1 r-(m) Recommended # Armour unit n=2
TOE BERM FOR COVER LAYER STABILITY
Stone Weight [Kn] 0.8 Width Toe Berm [m] 1 Height of the Berm [m] 0.609
Underlayer Thickness [r-(m)] 0.609
Design Damge Wave = 2m Damge Criteria = 0-5%
Copyright © 2021 Khaled Al-Salem. KBwater Program .All rights

Figure 7

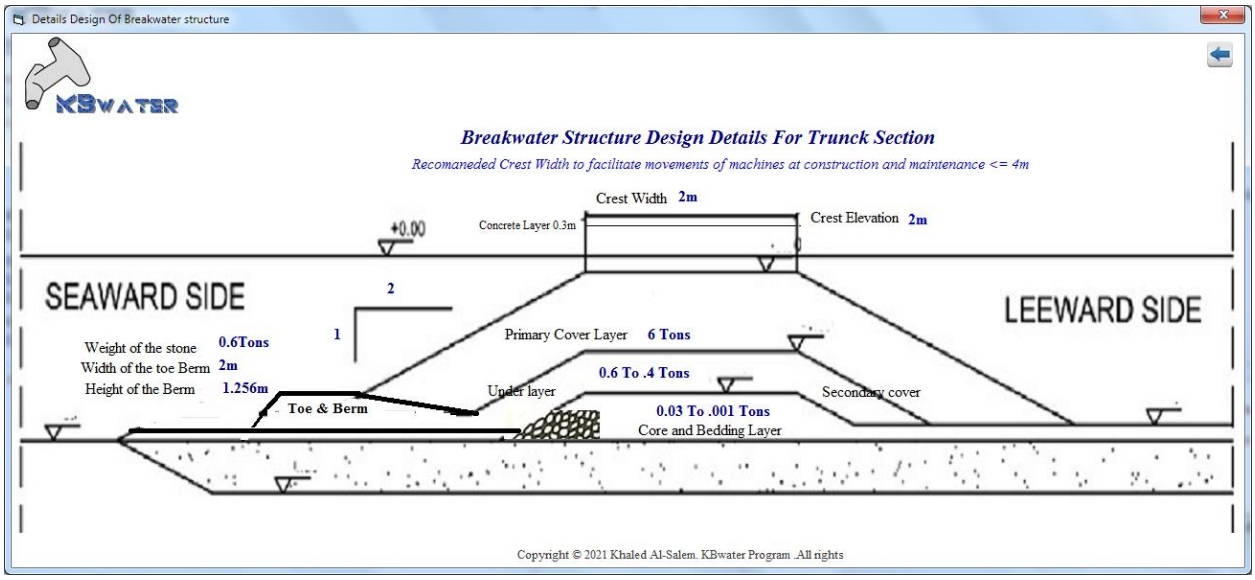

Figure 8

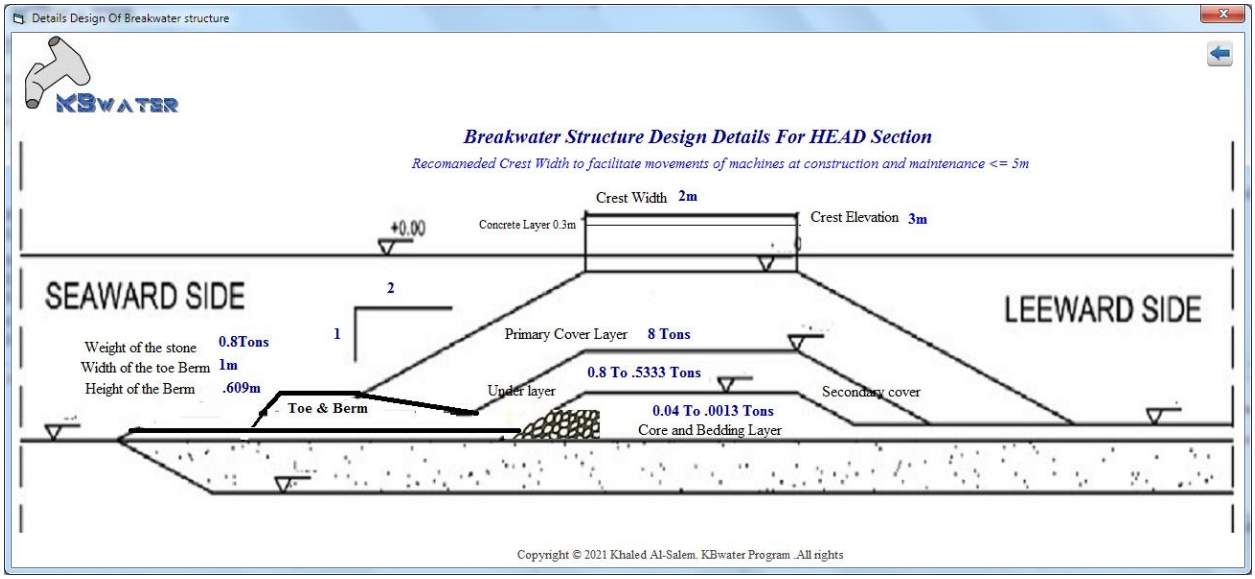

Figure 9

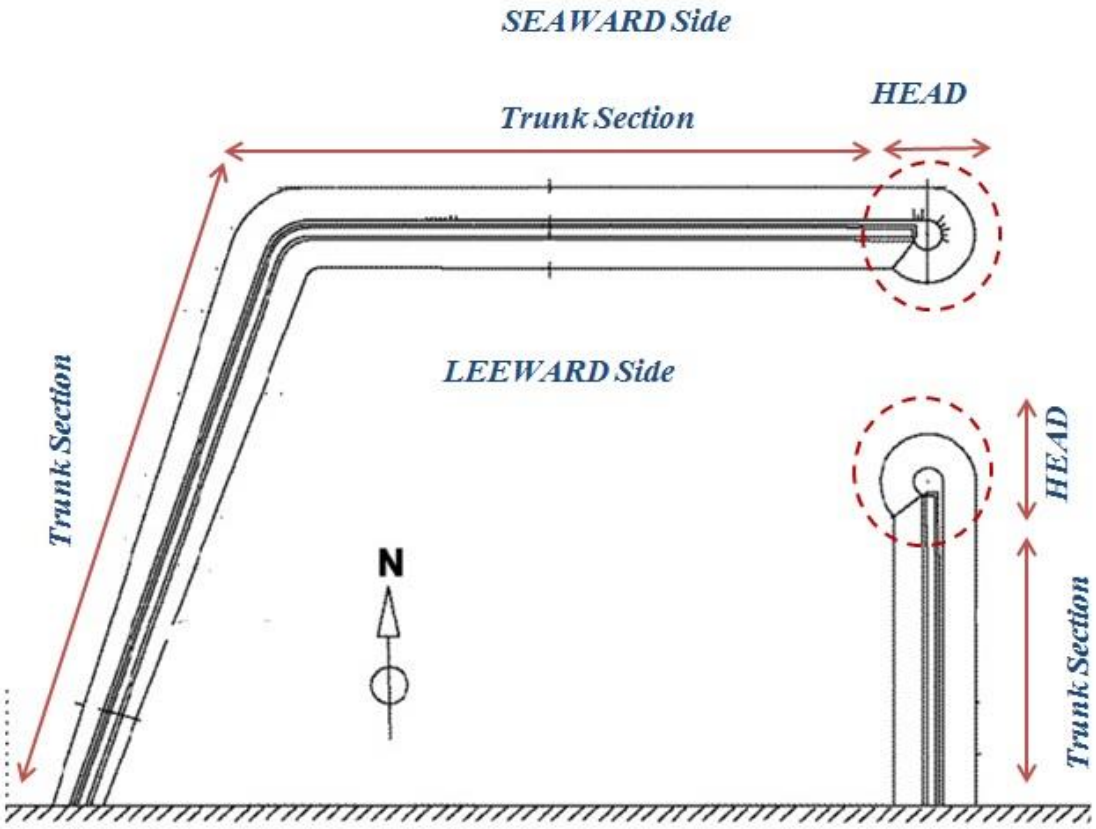
SEAWARD Side
HEAD
Trunk Section
LEEWARD Side
Trunk Section
N
HEAD
Trunk Section

Figure 10

DETAILS DESIGN FOR BREAKWATERS STRUCTURE

KBWater Model
:Khaled Al-Salem (2021)
Email: Ksms001@Gmail.com
WWW.hceatkuwait.net
Phone:(965) 99016700

Basically the weight of the stable armor stone/artificial unit is first estimated in the design. Then the weight of the stones in the inner layers and core needs to be estimated. The weights and sizes of the inner layers and core need to be selected based on the inverse filter principle. According to this principle, the size of pore at any layer must be smaller than the size of the inner material so that the inner material should not be finding its way to escape out due to the dynamic activity of the waves.

Details Design Breakwater Parameter

Breakwater Parameters Inputs

Breakwater Slow-Depth (m) : 0
Breakwater Deeper-Depth (m) : 5
Overtopping of Water Allowed(%) : 2
Unit Weight of Water(Kn/m3) : 10
Crest width [Recommended use n Amours : 3
Layer Thickness [Recommended used n Amours]: 2
Selected Damage Criteria(%) : 0-5%

Parameter Selected For TRUNK SECTION As shown In Figure 10
==========

Design TRUNK Section for Non Breaking Wave as shown in Figure 6
Selected Depth For Breakwater TRUNK Section(m) : 3
Selected Significant Wave Height [Used Extreme Wave H](m): 2
Selected Wave Period(sec) : 4.1
Selected Layer Type : Quarry Stone (Smooth)
Layer coefficient (Ka) :1.02
Selected Armor Unit Weight [kN/m3] : 30
Selected Structure TRUNK (KD) : 2.4
Selected Angle Of Structure Slop: V :1m and H:2m

Details stone Layer and Breakwater information Design For Construction at TRUNK Section

Layer Design Selected For TRUNK SECTION As shown In Figure 7.
Armor Details
Design Armor Units weight [W](Tons) : 7
Secondary cover Layer , First under Layer [W/10 => W/15](Ton) : 0.6 => .4
Weight of the First UnderLayer and Secondary Cover Layer[W/200 => W/6000](Ton): 0.03 => .001

Table For GRADATION DETAILS

Layer	*Rock Size(K-Ton)*	*GRADATION(%)*
Weight of Core and Bedding Layer	*W*	*75% to 125%*
	6	*7.5 to 4.5*
Secondary cover Layer , First under Layer	*W/10 => W/15*	*70% to 130%*
	0.6 => .4	*.78 to .28*
Core and Bedding Layer	*W/200 => W/6000*	*30% to 170%*
	0.03 => .001	*.051 to .0003*

BREAKWATER DETAILS
Crest Elevation[m] : 2 Note: only 2% of the waves during a storm will overtop the breakwater.
Crest Width[m] : 2 Note: Armor units Recommend used (n=3) for facilitate movements of machines
Amour Layer Thickness [m]: 1 Note: r-(m) Recommended # Armor unit n=2

TOE BERM FOR COVER LAYER STABILITY
Stone Weight [Kn] : 0.6
Width Toe Berm [m] : 2
Height of the Berm [m] : 1.25590203030453
Underlayer Thickness [r-(m)]: 1.25590203030453
Wave Height Damaged Criteria
Design Damage Wave = 2m
Damage Criteria = 0-5%

Figure 8 display Cross Section of Breakwater Details Design for TRUNK Section

Parameter Selected For HEAD SECTION As shown In Figure 10
==========

Design HEAD Of Non-Breaking Wave as shown in Figure 6
Selected Depth For Breakwater Head Section(m) : 4
Selected Significant Wave Height[Used Extreme Wave H](m): 2
Selected Wave Period(sec) : 4.1
Selected Layer Type : Quarry Stone (Smooth)
Layer coefficient (Ka) :1.02
Selected Armor Unit Weight [kN/m3] : 30
Selected Structure TRUNK (KD) : 1.9
Selected Angle Of Structure Slop: V :1m and H:2m

Details stone Layer and Breakwater information Design For Construction at HEAD Section
---

Layer Design Selected For HEAD SECTION As shown In Figure 7.
Amour Details
Design Armor Units weight [W](Tons) : 8
Secondary cover Layer , First under Layer [W/10 => W/15](Ton) : 0.8 => .5333
Weight of the First UnderLayer and Secondary Cover Layer[W/200 => W/6000](Ton): 0.04 => .0013

Table For GRADATION DETAILS

Layer	*Rock Size(K-Ton)*	*GRADATION(%)*
Weight of Core and Bedding Layer	*W*	*75% to 125%*
	8	*10 to 6*
Secondary cover Layer , First under Layer	*W/10 => W/15*	*70% to 130%*
	0.8 => .5333	*1.04 to .37331*
Core and Bedding Layer	*W/200 => W/6000*	*30% to 170%*
	0.04 => .0013	*.068 to .00039*

BREAKWATER DETAILS

Crest Elevation[m] : 3 Note: only 2% of the waves during a storm will overtop the breakwater.
Crest Width[m] : 2 Note: Armor units Recommend used (n=3) for facilitate movements of machines
Amour Layer Thickness [m]: 1 Note: r-(m) Recommended # Armor unit n=2

TOE BERM FOR COVER LAYER STABILITY

Stone Weight [Kn] : 0.8
Width Toe Berm [m] : 1
Height of the Berm [m] : 0.609471045531774
Underlayer Thickness [r-(m)]: 0.609471045531774

Wave Height Damaged Criteria

Design Damage Wave = 2m
Damage Criteria = 0-5%

Figure 9 display Cross Section of Breakwater Details Design For HEAD Section