FUDOTETRA

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Cover：Tokunoshima Kametoku Port（Kagoshima Prefecture）

2009.05

Dolos®

FUDOTETRA

Dolosse will continue to play an important role to protect port and harbor areas from very severe wave conditions, the kind that other wave-dissipating concrete blocks cannot withstand.

Dolosse in Japan is fully reinforced to prevent breakage caused by high interlocking forces, as experienced in Sines Port in Portugal in 1978 and other Dolos applications around the world. The weight amount of reinforcing bar used in Dolosse in Japan is about 100 kg/m^3, while that in Sines and Humbold Bay were 40 kg/m^3 and 45 kg/m^3 (Magoon et al. 1971).

Dolosse of 40 and 50 ton have been utilized in Japan since 1980s. In Naha Port in Okinawa, more than 10,000 units of 40 and 50ton Dolosse, reinforced with steel bars in the amount above, have already been used.

Dolosse of 40 and 50ton have been found use in many ports other than Naha under high wave conditions. The success in actual site applications in Japan especially in Naha Port with us more than 30 year experience is considered strong evidence that the reinforcement for Dolos in Japan is satisfactory.

■REFERENCES

Magoon, O. and Shimizu, N. (1971). Use of Dolos armor units in rubble-mound structures e.g. for conditions in the Arctic, Proceedings of POAC, 1089-1108.

Naha Port (Okinawa prefecture)

Advantages of Dolos

High Wave-Dissipating Performance

Dolos wave-dissipating works maintain large surface roughness and suitable porosity. They allow the reduction of wave pressure on the breakwater, wave runup, and wave reflection.

High Stability

Combining two anchors forms shape of a single Dolos. Dolos wave-dissipating work realizes high stability due to the interlocking of blocks caused by such an anchor-like shape.

Superior Economy

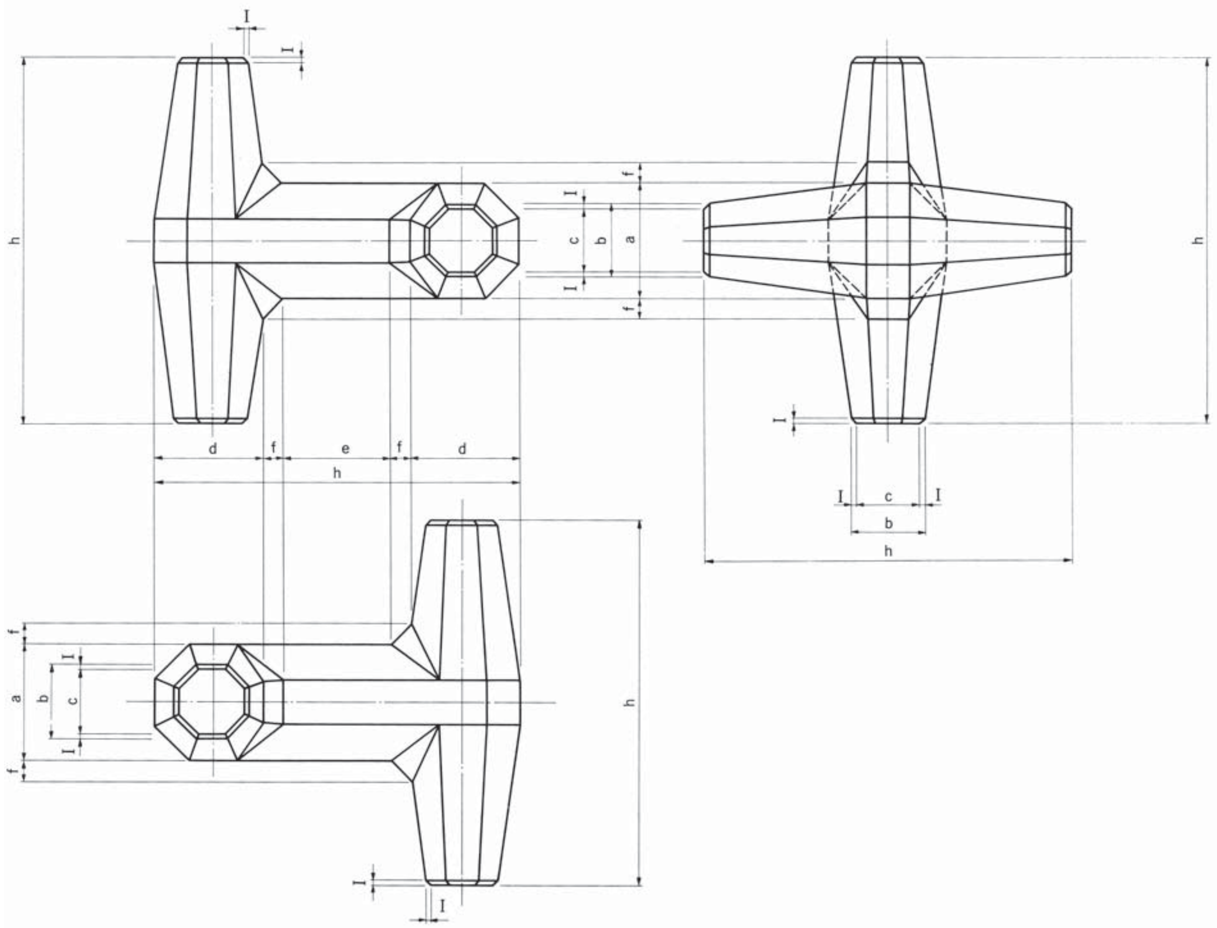
High stability of Dolos enable required mass against waves to be reduced up to a half of other conventional blocks. Therefore, the machinery for transport and installation can be reduced in size. Moreover, the high porosity of Dolos wave-dissipating works makes the total number of blocks fewer. Due to the characteristic above, Dolos wave-dissipating works indicate superior economy.

Ease of Fabrication and Placement

Thanks to the reduction in block size, we can freely select machinery, ships and the area of fabrication yard. No particular skill for block placement is needed because we can naturally obtain the entanglement of blocks caused by the shape of the block.

Shape and Dimensions

● Shape and Dimensions of Dolos



● Dimensions of Dolos

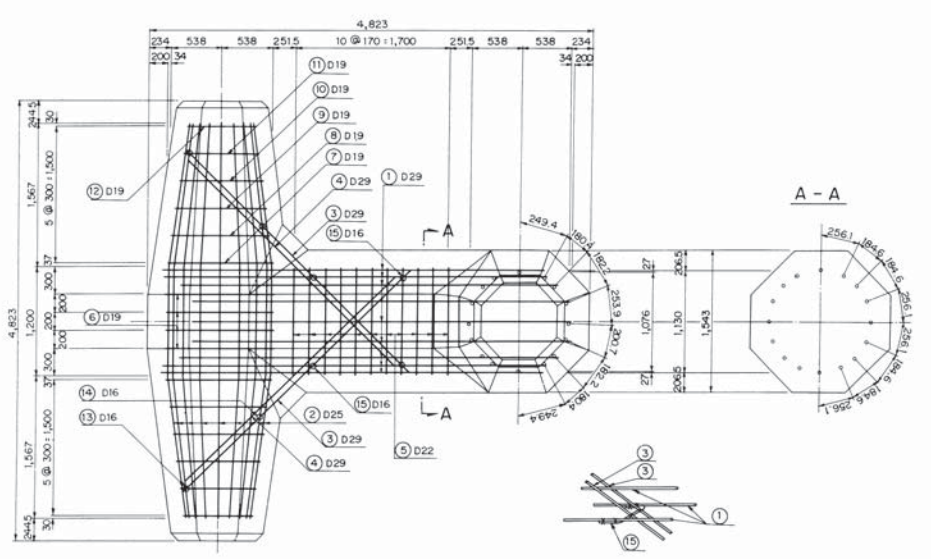
units in mm

Type (t)	※1 Actual Mass (t)	※2 Actual Weight (KN)	Volume (m^3)	Form area (m^2)	h	a	b	c	d	e	f	I
40	41.12	403.25	17.391	50.041	4823	1543	986	830	1441	1401	270	78
50	51.42	504.26	21.739	58.067	5196	1663	1062	894	1552	1510	291	84
80	82.32	807.28	34.787	79.443	6077	1945	1242	1045	1816	1765	340	99

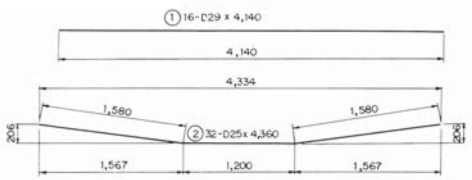
※1 Actual Mass and Actual Weight include Reinforcing Steel Weight
※2 Actual Weight＝9.80665×Actual Mass

Reinforcing Bar Arrangement

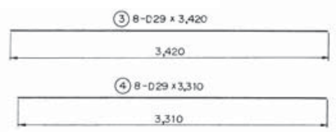
● 40ton



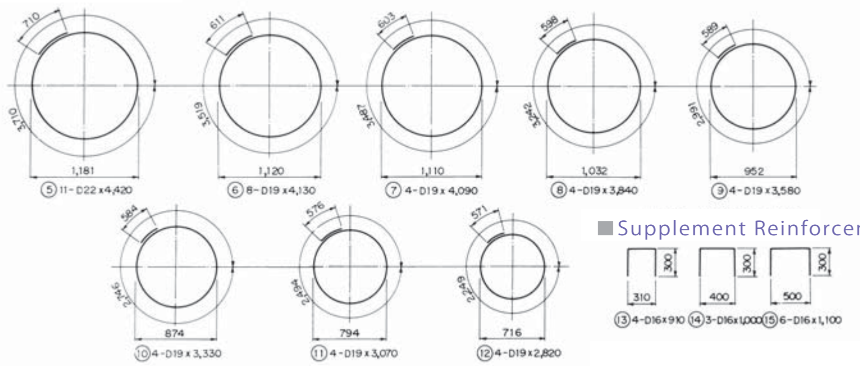
■Main Reinforcement



■Reinforcement for Haunch



■Shear Reinforcement



■Supplement Reinforcement

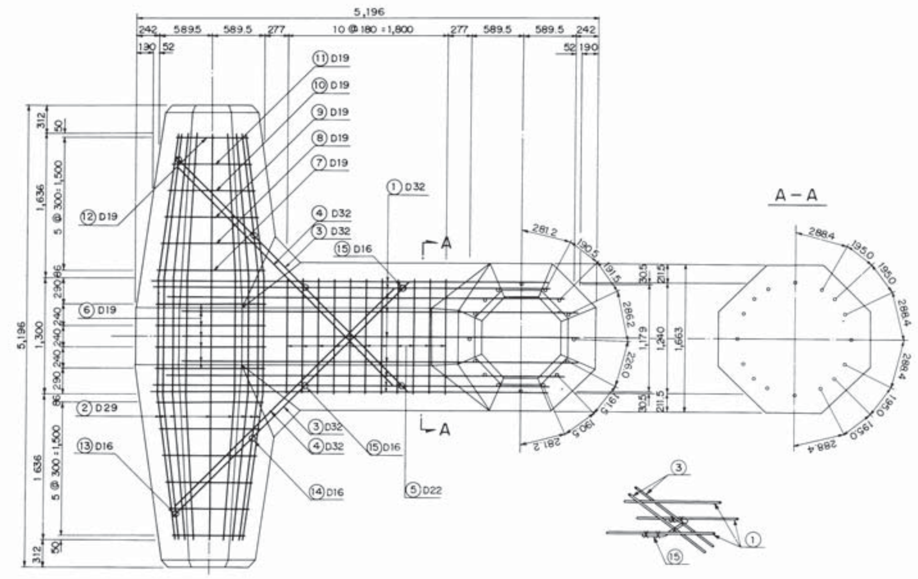
■Table of Reinforcing Bar

(S D295)

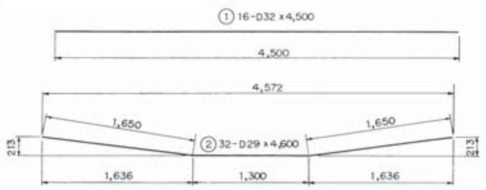
no.	φ	length (mm)	the number	Unit weight (kg/m)	a piece of weight (kg)	Weight (kg)	Shape
1	D29	4140	16	5.04	20.866	333.856	—
2	D25	4360	32	3.98	17.353	555.296	
3	D29	3420	8	5.04	17.237	137.896	—
4	D29	3310	8	5.04	16.682	133.456	—
						1160.504 k g	
5	D22	4420	11	3.04	13.437	147.807	○
6	D19	4130	8	2.25	9.293	74.344	○
7	D19	4090	4	2.25	9.203	36.812	○
8	D19	3840	4	2.25	8.640	34.560	○
9	D19	3580	4	2.25	8.055	32.220	○
10	D19	3330	4	2.25	7.493	29.972	○
11	D19	3070	4	2.25	6.908	27.632	○
12	D19	2820	4	2.25	6.345	25.380	○
						408.727 k g	
13	D16	910	4	1.56	1.420	5.680	コ
14	D16	1000	3	1.56	1.560	4.680	コ
15	D16	1100	6	1.56	1.716	10.296	コ
						20.656 k g	

Sub Total	D29	605.208 k g
	D25	555.296 k g
	D22	147.807 k g
	D19	260.920 k g
	D16	20.656 k g
Total		1589.887 k g

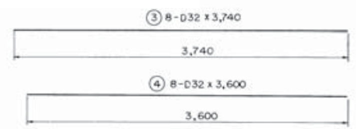
● 50ton



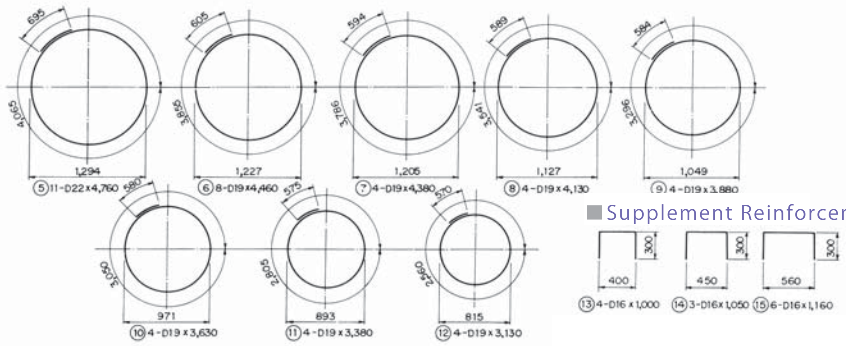
■Main Reinforcement



■Reinforcement for Haunch



■Shear Reinforcement



■Supplement Reinforcement

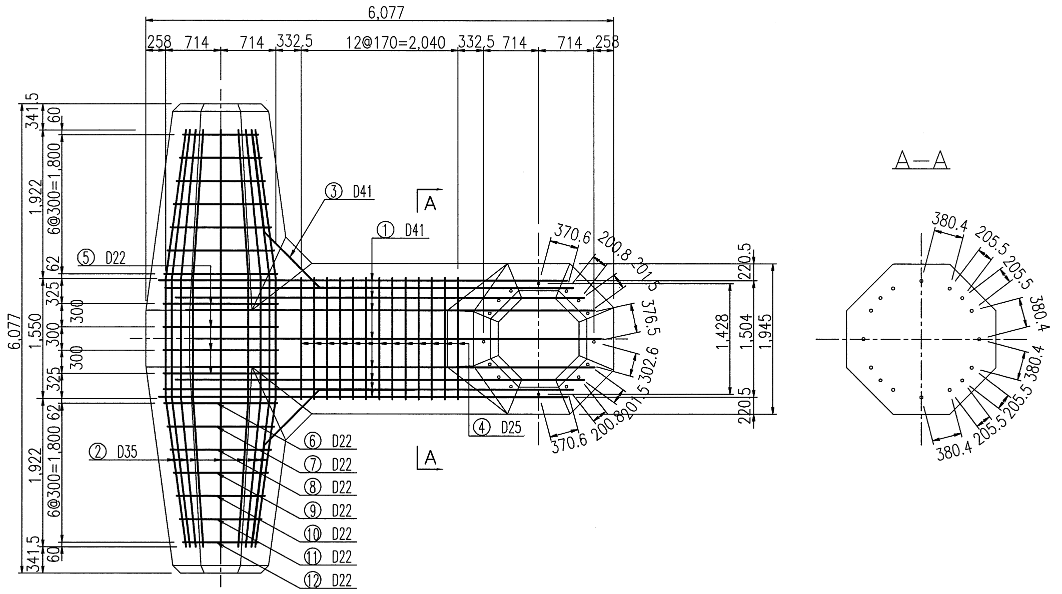
■Table of Reinforcing Bar

(S D295)

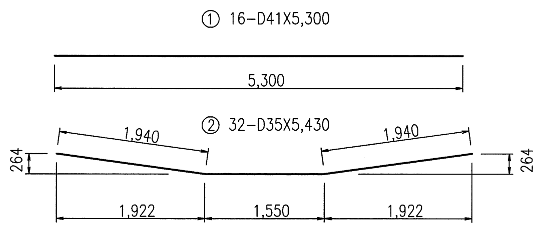
no.	φ	length (mm)	the number	Unit weight (kg/m)	a piece of weight (kg)	Weight (kg)	Shape
1	D32	4500	16	6.23	28.035	448.560	—
2	D29	4600	32	5.04	23.184	741.888	
3	D32	3740	8	6.23	23.300	186.400	—
4	D32	3600	8	6.23	22.428	179.424	—
						1556.272 k g	
5	D22	4760	11	3.04	14.470	159.170	○
6	D19	4460	8	2.25	10.035	80.280	○
7	D19	4380	4	2.25	9.855	39.420	○
8	D19	4130	4	2.25	9.293	37.172	○
9	D19	3880	4	2.25	8.730	34.920	○
10	D19	3630	4	2.25	8.168	32.672	○
11	D19	3380	4	2.25	7.605	30.420	○
12	D19	3130	4	2.25	7.043	28.172	○
						442.226 k g	
13	D16	1000	4	1.56	1.560	6.240	コ
14	D16	1050	3	1.56	1.638	4.914	コ
15	D16	1160	6	1.56	1.810	10.860	コ
						22.014 k g	

Sub Total	D32	814.384 k g
	D29	741.888 k g
	D22	159.170 k g
	D19	283.056 k g
	D16	22.014 k g
Total		2020.512 k g

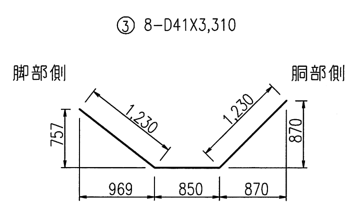
● 80ton



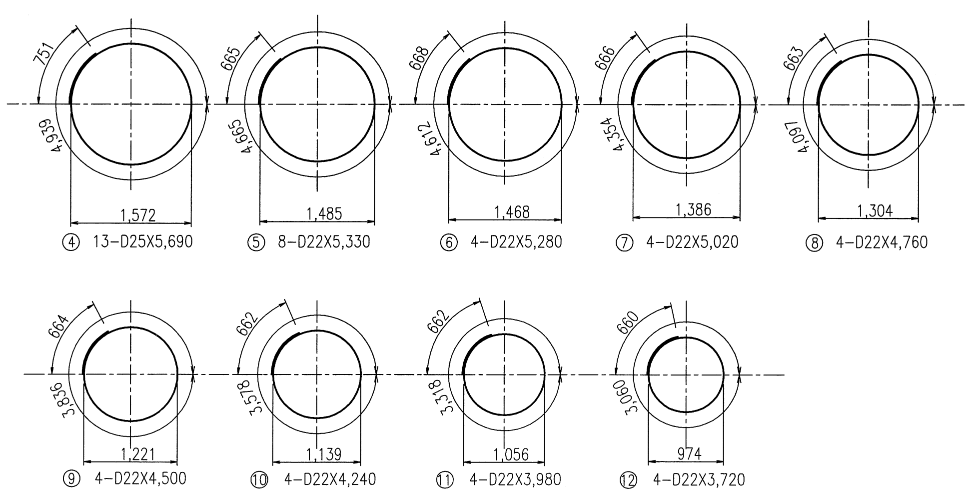
■Main Reinforcement



■Reinforcement for Haunch



■Shear Reinforcement



■Table for Reinforcing Bars (S D345)

no.	φ	Length (mm)	Number	Unit weight (kg/m)	Weight (kg)	Total weight (kg)	Shape
❶	D41	5300	16	10.5	55.650	890.400	
❷	D35	5430	32	7.51	40.779	1304.928	
❸	D41	3310	8	10.5	34.755	278.040	
						2473.368 k g	
❹	D25	5690	13	3.98	22.646	294.398	○
❺	D22	5330	8	3.04	16.203	129.624	○
❻	D22	5280	4	3.04	16.051	64.204	○
❼	D22	5020	4	3.04	15.261	61.044	○
❽	D22	4760	4	3.04	14.470	57.880	○
❾	D22	4500	4	3.04	13.680	54.720	○
❿	D22	4240	4	3.04	12.890	51.560	○
⓫	D22	3980	4	3.04	12.099	48.396	○
⓬	D22	3720	4	3.04	11.309	45.236	○
						807.062 k g	

Sub Total	D41	1168.440 k g
	D35	1304.928 k g
	D25	294.398 k g
	D22	512.664 k g
Total		3280.430 k g

Basic Design

Calculation of Required Mass

1 Hudson Formula

In general, the required mass is calculated by using the following Hudson formula:

$$M=\frac{\rho r \cdot H^3}{K_D(Sr-1)^3 \cot\alpha} \quad \text{Eg.(1)}$$

Where M : Mass of Dolos (t)
ρr : Density of Dolos (2.36 t/m³)
Sr : Specific gravity of Dolos to the seawater (ρr / ρw)
ρw : Density of sea water (ρw = 1.03 t/m³)
H : Design wave height (m)
K_D : Stability constant determined by the shape of the armor units and the damage ratio (K_D = 20)
α : Angle of the slope from the horizontal line

● K_D Value of Dolos

Condition	K_D	Position
Random placement Damage ratio 0 to 1 %	20	Breakwater Trunk

2 Hudson Formula with the Stability Number (Ns)

Recently, the "Hudson Formula with the Stability Number (Ns)" has become popular in ports and harbors design.
("Technical Standards and Commentaries for Port and Harbour Facilities in Japan", http://www.ocdi.or.jp/en/technical-st-en.html)

$$M=\frac{\rho r \cdot H^3}{Ns^3(Sr-1)^3} \quad \text{Eg.(2)}$$

Where M : Mass of Dolos (t)
ρr : Density of Dolos (2.36 t/m³)
Sr : Specific gravity of Dolos to the seawater (ρr / ρw)
ρw : Density of sea water (ρw = 1.03 t/m³)
H : Design wave height (m)
Ns : Stability number determined by the shape of the armor unit, slope angle and degree of damage

Equation(1) is an expression obtained by replacing Ns^3 by $K_D \cdot \cot\alpha$ in Equation(2).

$$Ns^3 = K_D \cdot \cot\alpha$$

The following equation for wave-dissipating concrete blocks that are randomly placed in all the front face of an upright wall have been proposed. In this formulation, various wave and structural conditions can be taken into account.

$$Ns = C_H\{a(N_0/N^{0.5})^{0.2}+b\} \quad \text{Eg.(3)}$$

$$C_H = 1.4/(H_{1/20}/H_{1/3}) \quad \text{Eg.(4)}$$

Where C_H : Coefficient of wave breaking
(C_H = 1.0 in the case of non-breaking wave)
N_0 : Degree of damage that is presented by the number of damaged blocks on width of representative diameter of the block (in the direction of the breakwater alignment)
N : Number of wave attack
a, b : Coefficients that depend on the shape of the concrete block and the slope angle. (please refer to the following table)

● Coefficients that are determined by the inclination of the Dolosse

Inclination of Slope	a	b
1 : 1.3	3.88	1.43
1 : 4/3		1.46
1 : 1.5		1.58

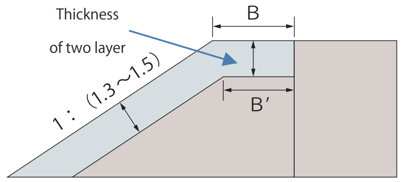
The value of $H_{1/20}/H_{1/3}$ in Eq.4 can be obtained by the diagram prepared in the Technical Standards.
(Technical Standards for Port and Harbor Facilities and their Explanations).

Typical Sectional Dimensions

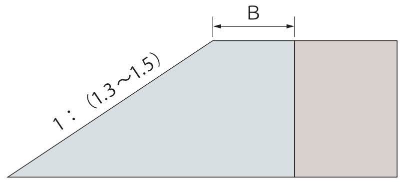
Typical inclination is 1 : (1.3～1.5)

1 Upright Wall

Two layer placement



Entire cross-section placement



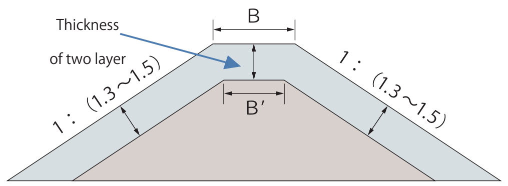
Dimensions (Typical slope angles)

units in m

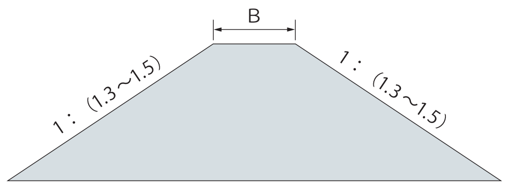
Type (t)	Thickness of two layer	2 rows width				2 rows width			
		B	B′			B	B′		
			1 : 1.3	1 : 4/3	1 : 1.5		1 : 1.3	1 : 4/3	1 : 1.5
40	8.6	8.6	5.7	5.7	6.0	13.0	10.1	10.1	10.4
50	9.3	9.3	6.1	6.2	6.5	14.0	10.8	10.9	11.2
80	10.9	10.9	7.2	7.3	7.6	16.4	12.7	12.8	13.1

2 Sloping Type Breakwater

Two layer placement



Entire cross-section placement



Dimensions (Typical slope angles)

units in m

Type (t)	Thickness of two layer	3 rows width				4 rows width			
		B	B′			B	B′		
			1 : 1.3	1 : 4/3	1 : 1.5		1 : 1.3	1 : 4/3	1 : 1.5
40	8.6	13.0	7.1	7.3	7.8	17.3	11.4	11.6	12.1
50	9.3	14.0	7.7	7.8	8.4	18.7	12.4	12.5	13.1
80	10.9	16.4	9.0	9.1	9.8	21.8	14.4	14.5	15.2

● The dimensions above are default values. Please contact us for other desighs.

Calculation of Required Number

The required number is calculated by using the following equation:

$$N = \frac{V(1-p)}{v}$$

Where
N : Required Number of Dolosse
V : Volume to be filled with Dolosse (㎥)
v : Volume of a Dolos (㎥)
P : Porosity (57.5%)

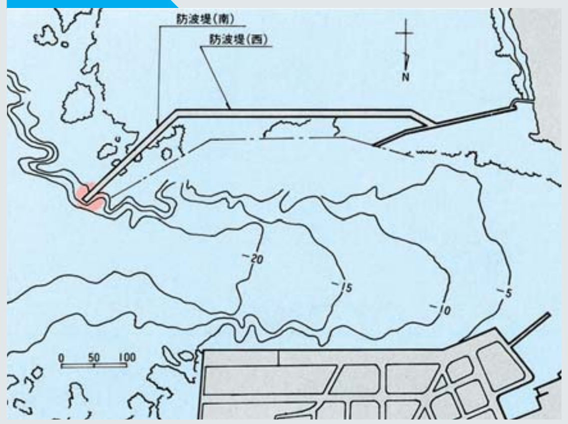
Confidence and Achievements

Tokunoshima Kametoku Port

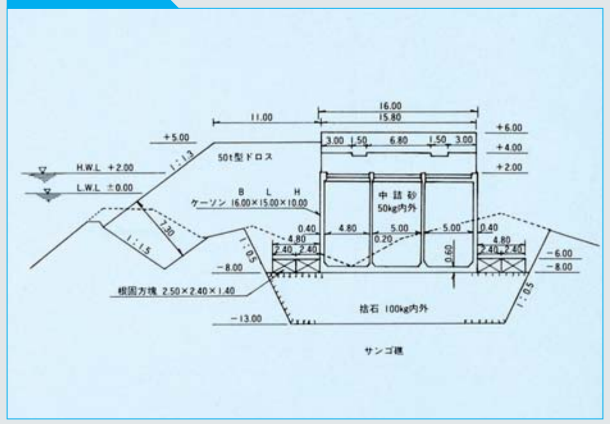
- Owner : Kagoshima Prefecture.
- Year Built : 1977・1978
- Tonnage : 50 ton
- Design Wave : H_o=11.80m,T_o=16.80s

MAP

Plan view



Cross section



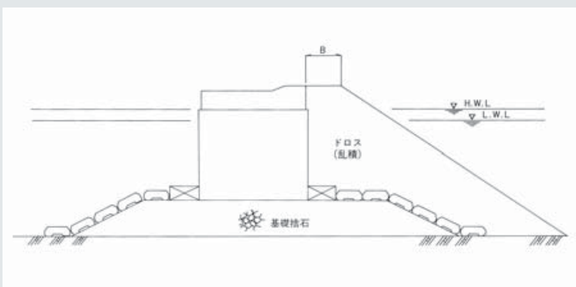
Naha Port　New port breakwater(No.1)

●Owner	：Okinawa General Bureau
●Year Built	：1980
●ton type	：40 ton、50 ton
●design wave	：H_o=11.50m,T_o=15.10s
	：$H_{1/3}$=9.70m,$T_{1/3}$=15.10s

Locality map

Plan view

Cross section



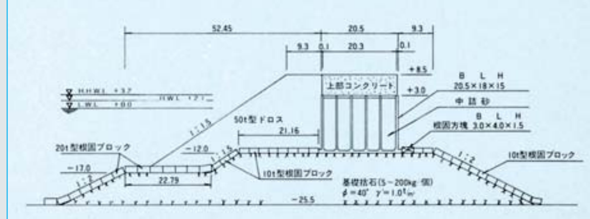
Naha Port　Urazoe breakwater(No.1)

●Owner	：Okinawa General Bureau
●Year Built	：1981～
●ton type	：50　ton
●design wave	：H_o=11.50m,T_o=15.10s
	：$H_{1/3}$=10.70m,$T_{1/3}$=15.10s

Locality map

Plan view

Cross section



Fabrication Process

1 Reinforcing bar assembly

Assembly needs support frames.

2 Mold assembly

3 Concrete pouring

4 Mold removal

5 Completion