

# Scale Selection for Hydraulic Model of the Lagos Costal Zone.

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## ABSTRACT

The proper selection of scales is quite important for the success of hydraulic model studies with moveable bed materials. In this paper, the practical design of coastal mobile bed materials is reviewed in depth. Since an entirely theoretical approach is not yet feasible on this subject [5, 9], a semi-theoretical approach is used to obtain the basic scale laws for a model of Lagos coastal region using sand as bed material.

(Keywords: hydraulic models, scale laws, moveable bed materials)

## INTRODUCTION

The use of reduced scale models for detail understanding of elaborate physical systems and real life situations are encountered in many fields of human endeavor including architecture, medicine, and engineering to mention a few. In this paper, the experience gained in hydrodynamic modeling of sand transport along the Lagos Coast provides useful insight to the proper selection of scales when moveable bed materials such as sand are used in the experimental investigations.

While it is relatively simple to obtain model scales for fixed bed models, it is not so for a movable bed model. The difficulties encountered arise on one hand because the bed morphology changes continuously, in which case, the parameters relating to the phenomenon under study change continuously, and on the other hand because certain processes of sediment transport resulting jointly from wave and current action are not totally well understood [9]. Nonetheless, as [10] pointed out, these disadvantages do not mean reliable movable bed models cannot be built, instead, it gives researchers chance to be flexible and unique in their approach to movable bed modeling, especially in the coastal zone. Reliable

results have been obtained in the past from such models, and beginning shortly after the Second World War, the state of the art has advanced to the point where movable bed models have become a powerful tool for investigating river and coastal engineering problems in general.

## GENERAL THEORETICAL CONCEPTS

For movable bed short wave models, where distribution is allowed, the basic model scales can be derived [8, 9, 11] as follows:

$$\eta_H = \eta_L = \eta_d = \eta \quad (1)$$

and

$$\eta_x = \eta_y = N_\eta \quad (2)$$

In respect of linear dimensions where the subscript H refers to wave height, L to wavelength, d to water depth, z to vertical dimension, and x and y to horizontal dimensions. N is the model distortion defined by equation (2) above while  $\eta$  is model scale, for example, for the length dimension by:

$$\eta_x = \frac{\text{prototype length}}{\text{model length}} \quad (3)$$

When  $\eta$  is used without subscripts, it refers simply to the basic vertical scale.

In respect of time and velocity scales for movable bed models;

$$\eta_c = \eta_u = \eta_T = \eta_t = \eta^{1/2} \quad (4)$$

where subscript u refers to orbital velocity, t to hydraulic time, T to wave period, and c to wave celerity.

When, as in this case, water is used as the fluid medium in the model, the scales for gravity, fluid viscosity and density, are unity.

### SEDIMENT TRANSPORT SCALE AND TIME SCALE FOR BED EVOLUTION

The general approach by most authors, for instance [11], is from a consideration of shear stress conditions in the microscopic boundary layer. The approach followed here however follows from the macroscopic point of a general acceptable boundary layer theory for wave motion over loose bed.

It has been conclusively shown by [2] and others, for instance [6], that the rate of sediment transport along sandy beaches by wave action is directly proportional to the specific energy flux of the waves reaching the shore:

$$G = AE_a \quad (5)$$

In which  $G$  is the submerged weight littoral drift rate,  $E_a$  is the alongshore component of the energy flux along the beach per unit length of beach, and  $A$  is the constant of proportionality to be deduced empirically.

From small amplitude wave theory, we can write for  $E_a$ :

$$E_a = \frac{1}{16} \rho g H_o^2 c_o K_r^2 \sin \alpha_b \cos \alpha_b \quad (6)$$

Where  $\rho$  is fluid density,  $g$  is acceleration due to gravity,  $H$  is wave height,  $c$  is the wave celerity,  $K_r$ , the refraction coefficient, and  $\alpha_b$ , the wave breaking angle. The subscript  $o$  refers to deep water conditions.

Thus we can write

$$G = A \rho g (H_o K_r)^2 c_o \sin \alpha_b \cos \alpha_b \quad (7)$$

where the refraction is already taken care of by the constant,  $A$ . It is worthy of note that in this formula, the influence of sediment size of the littoral materials as well as beach slope have not been reflected [3]. This is attributed to the fact that variation of grain size and beach slope of sandy beaches is very small, thus their influences are not felt. However, the empirical constant  $A$ , may be viewed as being dependent on these parameters.

Therefore, writing equation (7) in terms of scales, we have:

$$\eta_G = \eta_A \eta_{H_o}^2 \eta_{K_r} \eta_{c_o} \eta_{\sin \alpha_b} \eta_{\cos \alpha_b} \quad (8)$$

in which,

$$\eta_g = \eta_\rho = 1 \quad (9)$$

Since bottom topography, and thus the breaker angle is modeled in similitude, (which has been assumed in arriving at equation (1)) then,

$$\eta_{K_{rs}}^2 = \eta_{\sin \alpha_b} = \eta_{\cos \alpha_b} = 1 \quad (10)$$

and hence,

$$\eta_G = \eta_A \eta_{H_o}^2 \eta_{c_o} \quad (11)$$

In combination with equations (1) and (2), this yields:

$$\eta_G = \eta_A \eta^{5/2} \quad (12)$$

which is the scale of littoral drift rate.

Now assuming that  $t_b$  is the time for bed evolution, then if  $W$  is the total volume of littoral drift within a time interval  $t_b$ , then we can write in terms of scales,

$$\eta_w = \eta_G \eta_{t_b} \quad (13)$$

or,

$$\eta_w = \eta_A \eta^{5/2} \eta_{t_b} \quad (14)$$

Unfortunately, the time scale for bed evolution is very difficult to predict, and to date, no accurate and reliable theoretical prediction is yet possible [7], and therefore resort has to be made to experimentation.

In the special case where sand material is used, as is the case with the model of Bar Beach, the scale of constant  $A$  may also be deduced experimentally, though it is expected to be close to unity (and this may be extended to models in which material differs from sand).

Since the phenomenon under study is Littoral Drift as it affects coastal structures like groynes, breakwaters etc. equations (12) and (14) are now useful and adequate to predict the littoral drift

rate, and the time scales for bed evolution, as equation (14) may be written as:

$$\eta t_b = \frac{\eta_w}{\eta_A \eta^{5/2}} \quad (15)$$

## EXPERIMENTAL DETERMINATION OF SCALE OF CONSTANT, A

This can be deduced only if the littoral drift rate on the prototype beach is known, or can be estimated by well-known methods (e.g. [4] method).

The beach is modeled closely after the prototype beach with due regards to distortion. Thereafter, it is subjected to wave action modeled according to equations (1) and (2).

Records of the submerged littoral drift are made, versus the value of the alongshore component of the energy flux of the waves per unit width of model beach, from which the constant A for the model is obtained.

Similar data is used to deduce the value of constant, A, in the prototype. And hence the scale of A is deducible. For a model situation, in which the fundamental scales are defined, the scale of this variable has been found to be constant [1].

## EXPERIMENTAL DETERMINATION OF TIME SCALE FOR BED EVOLUTION

The procedure is similar to the above, except that prototype historical data of beach evolution is necessary. The historical data is reproduced in the model as closely as possible, such that the model time intervals corresponding to prototype time shifts can be deduced explicitly from experimental observations.

With the determination of these two values, equations (12) and (15) are now well defined.

## CONCLUSION

This method derived partly on experimental measurements is based on sound theory, the values of some variables crucial to the deduction of scales to be used in the investigation have to

be deduced experimentally. This implies that prior to the model investigations proper, preliminary investigations have to be carried out to deduce the scale of some variables. This follows because reliable theoretical prediction of these scales is still not possible. Though this increases the time of model investigations, this is a small price to pay for the reliability of this method (being based on a reliable and well accepted empirical relation of equation (5)). In addition, the model thus defined may be utilized repeatedly once the equations (12) and (15) have been established.

## REFERENCES

1. Ayankogbe, S.A. 1985. "Similitude in Coastal Movable Bed Models with respect to Littoral Drift". M.Phil. Thesis. University of Lagos: Lagos, Nigeria.
2. Bagnol, R.A. 1963. "Beach And Nearshore Processes, 1. Mechanics of Marine Sedimentation". In: *The Sea*, 2. M. N. Hill (ed.), Wiley: New York, N.Y. 507-528.
3. Bijker, E.W. 1968. "Littoral Drift As A Function of Waves And Current". *Proceedings of the 11th Conference on coastal Engineering*: Lisbon.
4. CERC. 1973. *Shore Protection Manual 12(1&2)*. U.S. Army Coastal Engineering Research Centre. Department of the Army Corps of Engineers: Huntsville, AL.
5. CERC. 1990. *Shore Protection Manual 12(1&2)*. U.S. Army Coastal Engineering Research Centre. Department of the Army Corps of Engineers: Huntsville, AL.
6. Inman, D. L, Komar, P.D, Bowen 1968. "Longshore Transport of Sand". *Proceedings of the 11th Coastal Engineering Conference*. 12(1). London.
7. Jain, S.C. 1982 . "Movable Bed Tidal Model." *Journal of the Water Ways, Port, Coastal and Ocean Engineering*. A.S.C.E. 12(108).
8. Kamphuis, J.W. 1972. "Scale Selection For Movable Bed Wave Models". *Proceedings, 13th Coastal Engineering Conference*. Vancouver. 12(2):1173 – 1196.
9. Kamphuis, J.W. 1974. "Practical Scaling Of Coastal Models". *Proceedings, 14th Coastal Engineering Conference*. Copenhagen. 12(3): 2086 – 2102.

10. Le Mehaute, B. 1970. "Comparison Of Fluvial".  
*Proceedings, 12th Conference on Coastal Engineering*. Washington, D.C. 12(2):1077 – 1096.
11. Yalin, S. 1971. *Theory Of Hydraulic Models*.  
Macmillan: London.

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