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Sea Wall Structure For Water Front - Coastal Road in Tahuna City - Sangihe Island at North Sulawesi Province

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ABSTRACT

Tahuna city was located in the west Sangihe island of north Sulawesi Province. The effort of regional development program is to enlarge the road facility by developing the water in front of coastal road on longshore ± 3.90 km by reclamation. Sea wall structure is chosen to provide coastal road protection from the attack wave activity implication as the fluctuation of sea water level such as tidal, wind set up, wave set up, and global warming impact.The supported data for determining design of water level and crest elevation structure was depended on wind rose speed, duration, tidal wave, and bahtymetric data. Design of sea wall foundation used the treatment of bambo pile for avoiding the settlement and lequefaction hazard. It was due to the the reason that foundation material consisted of uniform sandy gradation, and then, for reducing the earth force especially earthquake condition, design of sea wall also provided geogrid reinforcement with the type uniaxial of 40/40 and limited tensile strength of 40 kN/m. Construction schedule of sea wall needed multi years for implementation, it was caused by the high cost and limited available equipment. The last information showed that the result of development was satisfied enough and recently the whole road of coastal structure was called as boulevard of Tahuna city.

Keywords: coastal road, seawall, geogrid

INTRODUCTION

The longshore of Tahuna city existing condition untake care of zone was caused by the garbage dump of domestic waste. The people who is domicile surrounding shore region there be unconcerned of cleanliness. Therefore, Tahuna government wants to regulate the landscape coastal region and aesthetics shoreline. Then continuity plan development is carried out in the relation to enlarge the road fasility by changing the longshore for main acces road and water front region. In addition, the government has made the agreement with people who stay on a long development area by carrying out the public consultative meeting event. The most people there support the whole program to be reclaimed with the embankment and protection of Tahuna bay. The commitment of decision is if the on doing project implementation should be involved the young people as the workers.

Design for protection of a long shoreline developing was decided as the seawall structure. The choice by protecting the design of road coastal water front was restricted as follow: 1) the composite structure type1 (concrete masive part above which was combined with concrete frame fill on foundation), 2) the rubble-mound structure type2, and 3) revetment structure type3. This study was only disscusing about seawall structure type1 which was located from station P_1 untill P_{77} (Tidore – Sawangbendar – Apengsembeka).

MATERIALS AND METHODS

Hydro Oceanografi

Some data was needed for providing hydro oceanografi on the design of seawall. This data are mostly collected from legal company of government such as BMKG and DISHIDROS. Design of sea wall for retaining coastal road, bathymetric survey was carried out in the area of longshore Tahuna ± 3.90 km [1].

a. Wave Data

Wave data used in tdesign was based on wind data of local station on Naha airport for 10 years time series (Figure 1)[1]. Then, analysis of wave data used Full Developed Sea (FDS) and it was formulated by wave significant method [2][3]. The result of generation wave is presented as in Table 1 and the wave rose as in Figure 2 below.

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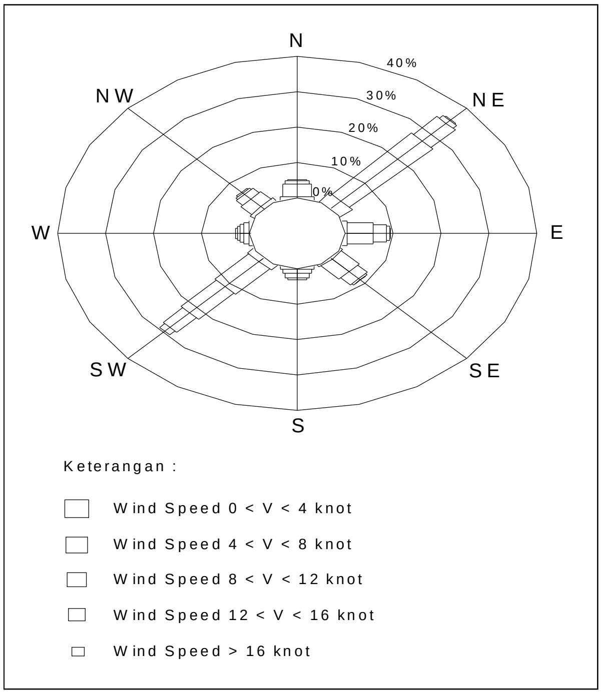

Figure 1 Wind data of local station on Naha airport for 10 years time series

Table 1. Result of wave generation

Hs (m)	Wave Direction								Total
	N	NE	E	SE	S	SW	W	NW	
0.0 - 0.5	37.00	263.00	42.00	41.00	11.00	110.00	13.00	55.00	572.00
0.5 - 1.0	97.00	702.00	168.00	150.00	35.00	298.00	30.00	78.00	1558.00
1.0 -1.5	27.00	176.00	61.00	71.00	29.00	199.00	14.00	48.00	625.00
1.5 - 2.0	12.00	83.00	40.00	31.00	18.00	177.00	14.00	19.00	394.00
>2.0	11.00	52.00	31.00	19.00	20.00	265.00	33.00	29.00	460.00
Total	184.00	1276.00	342.00	312.00	113.00	1049.00	104.00	229.00	3609.00

Table 2 Percentage of wave rose

Hs (m)	Wave Direction Procentage (%)								Total
	N	NE	E	SE	S	SW	W	NW	
0.0 - 0.5	1.03	7.29	1.16	1.14	0.30	3.05	0.36	1.52	15.85
0.5 - 1.0	2.69	19.45	4.66	4.16	0.97	8.26	0.83	2.16	43.17
1.0 -1.5	0.75	4.88	1.69	1.97	0.80	5.51	0.39	1.33	17.32
1.5 - 2.0	0.33	2.30	1.11	0.86	0.50	4.90	0.39	0.53	10.92
>2.0	0.30	1.44	0.86	0.53	0.55	7.34	0.91	0.80	12.75
Total	5.10	35.36	9.48	8.65	3.13	29.07	2.88	6.35	100.00

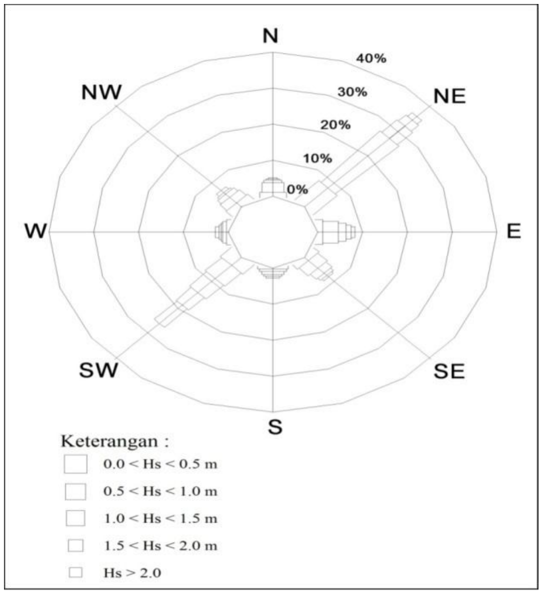

Figure 2. Wave rose

b. Tidal Data

Wave tidal was found in site near the harbor of Tahuna [1]. The data performance showed that the highest water spring (HWS) was + 1.35 m and lowest water spring (LWS) was - 1.35 m.

RESULTS AND DISCUSSION

Design of Sea-Wall

Safety infrastructure is the most important in design of seawall structure. It is due to the principals as follow: [4]

a. Hydraulic safety:
- Failure/damage structure (force of wave impact)
- Erosion (wave current impact)
- Overtoping (wave run-up impact)

b. Geothenic safety:
- Sliding
- Failure structure (consolidation impact)
- Failure foundation (settlement and lequefaction impact).

1) Design of Water Level (DWL)

Determination on the design of water level is influenced by the wave tidal, surge storm or wind set up, wave set up occurence and global warming. They would rise the sea level. Detail calculation for DWL was as follow:[2][3][5][6]

a) Tidal

summary tidal wave is :

- HWL : + 1.35 m
- MSL : 0
- LWL : - 1.35 m

b) Storm surge or wind set up, 0.25 m (assumed breaking wave, SPM 1973)

c) wave set-up

sea level rise calculation base on formula :

$$Sw = 0{,}19\left[1 - 2{,}82\sqrt{\frac{Hb}{gT^2}}\right]Hb$$

Note :

Sb = wave set-up in breaker zone (m)

T = wave periode (second)

Hb = height breaking wave (m)
g = gravity acceleration (m/sec^2)
breaker wave height was found at north west Hb of 2.38 m for return period 25 years and wave period (T) = 7,789 second, and then S_w= 0.371 m.

d) Global warming (SLR)
Estimation for global warming base on figure 3 and find 0.30 m

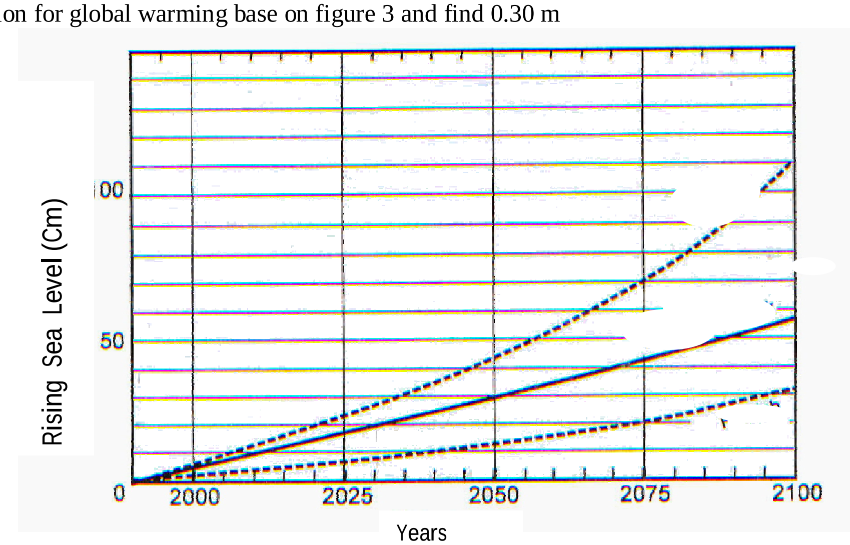

Figure 3. Estimation sea level rise which causes global warning

2) Wave design

If non breaking wave and height of wave which was used for setting crest elevation is wave height incident and the formula was as below : [2][3][5][6]

$$Hd = Ho.Kr.Ks$$

Note:
Hd = wave height incident at site (m),
Ho = wave height significant for deep water (m),
Kr = refraction coefficient,
Ks = shoaling coefficient.
Return period of 25 years for wave significant (Ho) from north-west direction (NW) = 3,12 m, Kr = 0,998, Ks = 0,96 and based on formula above become :

$$Hd = 3{,}12 \,.\, 0{,}998 \,.\, 0{,}96 = 2{,}1 \text{ m}$$

3) Crest Elevation Sea Wall

Sea wall crest elevation decided : [2][3][6]

$$\begin{aligned} \text{El. Crest} &= DWL + Ru + F_b \\ &= HWS + Sw + Ss + SLR + Ru + F_b \\ &= 1.35 + 0.37 + 0.25 + 0.3 + 0.50 + 0.25 \\ &= +3.02 \text{ m} \approx +3.00 \text{ m (provided wave reflector structure)} \end{aligned}$$

4) Dimention of seawall

Dimention of sea wall such as in Figure 4 (ilustration) and Figure 6 (detail of seawall), safety factor for stability against overturning and horizontal force to initiate sliding is ensure enough. Material of foundation consisted of sandy uniform gradation with uniformity coefficient Cu < 6, then lequefaction hazard must be considerated. Therefore, for the protection on foundation safety of soil bearing pressure especially earthquake condition was to provide pile foundation suggestion.

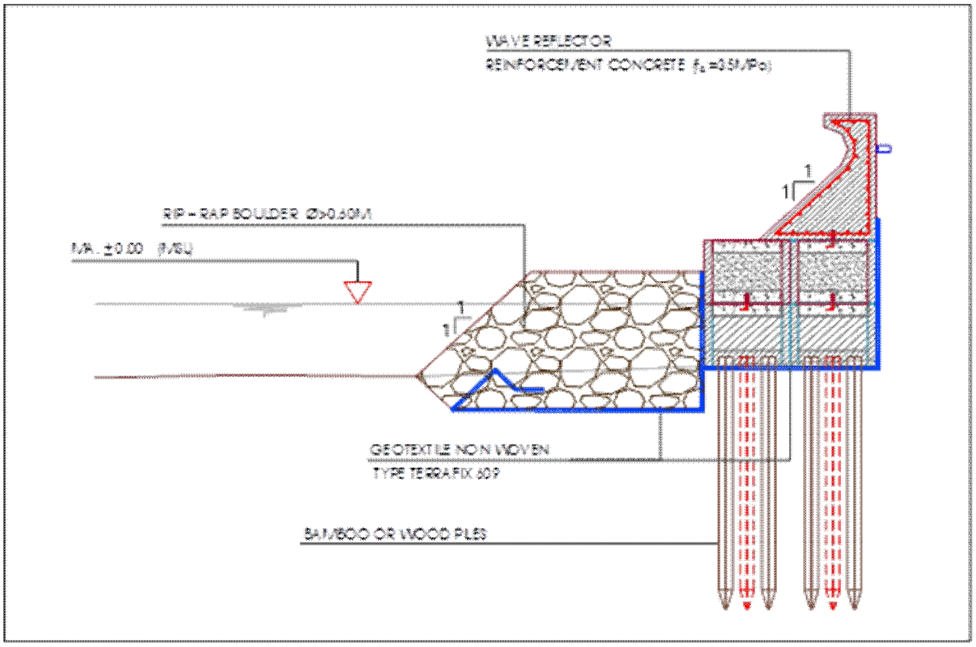

Figure 4. Seawall structure ilustration

5) Foundation treatment

The alternative for treatment foundation is based on being cheap of construction cost. According to the available material in Tahuna, the treatment foundation used the bamboo tree with the specification as below :

- Each unit of pile consist of 2 trunks of bambo tied together by wire and palm fiber rope (ijuk)
- Wire rope diameter = 2 mm,
- Length of bamboo = 8 meters with minimum 2 years old,
- Diameter of bamboo = 8 to 10 cm

Bundling and tightening of bamboo piles was conducted on the land (onshore) nearby coastal line.

Analysis of bamboo plies for foundation of seawall [4][7]

a) Loading on bamboo piles :

$$P = \frac{\Sigma V}{n} \pm \frac{M.Y_n}{\Sigma Y^2}$$

Note :

P = reaction on pile due to vertical force and moment (ton),

V = total vertical force acting on the foundation (ton),

n = number of piles,

M = sum of moments at the center of piles (ton.m),

Y = distance from the center of piles to each piles (m),

Y_n = maximum distance from the center of piles (m)

Y_n = 0.93 m

ΣY^2 = 3.46 m

$$P = \frac{13.23}{8} \pm \frac{18.09 \times 0.93}{3.46}$$

$= 1.65 \pm 4.86$

P_{max} = 6.51 ton.

b) Bearing Strength

b.1. Allowable Strength of bamboo piles

Allowable stress σ_{bamboo} = 80 Kg/cm^2

Diameter a bamboo pile using D = 10 cm (double trunks of bamboo tied together)

A_{pile} $= 2 \times \frac{1}{4}\Pi D^2 = \frac{2}{4}.\Pi.(0.10)^2 = 0.0157\ m^2 = 157\ Cm^2$

$\overline{P}$ = A. σ= 0.0157 x 800 = 12.57 ton/pile.

b.2. Allowable Strength of foundation

O = π.D = 62.83Cm (perimeter of bamboo)

P = 60 Kg/Cm^2 (value of conus by static cone penetrometer investigation)

C = 596 Kg/Cm^2 (value of cleef average investigation)

$$Q_{pile} = \frac{A_{pile}.P}{3} + \frac{OxC}{5}$$

$$Q = \frac{157.08 \times 60}{3} + \frac{62.83x596}{5}$$

= 3141.60 + 7489.34 = 10630.936 Kg = 10.63 ton.

6) Retaining Sea-Wall Structure With Geogrid Reinforcement

Geogrid are high – modulus polymer mater*ials, such as polypropylene and polyethylene. The major* function of geogrids is reinforcement. Geogrids are relatively stiff netlike materials by opening is called apertures that are large enough to be allowed the interlocking with surrounding soil or rock for performing the function of reinforcement or segregation (or both of them). So, to avoid the pressure of earth on Tahuna seawall design, it was used the uniaxial geogrid which spesification : Sequgrid Q_1 40/40, tensile strength 40 kN/m.
Determination ofn the vertical spacing of layers at any depth z uses the formula :[8]

$$s_v = \frac{\sigma_G}{\sigma_a^{'}.FS_{(B)}} = \frac{\sigma_G}{(\gamma_1.z.K_a).[FS_{(B)}]}$$

Note

σ_G = allowed strength (kN/m),

K_a = rankine active pressure coefficient,

$\varphi_1^{'}$ = friction angle of granular backfill,

γ_1 = unit weight of the granular backfill (kN/m^3),

$FS_{(B)}$ = 1.3 – 1.5

Determination on the length of each layer uses the formula : [8]

$$L = \frac{(H - z)}{\tan(45 + \varphi_1^{'})} + \frac{S_v.K_a[FS_{(p)}]}{2\tan\varphi_F^{'}}$$

Note:

H = height of sea wall (m),

z = distance from surface top embankment (m),

K_a = rankine active pressure coefficient,

$\varphi_1^{'}$ = friction angle of granular backfill,

φ_F = $2/3x\varphi_1^{'}$

S_v = vertical spacing distance (m),

$FS_{(P)}$ = 1.3 – 1.5

Table 3. Geogrid calculation

	Angle repose φ		30				
	φf		20				
	Tensile Strength		40	KN/m			
	earthquake Coeff.		0.4				
	Ka		0.3333				
	Kae		0.48				
	Cohesion coeff.		1	KN/m^2			
	Unit weight		18	KN/m^3			
	Load		10	KN/m	Sv :	1.00	m
	Safety factor		1.5		L :	4.00	m
H (Tot.depth)	Z (m)	Sv (m)	L (m)	Ts max KN/m	Ts max earthquake (KN/m)	Td Geogrid (KN/m)	Remarks
3	1	3.1	1.56	9.33	13.44	40	OK
3	2	1.5	0.78	15.33	22.08	40	OK
3	3	1.0	0.13	21.33	30.72	40	OK

CONCLUSION

Based on the design of seawall as above, it was concluded as follow :

1. The seawall structure aim which was for the protection on longshore reclamation of water front in Tahuna City would improve the aesthetics environment and enlarging the transportation facility.
2. The bamboo piles was sufficient safety for foundation treatment on sandy uniform gradation. The source material was easy to find and it was strength enough for a long life time.
3. Geogrid for reinforcement of retained seawall was effectively to reduce the horizontal force acting and safety against the overturning ensure. Thus, the analysis of bending moment acting on pile and displacement at the pile head has been neglected (assumed small value).
4. Recently, implementation on construction of seawall in Tahuna showed that the structure design was satisfied enough and strengthen the protection of wave acting incident.

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