Wave Transformation In The Surf- Zone Of Pondicherry Coast

Dr. G. Vijayakumar *****, Dr. D. Govindarajulu ******, Dr. T. Sundararajan******
*Associate Professor, **Professor
Department of Civil Engineering,
Pondicherry Engineering College, Pondicherry.

Abstract

Transformation of near shore waves at the surf zone attribute to the morphological change of a coast. For the study, the Veerampattinam beach located at the Pondicherry region was selected. The beach is straight and extend to about three Km. The breaking wave height was determined from the available deep sea wave data acquired from the wave float gauge designed by the department of Civil Engineering, Pondicherry Engineering College, Pondicherry (Vijayakumar, G., Pandurangan, K., and Govindarajulu, D.,(2004). The type of transformation of waves at the surf zone was determined by analytical approach using Matlab software. From the model developed based on the observed wave climate data and bathymetry of the area for a period of one year(June 2008 – May 2009), it was found that , the predominant type of breaking was plunging which has occurred from the Month of October to January which is mainly responsible for sediment transport and modification of beach profile. From the month of June to September the predominant type of breaking was collapsing and surging which are responsible for steepening of beach (Aagaard,T., Robin,D-A., Greenwood,B., Nielson,J., (2004),.

Index Terms: *Beach Morphology, spilling, plunging, surging, collapsing, wave float gauge*

1. Introduction

Wave approaching the coast increase in steepness (H/L) as the water depth decreases (Andrew, C.J.F., 1999). However, there is a physical limit to the steepness of the waves and when this physical limit is exceeded, the wave becomes unstable and breaks, dissipating energy and inducing near-shore currents and an increase in mean water level (Bayram, A., Larson, M., 2000). Waves break in a water depth approximately equal to the wave height. The 'surf zone' is the region extending from the seaward boundary of wave breaking to the limit of wave up rush. Within the surf zone, wave breaking is the dominant hydrodynamic process. The surf zone is the most dynamic coastal region with sediment transport and bathymetry change driven by breaking waves and near – shore currents (Chen Y-Y., Yang, B-D., Tang, L -W., Ou, S _H., Hsu, J.R- C., 2004). Surf zone wave transformation study is an essential tool to estimate potential storm damage, shoreline evolution and cross – shore beach profile change, and in the design coastal strucutures (jetties, groins, seawalls) and beach fills (Gadre, M.R., Kantkar, C.N., 1989).

1.1 Breaker Types

As a wave approaches a beach, its length (L) decreases and its height (H) may increase, causing the wave steepness (H/L) to increase. Wave breaks as they reach a limiting steepness, which is a function of the relative depth (d/L) and the beach slope (tanβ) (Bayram, A., Larson, M., 2000). Wave breaking parameters, both qualitatively and quantitative, are needed in a wide variety of coastal engineering applications. 'Breaker type' refers to the form of the wave at breaking. Wave breaking is classified under four types as: spilling, plunging ,collapsing and surging (Galvin 1968). The breaker type is a function of the beach slope (tanβ = m) and the wave steepness (H/L). These may be combined into a ratio, usually called the surf similarity parameter, as Eqn.(1):

$$\xi_b = m / (H_b / L_o)^{0.5} \qquad \text{---(1)}$$

1.1.1 Spilling breakers

Spilling breakers, Battjes (1974) occur when $\xi_b < 0.4$. This type of breaking waves occur when the approaching nearshore consists of a flat beach for steep waves or both. Therefore when sea breaks on a flat sandy beach, the breakers are predominantly of spilling type. Several wave crests may be breaking simultaneously, giving the appearance of several rows of breaking waves throughout the breaking zone. Such beaches are often called as dissipative beaches (Battjes 1974).

1.1.2 Plunging breakers

Plunging breakers occurs on steeper beaches and /or for flatter waves, when $0.4. < \xi_b < 2.0$. In this case, the wave crest runs ahead of the main body of the wave and plunges forward violently. This type of breaking of waves tend to roll and break thereby creating a slurry in the breaking area and makes the sediment to be in suspension and move in lateral direction depending on the cross - shore current. Hence, this type of breaking waves are more responsible of sediment movement (Battjes 1974).

1.1.3 Collapsing

Collapsing type of breaking occurs when $\xi_b > 2.0$. These waves are characterized by a wave front that more or less explodes forward , may be found where swell breaks on steep beaches made up of coarse material (Battjes 1974).

1.1.4 Surging

Surging breakers occur on very steep beaches. The waves simply surge up and down the beach and there is very little or no breaking. Beaches with surging and collapsing breakers are often called 'reflective beaches'(Battjes 1974). A schematic view of different types of breakers is shown in Fig. 1.

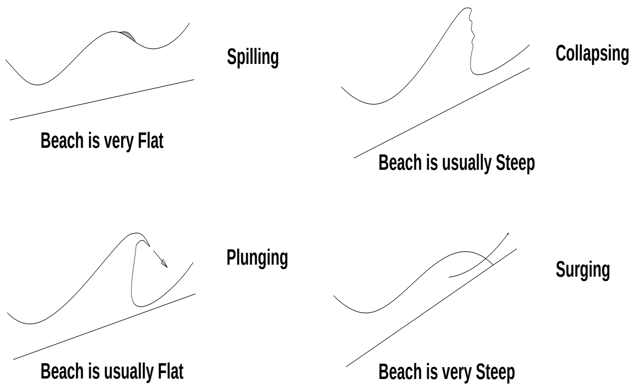

Fig.1.Typess of Breaker

2. Methodology

2.1. Breaking wave height

2.1.1. Wave Ray Method

The wave-propagation problem can often be readily visualized by construction of wave rays Fig.2. If a point on a wave crest is selected and a wave crest orthogonal is drawn, the path traced out by the orthogonal as the wave crest propagates onshore is called a ray. Hence, a group of wave rays map the path of travel of the wave crest. For simple bathymetry, a group of rays can be constructed by hand to show the wave transformation, (Harrison and Wilson 1964, Dobson 1967, Noda et al. 1974). Refraction and shoaling analyses typically try to specify the wave height and direction along a ray.

From the wave data acquired from the wave float installed near the pier of the Pondicherry port was collected for the above said period from which, the average values of wave height of each month (H_s), wave length (L), α_o (wave direction), significant wave period (T_s) constitute the input parameters for wave transformation studies. Eqn. (2), (3), (4), and (5) were used to obtain the wave parameters corresponding to deep water condition and then to obtain the transformed wave height at incipient wave breaking condition i.e, (H_b) (Bayram, A., Larson, M., 2000). This value of H_b will be subsequently used in the surf – zone transformation studies (Bryant, E. (1979). Using a standard commercial package (MS – Excel) the above computations were carried out and the output consists of, α_b and H_b for each month for the year 2009 Table.1 .

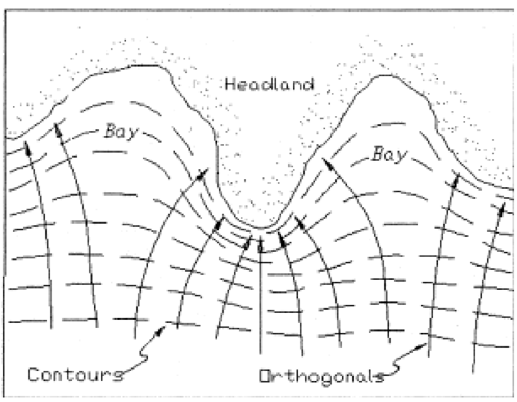

Fig.2 Idealized plot of wave rays

H_d at any depth can be related to deep water wave height H_o as:

$$H_d/H_0 = \sqrt{n_0C_0/nC}$$
$$= \sqrt{1/[2\ n\ \tanh(kd)]} = K_s \quad \ldots(2)$$

$$H_d/H_0 = \sqrt{n_0\ C_0\ b_0/n\ C\ b}$$
$$= \sqrt{1/\ [2n\ \tanh(kd)]}$$
$$\sqrt{b_0/b} = K_s.\ K_r$$

where, $K_r = \sqrt{b_0/b}$, is called the 'refraction coefficient'= $(\cos\theta_0/\ \cos\theta)^{1/2}$

$$= (1 - \sin^2\theta_0/1 - \sin^2\theta)^{1/4} \quad \ldots.(3)$$

where,

K_s&K_r = Shoaling and Refraction coefficient

θ_0 = wave angle at deep water.

b/b_o = Distance between adjacent wave rays, at breaking and deep

C/C_o = Wave celerity at shallow and deep

n = Number of waves recorded

$$H_d = H_o\ (\ \tanh kd(1 + (2\ kd/\ \sinh kd)))^{0.5} \quad \ldots(4)$$

Where,

H_0 =deep water wave height (in m);

H_d = wave height measured at depth d (in m);

d = depth of wave measured (in m);

k = wave number = 2 Π / L and

L = wave length (in m)

The wavelength is then given as

$$L = T\sqrt{gd/F} \quad \ldots.(5)$$

$$gT/2\pi\tanh(2\pi d/L) \approx \sqrt{gd/F}$$

where, gd/F an approximation for the wave celerity and

$$F = G + \frac{1}{1.0 + 0.6522G + 0.4622G^2 + 0.0864G^4 + 0.0675\ G^5}$$

and

$$G = 2\ \pi\ (d/L_o) = (2\ \pi/T)^2\ d/g$$

Where ,g = gravitational acceleration L/L_o = shallow and deep water wave length

d = depth of wave at breaking

H_d can be taken approximately equal to H_b (breaking wave height)

Sl. No.	Month	$H_{b(app)}$	α_b
1	Jan	1.07	19.08
2	Feb	0.80	18.25
3	March	0.71	12.40
4	April	0.79	14.08
5	May	0.96	14.29
6	June	0.97	15.47
7	July	0.68	17.06
8	August	0.76	18.06
9	Sept	1.13	10.75
10	Oct	1.04	12.66
11	Nov	0.87	18.36
12	Dec	1.00	21.31

Table 1. Breaking wave height (H_b) and wave angle (α_b) year 2009

2.2 Near shore transformation

2.2.1 Analytical Model

Near – shore wave height obtained by the wave ray method, the deepwater wave length and the slope were used to evaluate the 'surf similarity parameter'(ξ_b) using Eqn.(1), for each month for the observatory period(June 2008-May 2009) . Based on the value of ξ_b obtained, the type of wave breaking was determined. A separate program was developed for the above in Matlab (ver.7.0) which is listed in Appendix – 1.

3. Results and Discussion

The type of wave breaking for each month of the year 2009 is given in Tables 2. It can be seen that during October – January (N – E monsoon) the predominant type of breaking is 'plunging', thus contributing to the sediment movement, in this part of the coast. During S – W monsoon (June-September) the predominant type of breaking is 'surging and collapsing' which is responsible for steepening of the beach.

4. Conclusion

Result from near shore transformation studies show that the numerical solution gives better results and can closely represent the physical phenomenon of waves in near-shore. The type of breaking has been identified based on the 'surf similarity parameter' and its influence on the coastal process has been identified.

Type of Breaking	Spilling	Plunging	Collapsing	Surging
Jan	---	95%	05%	
Feb	---	40%	60%	
March	---	55%	45%	
April	---	25%	75%	
May	---	55%	45%	
June	---	25%	75%	
July	---	05%	95%	
August	---	---	100%	
September	---	75%	25%	
October	---	---	100%	
November	---	75%	25%	
December	---	75%	25%	

Table2. Types of near shore wave breaking year 2009

Appendix I

Mat lab programme for determining the type of wave breaking

d = input('enter depth at breaker zone:n')
ratio _ of _ depth _ to _ wave _length = (d/wave _length)
ratio _ of _wave _heights = input('enter the ratio of wave heights corresponding to that of d/lo:n')
significant _ wave _ height _ in _ breaker _ zone = (significant _ wave height _ in _ metres)*(ratio _ of _ wave _ heights)
slope(m) = 0.03
c = sqrt(significant _ wave _ height _ in _ breaker _ zone/ wave _ length);
surf _ similarity _ parameter = m/c
if (surf _ similarity _ parameter < 0.4)
fprintf('Type _ of _ breaker _ is _ spilling\n')
elseif(surf _ similarity _ parameter > 0.4) & (surf _ similarity _ parameter < 2.0)
fprintf('Type _ of _ breaker _ plunging \n')
elseif(surf _ similarity _ parameter > 2.0)
fprintif('Type _ of _ breaker _ collapsing \n')

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