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Hydraulic Experimental on the Effect of Mangrove Forest to Reduce Tsunami

マングローブの津波減災効果について

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1. Introduction

Mangroves are heavily vegetated intertidal wetlands, an effective buffer against large waves such as storm surges and tsunamis. However, the quantitative rule of mangrove to reduce attacking wave are not well known and formulated.

In order to study the effectiveness of mangrove forest on tsunami, hydrodynamic phenomena and hydraulic resistance due to the boundary roughness and vegetation should be analyzed. In the present study aims at understanding that behavior and its effectiveness against tsunami impact.

2. Experimental Set-up

Hydraulic experiments for unsteady flow of tsunami with a single wave was carried out in an open channel of 100m in long, 0.5m in high and 1m in wide. A mangrove model was placed in the channel by means to reduce the incoming wave.

The model comprises of roots, trunk, and leaf. Roots and leaf are constructed by porous medium and trunk by cylindrical piles. Root high is 5cm, diameter trunk is 1.2cm and 20cm distance between trunk to trunk. Ratio of total volume occupied by model to a total water column in condition under sub-water is 35.17% where root, trunk and leaf are 2.74%, 0.75%, and 31.68% respectively (see Fig. 1). However in the experiment the calm water depth is 23 cm.

Recently study considers the model was placed before breaking point with 5 cases such as 2m long model with no leaf (N2), with leaf 32cm (H2) and 22cm (L2) in high from the bottom, also 1m long with leaf 32cm (H1) and 22cm (L1) in high.

Water elevations are measured at close in front (X3), inside (X4) and close behind (X5) of the model. Also several points at upstream and downstream. Current profile are measured at the same points with wave gauge, i.e. at X2, X3, X4, X5 and X6, with various in depth (see Fig. 1)

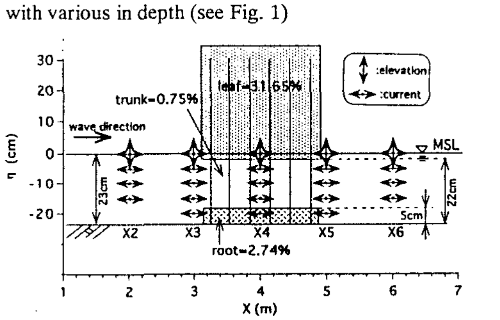

Fig. 1 Mangrove Model

3. Experimental result

The experimental results of water elevation and current with model (i.e. L2) and without model (Wo) at front (X3) and behind (X5) are shown in Fig. 2a and Fig. 2b respectively.

Fig. 3a shows the max and min elevations and of the Wo, L2, H2, N2 cases. The Elevation of incoming wave at X2 is around 14.5cm. In case Wo the elevation is to be increased by shoaling effect, then is be broken at around X7 (breaking height around 24cm). However the model is putted the max elevation at front (X3) increased to 19.5cm (18%) and at behind (X5) decreased to 8.5cm (58%).

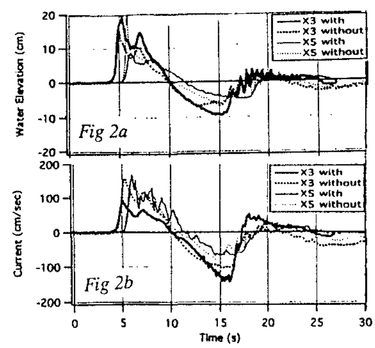

Fig 2(a) Elevation and (b) current of L2 and Wo

Contrarily, the min elevations, at X3 decreased to -9.6cm (44.4%) and at X5 increased to -4.84 cm (19.7%).

Fig 3b shows that wave height reflection at front and reduction and at behind are strongly depend on the occupied volume.

However Fig. 3c shows that the length of model is not significant to reduce wave height.

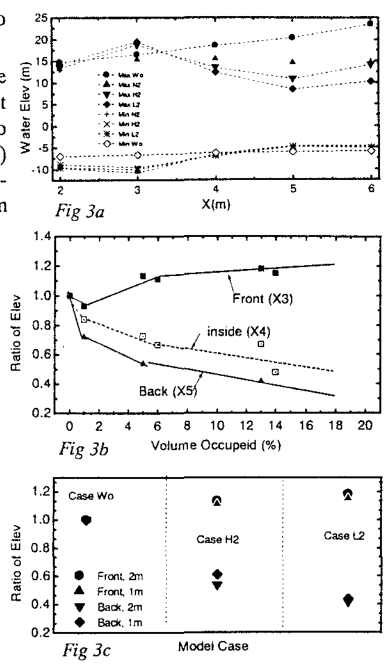

Fig 3 (a) Max and min elevation,
(b) Ratio elev function of occupied volume
(c) Ratio elev function of model length

The incoming currents without model at X3 is around 170cm/s and increase to be around 200cm/s at breaking point, X7. The back current is around 90cm/s. Those currents are relative uniform in depth. However the model is present, the incoming current at front (X3) would be reduced, but the back current increased.

Existence of model defecting the current profile to be a curve (see Fig. 4), then normal (uniform) again after several meters left the model. Different porosity of the model generated a current stratification trough on each part, such as max current in the root, trunk and leaf areas are in the order of 15-40, 150-200, and.85-100cm/s respectively.

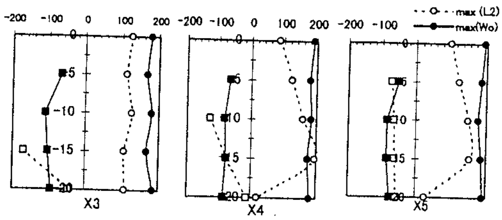

Fig 4. Current Profile (case L2)

4. Numerical Computation

A method applied to examine an equivalent roughness for mangroves model is 1-D momentum equation including Inertia, Manning and Drag coefficient as follows:

$$(1+C_M\rho V)\frac{\partial M}{\partial t}+\frac{\partial}{\partial x}\left(\frac{M^2}{D}\right)+gD\frac{\partial\eta}{\partial x}+\left(\frac{gn^2}{D^{7/3}}+\frac{C_{Dtr}\rho A_{tr}}{2}+\frac{C_{Dlf}\rho A_{lf}}{2}\right)M|M|=0$$

where: M is flux discharge; $D(=h+\eta)$ is total depth,

C_M is mass coefficient; V is model volume; n is Manning coefficient; C_{Dtr} and C_{Dlf} is drag coefficient due to trunk and leaf A_{tr} and A_{lf} is projected area of trunk and leaf.

Hydraulic resistance is calculated by numerical method with mesh size (dx) is 2.0m and time stepping (dt) is 0.1sec. Two cases are considered, i.e. model with leaf (L2) and model without leaf (N2). Calculation result of n, C_D, and C_M are shown in Fig. 5a, 5b, and 5c respectively. The figures are considered only from 3sec to 17sec, because after 17sec is unrealistic result.

Fig. 5a shows n is strongly depends on the elevation. When the max elevation, n is to be around 0.1, then decrease to be 0.04 accordance with decreasing of elevation till MWL and to be around 0.02 during the negative wave. However the discharge approximates to zero, the n become large, this case occurs at around reverse point of positive to negative (contrary).

Fig. 5b shows C_D is large at the max elevation (ie L2 is around 70 and N2 is around 50), and decreasing (to be around 20) accordance to elevation, then around 2 during the negative wave, caused by the projected area is very small that only due to the root and trunk.

Fig. 5c shows when the max elevation, C_M is also large, then decrease appropriate to the elevation. But C_M become large during the negative wave caused by the projected area is small. Fig 5d shows the elevation data as reference for those behavior. Behavior of each term in the above Eq. in which Term-1 is acceleration, Term-2 is momentum flux, Term-3 is pressure gradient, and Term-4 is hydraulic resistance are shown in Fig. 5e and 5f.

5. Conclusion

The existence of the model with ratio occupied around 13.2% could be reduced the elevation around 58% at behind model, and increased (reflected) to be around 18% in front of the model. Therefore the effectiveness to reduce the wave height are strongly depend on the occupied volume, however a length of model is not significant.

The model also could be reduced the incoming current and deflected the current profile to be a curve, especially inside and behind the model. Furthermore the model could be generated a strong back current at in front of the model.

Manning coefficient is around 0.1 during the maximum elevation and decrease to be 0.4, then 0.02 when negative wave (0.02). Drag coefficient at the max elevation around 50 to 70 and decrease around 15 to 20 accordance with decreasing of elevation and very small (as averaged around 2) during the negative wave.

Fig 5a

Fig 5b

Fig 5c

Fig 5d

Fig 5e

Fig5f

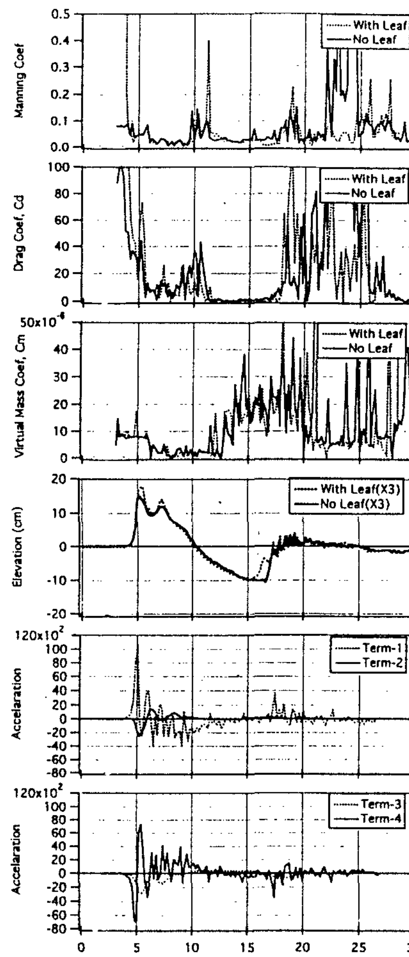

Fig.5 Calculation result of hydraulics resistance, (a) Manning coef, (b) Drag coef, (c) Virtual mass coef. (d) Elev data, and (e)&(f) Accelaration of each term of the equation

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