J. Basic. Appl. Sci. Res., 2(5)4556-4562, 2012
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ISSN 2090-4304
Journal of Basic and Applied Scientific Research
www.textroad.com

Field Study of Longshore Current along the Anzali Coast in Caspian Sea

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ABSTRACT

Waves are changed on shallow water; one of the most common changes is breaking of these waves. Near-shore wave breaking generates longshore current which is studied in Anzali Coast during the present study. The velocity of current as well as the pattern of long- shore current were calculated and modeled using the most appropriate equations and field data. The beach slope is computed in this study using the hydrographic map of the study area and then the velocity of long-shore currents are calculated by employing mathematical equations, field data collected by buoy in Anzali Station and also the long-term wave rose diagram available through Anzali Station. The obtained current velocities are compared with values obtained through ADCP current meter along the shoreline in Anzali Station. Finally the most suitable equation is applied regarding the results of comparison and then calibration coefficient is estimated for the employed equation.
KEYWORDS: longshore current, Caspian Sea, wave breaking.

INTRODUCTION

The history of long shore current research is relatively short. Several theories provided for study of long shore current such as: Languet Higgins (1970), Komar et al (1975),Komar Inman (1970), Galvin (1987), Pilirczyk (1999),Reniers(1997) and Ruessinketal(2001)[1-7].The aims of long shore current research to be able to predict the current field in the near shore and its effect on environment .Due to economic and political significance of the Caspian Sea the Caspian Coast needs more attention for better use of its resources. Climatologic conditions as well as other natural phenomena governing Anzali port make it a unique place for such kind of marine studies. The present research intends to study the pattern of long shore currents out of Anzali port basin using wave and current data. Long-shore current is the alongshore component of near shore currents that plays the most important role in changing coastal morphology, sediment transportation and coastal topography. For this purpose, wave data such as wave length, period and direction obtained by buoy were used along with current meter (ADCP) data such as current velocity and direction, gathered by Iranian Port and Maritime Organization in 2003[8].

MATERIALS AND METHODS

1. models overview

When waves are developed, they gradually propagate coastward and are influenced by sea floor topography. Such process affects wave dynamism along the littoral zone. The most common processes are as followings:

Wave refraction, wave diffraction, dissipation due to friction, dissipation due to percolation, additional growth due to wind, wave - current interaction, wave - wave interaction, wave breaking and so on. In terms of hydrodynamic phenomena breaking zone is the most active part of coastal zone in which sediment transportation and sea floor changes occur due to wave breaking and long shore currents. During the wave breaking process, water pile near the wave base collides to the sea floor and moves backwards due to friction, resulting to an increase in wave height and decrease in wave length. Wave height increases so much that the wave breaks. Then wave moves forward as a vertical column of turbulent water towards the shore. Diffused water in breaking zone will inevitably return towards the sea. This return process will be performed by alongshore currents called "long- shore currents", then, going some distances, water turns and moves in the form of a quick narrow rip current which is perpendicular to the shore. Rip currents usually occupy hundreds of meters along the shore.

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Long-shore current velocity depends on some factors such as wave height, breaking wave angle and the beach slope[9]. There are different models and equations for calculating the longshore current velocity[10]. Some of these models are momentum equations, mass continuity equations and radiation stress equations which are explained in brief. Although radiation stress equations are also on the basis of momentum and their theories are different from classical momentum. Nowadays radiation stress theory is more commonly used(Languet-Higgins 1970 a):

$$V = 20.7m\sqrt{gH_b}\,\sin 2\alpha_b \qquad (1)$$

m: the beach slope, H_b : the wave height in breaking point, α_b : wave angle in breaking zone.
Languet- Higgins (1970 b), has also proposed the following equation to calculate long-shore current velocity in the middle of breaking zone considering some assumptions. The bases for the above mentioned equation are following assumptions:
The linear theory is applicable for wave's behavior, the beach slope is smooth.

$$V_0 = 253m\sqrt{H_b}\,\sin\alpha_b \qquad (2)$$

Komar (1975) proposed a new solution to develop the following equation to calculate longshore current velocity in the middle of breaking zone using Languet-Higgins solution.

$$V = 2.7U_m \sin\alpha_b \cos\alpha_b \qquad (3)$$

$$U_m = \sqrt{\frac{2E_b}{\rho h_b}} \qquad (4)$$

U_m is maximum wave orbital velocity, ρ is water density, E_b is wave energy in breaking point and h_b is the depth of water in breaking zone.
Komar (1979) proposed an equation for calculating longshore current velocity in the middle of breaking zone based on sediment rate introduced by Komar.

$$V = 1.17\sqrt{gH_b}\,\sin\alpha_b \cos\alpha_b \qquad (5)$$

Galvin (1987) showed that the continuity equation (resulted from the conservation of mass) for calculating the average longshore current velocity, is compatible with laboratory data in a large extent. He also proposed the following equation:

$$V = gmT\sin 2\alpha_b \qquad (6)$$

T`: wave period
Pilirczyk (1999) suggested the following equation to calculate longshore current velocity with a good approximation in which K_L is a coefficient ranging from 0.3 – 0.6.

$$V = K_L\sqrt{gH_b}\,\sin 2\alpha_b \qquad (7)$$

Also, wave height in breaking point is calculated from Singamsetti-Wind's equations (1980)[11]:

$$H_b = H_0(0.575m^{0.031}(\frac{H_0}{L_0})^{-0.254}) \qquad (8)$$

Where H_0 represents wave height in deep water and L_0 is wave length in deep water.
Wave breaking angle is estimated by Snell's Law as the following:

$$\frac{\sin\alpha_0}{L_0} = \frac{\sin\alpha_b}{L_b} \qquad (9)$$

Where α_0 is wave approaching angle to the shore in deep water, α_b is wave breaking angle and L_b is wave length in breaking point.

2. Beach model

Anzali port is located in southwestern part of the Caspian Sea (37° 28´ N&49° 28´ E). Figure 1 shows hydrographic map of the studied area.

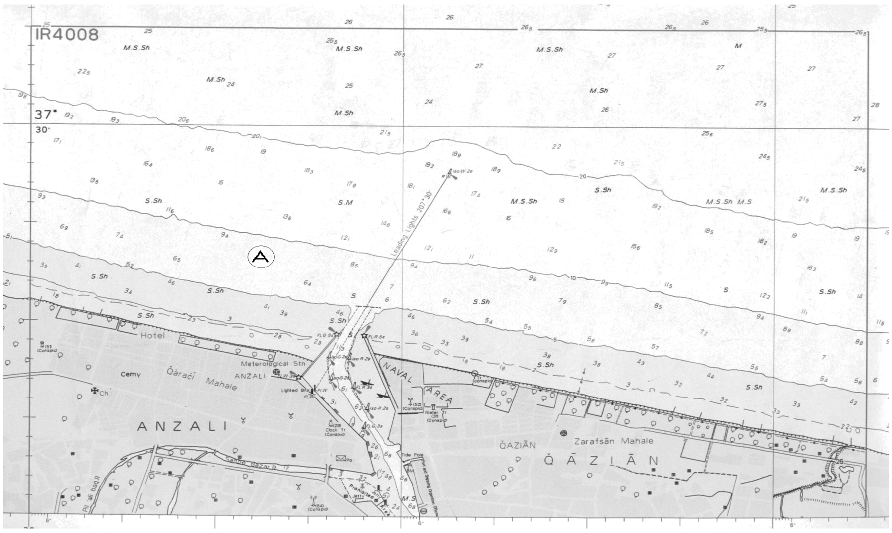

Fig.1. Hydrographic map showing the studied area and off shore measurement points

Beach slope was also calculated as 0.0096 using 1:25000 hydrographic map published by the National Cartographic Center of Iran (N.C.C).Stations for wave and current measurement are located in 49º 50′ east and 37º 62.5' north and in the depth of 5-9 m out of the Anzali pool. The situations of stations are indicated by letter A in figure 1. Wave data obtained by buoy in Anzali station in April, May, and June 2003 were used in order to achieve the most appropriate equation to calculate longshore current velocity in Anzali Port(Fig2). Also in order to compare the current velocities calculated by different equations with the measured values, the current meter data (ADCP) of Anzali station obtained in April, May, and June 2003 were used(Fig3).

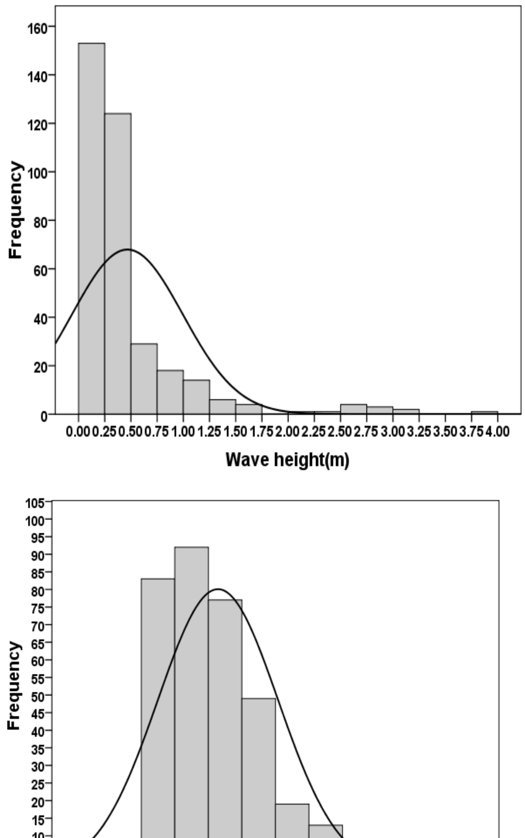

Fig.2. The frequency of wave height, and wave period obtained by buoy in Anzali Station in April, May, and June 2003

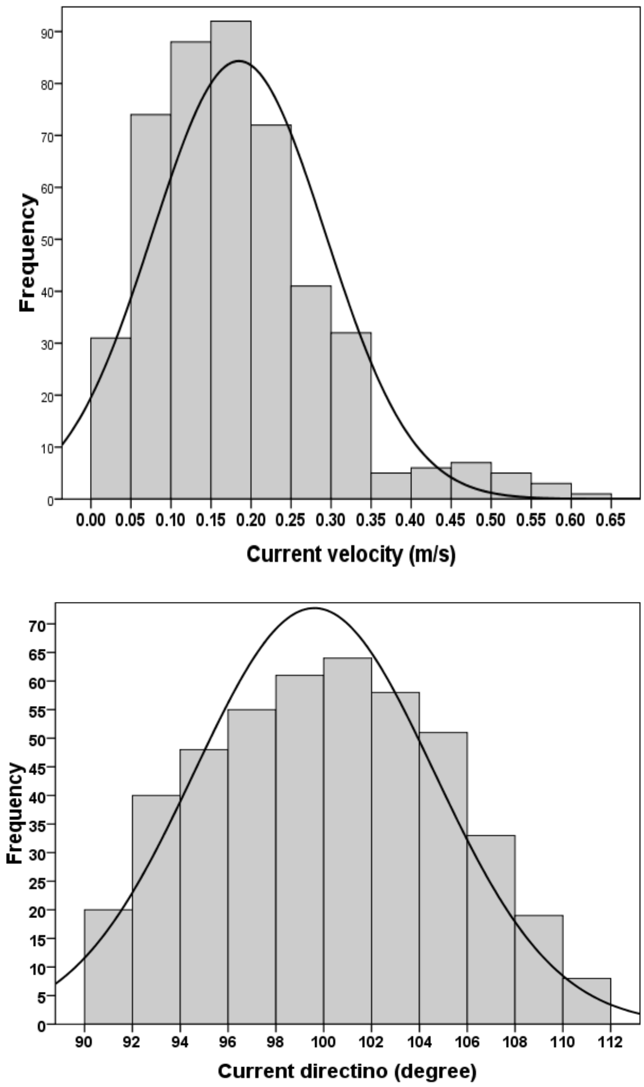

Fig. 3. Frequency of current velocity and current direction obtained in Anzali Station in April, May, and June 2003

Twelve-year wave rose in the nearshore zone of Anzali is used to obtain the appropriate pattern for longshore current velocities of Anzali port. Figure 4 shows the wave rose .

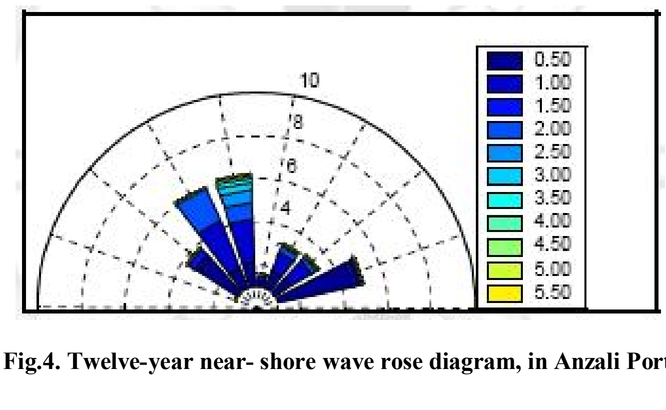

Fig.4. Twelve-year near- shore wave rose diagram, in Anzali Port.

RESULTS AND DISCUSSION

Then the wave angle in deep water which is defined as the angle between the entering wave and depth contour line is estimated considering the wave direction**.** This angle is used to estimate the breaking wave angle employing the Snell's equation.

Then longshore current velocities were calculated using appropriate equations. The two measured and calculated current velocity graphs are shown in Figure 5 to choose the most appropriate equation.

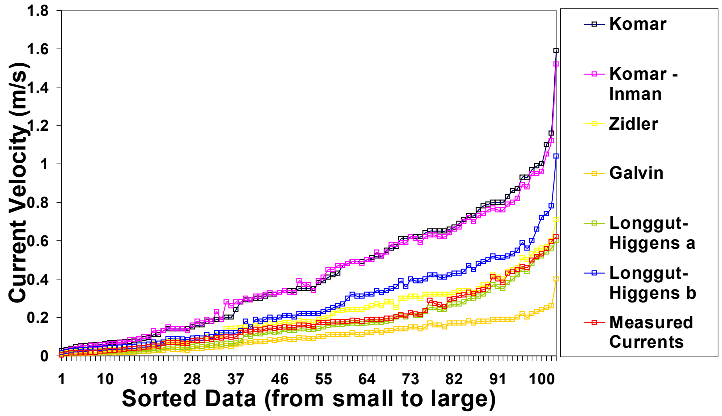

Fig.5. Comparison graphs between the measured and calculated current velocities using different equation

In the next step, a calibration coefficient is determined using the proposed equations and comparing them with the measured velocities for every equation by drawing scattering graphs for the estimated velocities. Results of this verification have been shown in figure 6.

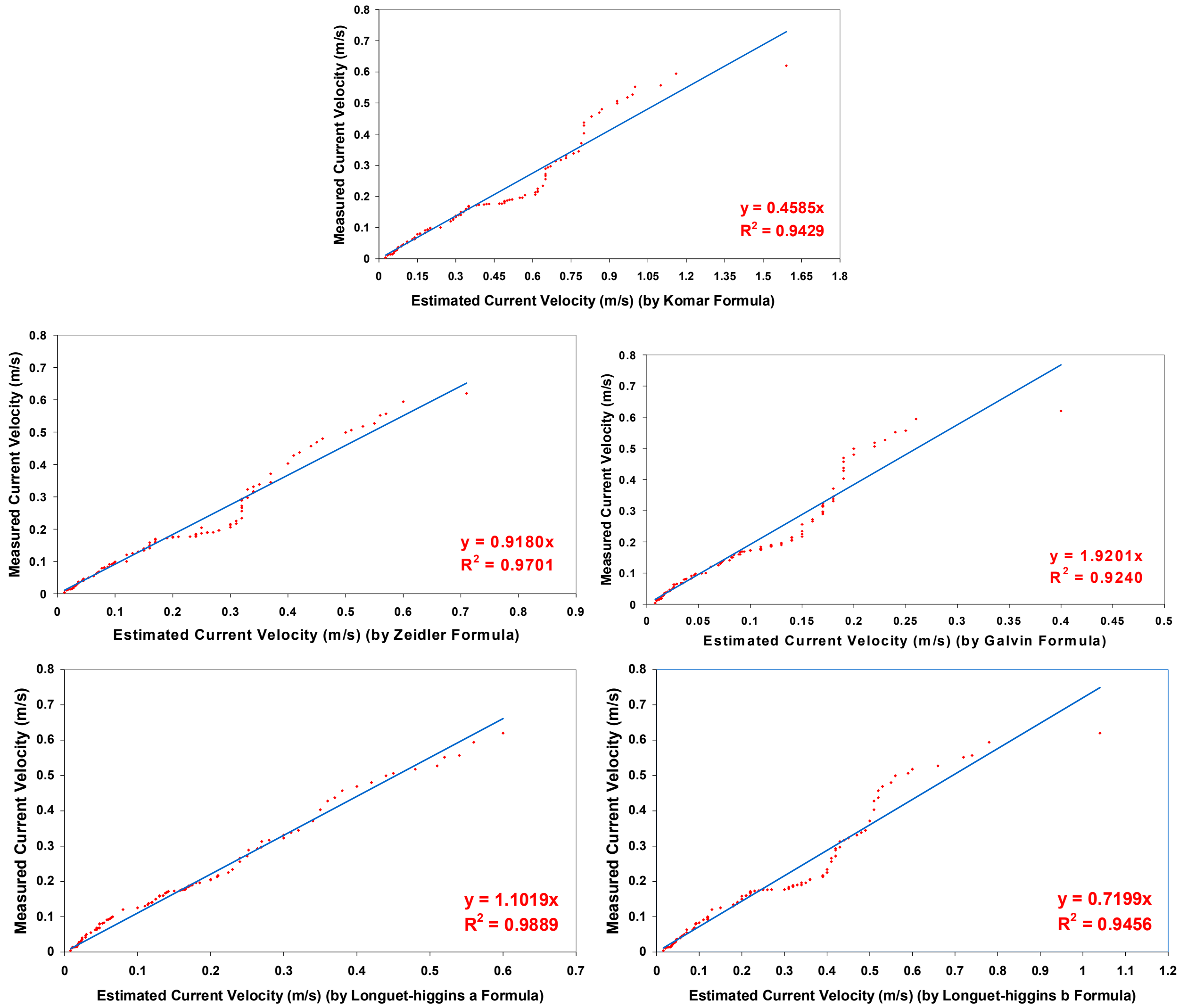

Fig.6. Calibration coefficient for long-shore current velocity equation for Anzali Port

The results revealed that Languet-Higgins(a) is the most appropriate equation for calculating longshore current velocities in Anzali Coast for the following reasons: Firstly, the difference between velocities calculated by this equation and also measured velocities are small and rather steady. Secondly, the average longshore current velocities of this equation are close to the average measured longshore current velocities. Thirdly, R-square (R^2) of this equation is larger than those of other equations. Considering these facts, the following equation for calculating longshore current velocities in Anzali Port is obtained as the following:

$$V = 23m\sqrt{gH_b}\sin 2\alpha_b \qquad (10)$$

During the present research, at first some parameters such as wave height, wave length in breaking point and also the width of surf zone have been calculated[12,13]. Figures 7,8 show the breaking height and surf zone width.

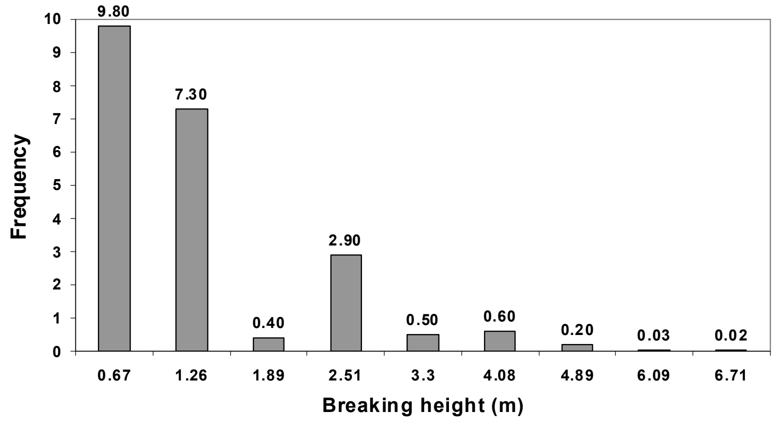

Fig. 7. Frequency of breaking height of the wave obtained from twelve-year wave rose diagram, in Anzali port

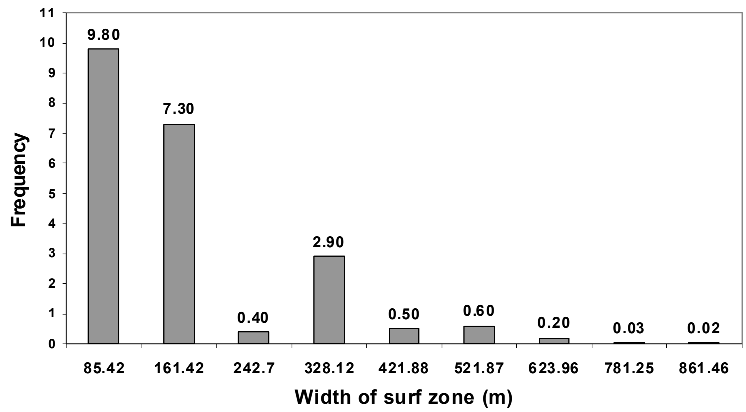

Fig.8. Frequency of the surf zone width obtained from twelve-year wave rose diagram, in Anzali port

Finally by using near shore wave rose diagram estimate frequency of long shore current velocities (Fig.9).

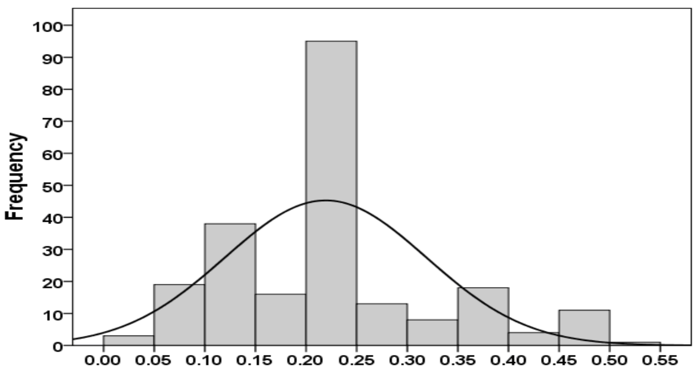

Fig.9. The frequency of long shore current velocities in the Anzali port

CONCLUSION

Significant breaking occurs for those waves entering the coast from north-western flank with the breaking height of 1.26 m, breaking wave length of 9.5 m, breaking depth of 1.55 m and breaking angle of 8.62 degree in Anzali Coast.

The frequent width of surf zone is estimated 85.42 m and the highest value is estimated at 841.46 m, for north waves. Comparison of the graphs in figure 4 shows that velocities estimated Using Languet_Higgins –a equation are compatible with the measured velocities. The average measured longshore current velocity is 0.192 m/s.

Languet_Higgins a equation has the largest R square (R^2= 0.9889) of all. Also, the calibration coefficient for this equation is 1.1019.estimated longshore current velocities obtained through the long-term wave rose diagram in Anzali are confirmed by the longshore current velocities obtained using the information gathered by buoy .Therefore, the most observed longshore current velocity in this port is 0.2 – 0.25 m/s and 0.1 – 0.15 m/s respectively.

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