HYDROMORPHOLOGICAL RELATION CHARACTERIZING THE DANUBE RIVER MOUTHS AND THE COASTAL ZONE IN FRONT OF THE DANUBE DELTA

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Abstract. This paper presents the main hydromorphological functions that characterize the Danube mouths and coastal zone in front of the Danube Delta. These functions have obtained either by computations or empirically, based on the researches developed by the author between 1958 and 1998. Among these, the following empirical relations are presented: the relations between the mean diameter (d50%) of the coarse Danube alluvia and the water discharges and depths; the relations between the coarse sediments discharge and the water discharges and depths; the correlation between the critical water discharge at which the salty marine water begins to enter river mouths, and the sediments bars bathymetries; the correlation between the neutral depth at which the sediments motion is becomes perpendicular on the shoreline and the waves period; the correlation between the shoaling depth and the waves heights and periods; correlation between the depth of the breakers and the waves height and period. This functions are the base for mathematic modeling of the evolution of the bars from the Danube mouths, parallel to shore and ridges formation coastal circulation of water and sediments and of the littoral morphologic processes.

Key words: specific water discharge, critical specific water discharge, specific coarse alluvia discharge, mean diameter of the grain, breaking depth, neutral depth, rummaging depth

GENERALITIES

According to liquid mechanics, hydraulics and physical oceanography a series of parameters that define water dynamics is established. Among these the following are to be remarked: "friction depth", related to study of Ekman currents, "shoaling depth", related to waves, "turbulence" currents, related to critical velocities for the beginning of sediments motion by dredging and suspension, etc.

In what regards the study of coastal morphologic processes in lakes and seas as well as the processes from the riverbeds, it is necessary to define the critical morphologic parameters at which the respective processes begin to take place.

For example, in the case of waves propagating towards the coast, the influence of shallow waters is "felt" by the waves beginning from the izobath that has its value equal (smaller than) to half of the wave length. Otherwise said, the bottom feels the waves whose length is equal to or higher than the double of depth.

In their motion towards the shore, the waves arrive in even shallower waters, they begin to move the bottom sediments, inducing the excavation of the bottom and the rising in suspension of sediments when the waves break near the shore.

From another point of view during the wave propagation towards the shore, a specific stratified kinematics is induced between the shoaling and the breaking depths, witch complex dynamic effects of perpendicular on and parallel to the shore bottom sediments motion. Under these conditions are formed the coastal bars, that are parallel to the shoreline.

Similar problems occur in the case of river mouths that discharge their freshwater in salty seas, with higher water densities. At the contact between the freshwaters and marine salt waters a series of hydrodynamic processes occur, being influenced by the depths and the rivers energies. In what regards also the riverbeds, the alluvia transport and bars formation processes are related to the river bed depth. For the river currents equal specific energies, the bottom sediments motion and suspension is more intense in the shallower zones.

There are mathematic correlations that explain all these hydrodynamic aspects. These correlation were established either by computation by experimental means, using field and laboratory measurements.

The current paper presents several characteristic relations and depths, obtained either by computations or by experimental means after long researches, that control the coastal hydromorphologic processes in the Romanian littoral zone.

CHARACTERISTIC RELATIONS AND DEPTHS

At the contact with the Black Sea, the Danube waters discharge the transported alluvia, accumulating bars that are transversal on the riverbeds. The alluvia sedimentation occurs as result of the decrease of the river current speed at

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the contact with the Sea. The first to be sedimented are the coarser alluvia (sands transported by the river), forming the bar in the vicinity of the river mouth, followed by the sedimentation of finer particles at longer distances from the mouths, in correlation with the waves and currents regime in that area. In the same time, an important part of the coarser Danube alluvia that are not accumulated in the mouth bars, migrate along the Romanian Black Sea shore, feeding the beaches with sand.

From the field hydrological researches performed by the author /1-11/ several correlation emerged, that control the alluvia transport processes in the riverbed at its mouth, the alluvia sedimentation in the sea and the Danube mouth bars formation. Some of these correlations are presented below.

2.1. At the Sulina mouth, the following empiric relations exist between the river bed morphometric elements (mean depth and width) and the water discharges:

$$h=ah+bh*q^{0.6} \quad (1)$$

$$b=ab+bb*Q \quad (2)$$

Where:

b is riverbed width (in meters),

h – mean water depth, expressed in m,

q – specific water discharge, expressed in m^2/s,

Q – water discharge (in m^3/s),

ah, bh, ab, bb - constants with the following values: 8.425; 0.1037; 162.1; 0.000529

2.2. The specific coarse alluvia discharge in the riverbed at its mouth depends on the water current energy and depth and is expressed by the following empirical relations:

$$rg=26.334*(-0.00206+0.0238*q^2/h^{2.15})^{1.195} \quad (3)$$

$$qcrg=0.2942*h^{1.075} \quad (4)$$

Where qcrg is the characteristic water discharge of the river current for the putting in motion the coarse alluvia particles (kg/m/s).

From function (4) it results transported by the river current depends on the water discharge and on the riverbed mean depth. This is expressed by empirical relation:

$$d50=ad50+bd50*q^2/h^{2.15} \quad (5)$$

$$q=Q/b \quad (6)$$

where:

q is the specific water discharge of the river current, expressed in m^2/s;

Q - water discharge at the river mouth, expressed in m^3/s;

b - river with at the water surface, in m;

h - mean water depth, expressed in m;

ad50 and bd50 - constants with the values of 0.210 and 0.0000768, obtained from the numerical processing of grain size depth and water discharge measurements executed at the Sulina canal mouth.

2.4. Due to the difference of density between the salt marine water and the river freshwater, at the contact between the two water masses their stratification occurs by the raising from the riverbed of the river water jet. This hydraulic process is expressed by the computed formula:

$$qcrs=[(g*dgmf/gf)^{0.5}]*h^{1.5} \quad (7)$$

where: qcrs is the critical specific river water discharge for rising from the bottom of the river water jet;

g - gravity (9.81 m/s^2);

h - water depth in m;

dgmf - difference between the specific seawater weight (gm) and the specific river water weight (gf), expressed in kg/m^3. AT the Danube mouth, gm = 1010 kg/m^3, gf =1000 kg/m^3 and dgmf = 10 kg/m^3.

According to the before mentioned data, relation (7) becomes,

$$q\ crs=0.313*h^{1.5} \quad (8)$$

The critical values for the specific water discharges expressed by relations (4) and (8), become equal when the mean river depth is 8.57 m. This mean river mouth depth can not be obtained by natural means, the only way dredging. As the mean river mouth depth is smaller 8.57 m, it results that salt waters enter the river. Their hydraulic effect is the stimulation of alluvia sedimentation and mouth bar formation right in riverbed. Therefore it can be said that there are hydrologic regime situations when, because of the salt-water wedge, the mouth bar appears in the riverbed and not in the marine zone. This conclusion has a high practical importance as, by its use, a more proficient dredging can be completed at the river mouths. This more proficient dredging, completed for the maintaining of the maritime navigation depth, must take in consideration the Danube River and Black Sea hydrologic regime.

2.5. The raising from the sea floor of the river water jet induces the appearance in the bottom strata of a marine water wedge whose immediate hydrodynamic effect is the blocking of the coarse dredged river alluvia and forming of the mouth bar, whose crest is situated approximately in the same section.

The forming of the bar in the marine environment is also controlled by the waves that model the sea bottom and induce the sediments motion towards the shore.

The shoaling depth when the waves mobilize the bottom sediments is expressed by the empirical relation,

$$hsc=5*H*T^{0.5} \quad (9)$$

Where:

hsc is the shoaling depth, expressed in m;

H - the average waves height, considered for distinct high waves from the front, expressed in m.

T - mean period of the waves, expressed in s.

2.6. The mean vertical concentration in bottom sediments raised in suspension by the waves, due the shoaling effect, and the specific water and alluvia discharges are expressed by the following empiric functions:

$$cs=7.749*T/h^{0.5}*[25*T*(H/h)^2-1]^{0.745} \quad (10)$$

$$qv=0,497*h*T*(H/h)^2/(1.767*T/h^{0.5}-1) \quad (11)$$

$$rsv=cs*qv/1000 \quad (12)$$

where:

Cs - mean vertical concentration in sediments, expressed in g/m^3;

qv - specific water discharge, expressed in m^2/s;

rsv - specific sediment discharge, expressed in kg/m/s.

Function (12) is active in the depth zone between the shoaling and the breaker zone depths.

2.7. According to the field measurements the waves breaking depth depends on the waves mean height and period according to the following hydraulic function:

$$hsp=0.66*H^{0.74}*T^{0.52} \quad (13)$$

Where H and T have the same significance as in formula (9), the waves breaking depth being expressed in m.

In the area in front of the Danube mouths, the mean height of high distinct waves, is of about 0.95 m and the mean period of the waves is of about 5.2 seconds. Therefore, according to formula (9), it can be affirmed that the shoaling depth goes down to more than 12 m. The result obtained considering a different method that regards the distribution of bottom sediments grain size is about the same as will be seen at 2.8.

According to the waves elements mean values and to formula (13), the waves breaking depth at the Danube mouths is about 1.5 m. At this depth the submerged bars from the littoral zone are generally formed.

From the hydromorphologic point of view these bars have the same signification with the Danube mouth bars, the difference residing in the fact that no river mouth contributes to the formation of the littoral bars.

In the 19th century at the Sulina mouth before the works developed for the improvement of maritime navigation, the mean depth on the mouth bar maintained itself at about 9.74 English feet (2.97 m), because of the activity of the river current.

2.8. Along the littoral zone a process of spreading and distribution of sediments according to their size takes place under the waves influence. On the Danube Delta coastal zone and at the Danube mouths the sediment particles mean diameter depends on the depth. This relation is expressed in the following empirical formula,

$$ds50=0.186*\exp[-0.0745*h] \quad (14)$$

where:

ds50 is the mean diameter of the sediment particles, expressed in mm,

h - water depth, expressed in m.

Knowing that the lower limit of coarse alluvia mean diameter is of about 0.08 mm, from formula (14) it results that the shoaling transformations critical depth is about 11 m.

2.9. Due to the waves activity sediment motions with opposite directions take place and the shore on two areas separated by the neutral isobath. The sediments motion between the neutral isobath and the shoreline is oriented towards the shore. Offshore the neutral isobath of the sediments motion is oriented seawards. The depth of this isobath depends on the mean period of the waves, being expressed by the following empirical function;

$$hne= 0.2463*T^{1.908} \quad (15)$$

where T and hne are in seconds and meters, respectively.

Due to the lack of uniformity of the sediments specific discharges variations perpendicular on the shoreline, the morphologic processes that take place along a transverse section do not have the same orientation with the sediment discharges. Generally, between the shoreline and the waves breaking isobath sediment accumulations occur, while seawards this isobath the predominant process is the erosion and the sediments transport offshore.

CONCLUSIONS

Due the their cinematic and hydrodynamic the waves properties put in motion and raise in suspension the bottom sediments that are thus transported both towards the shore and parallel to the shoreline.

Because of their relatively limited hydrodynamic capacity, the coastal marine currents contribute mainly at the bottom sediments raised in suspension by the wave motion in the current direction.

The Danube sediment discharge is dynamically added to the coastal morphologic processes, contributing at the sediment accumulation by the formation of bars and the sand accumulations on the beaches.

The Danube mouth and littoral bars are formed because of the dynamic interaction of the three factors. The bars morphometric (depth, lengths and widths) and temporal features, depend on the three dynamic natural factors regimes and on the anthropic intervenes, in the case of dredging and protection works at the respective mouths.

The entire system of functions and correlation obtained from researches, are the base of mathematic modeling of the Danube mouths and littoral bars formation, of the water and alluvia coastal circulation and of the littoral morphologic processes.

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