CHAPTER 26

LITTORAL DRIFT AS FUNCTION OF WAVES AND CURRENT

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1. SYNOPSIS

For the computation of littoral drift due to waves hitting a coast obliquely, most formulae are based upon the assumption that this long-shore transport is some function of the energy flux of the waves towards the coast. For the actual computation the component of this flux parallel to the coast is introduced. Most of the available prototype data are incorporated in the formula of the U.S. Army Coastal Engineering Research Center (ref. 4 and 1). In this formula no reference is made to the grain size and the slopes of beach and foreshore. The explanation for the fact that nevertheless reasonable results are obtained is probably owing to the fact that variation of grain size and beach slope for sandy beaches is not so very great. A more serious disadvantage is, however, that it is not possible to take into account the influence of a possible long-shore current which is not generated by the wave motion, such as for instance tidal currents.

In this paper an attempt is made to compute the littoral drift, starting from the longshore current velocity as it is generated by the waves or as it may originate from other causes (ref. 4). For the actual computation of the bed load transport a normal bed load transport formula is used, in which, however, according to the method developed by the author in earlier studies, the bed shear is increased as a result of the wave motion (ref. 2). From the tests briefly described in the present paper it becomes clear that the transport may be treated indeed as a function of the longshore current, even when this current has a direction opposite to that of the component of the wave propagation parallel to the coast.

Finally, a computation procedure for littoral drift is presented in which also the transport of suspended load is taken into account, and an example is given of the computation of the littoral drift along Ivory Coast near Abidjan. The result of this computation corresponds rather well to the data known from the prototype.

2. DERIVATION OF BED LOAD TRANSPORTATION FORMULAE AND DESCRIPTION OF TESTS

Most bed load formulae may be written in the form

$$\frac{S}{f(D^{3/2} g^{1/2} \Delta)} = f\left(\frac{\Delta D}{\mu h I}\right) \qquad (1)$$

where Δ = relative apparent density, D = grain size, h = waterdepth, I = energy gradient, μ = ripple coëfficient and g = acceleration of gravity.

Frijlink (ref. 6) suggested, starting from the formula of Kalinske, to write formula (1) in the following way:

$$\frac{S}{D(\mu\tau/\rho)^{1/2}} = b\ e^{a \frac{\Delta D \rho g}{\mu \tau}} \qquad (2)$$

where C = resistance coëfficient, and τ = bed shear = $\rho g h I = \rho g\ v^2/C^2$ (ref. 6).

In an earlier paper the present author called the first term the transport parameter and the exponent of e in the second term the stirring parameter (ref. 2). For the bed shear in the stirring parameter, the mean resultant bed shear of the combination of waves and current will be introduced. This shear is denoted by τ_r in figure 1. This resultant bed shear is hold responsible for the stirring up of the material. Once the material is stirred up it will be transported by the normal current. Hence, in the transport parameter, the value of the bed shear τ_c, resulting from the current only, is introduced. As demonstrated by the present author in ref. 2,

$$\tau_r = \left[1 + \frac{1}{2}\left(\xi \frac{u_o}{v}\right)^2\right] \tau_c \quad , \qquad (3)$$

in which u_o = amplitude of orbital velocity near the bed, v = mean current velocity, and ξ is a coëfficient which has been determined theoretically and emperically and which has a value $\xi = 0.45\kappa \, C/g^{1/2}$ = 0.0575 C.

In figure 2 all data are represented, viz.: data for current only, for current and waves combined with wave crests parallel to the current, and for current and ditto, with wave crests making an angle of 15° with the current.

The regression line for all data with regression of $\log S/D(\tau_c/\rho)^{1/2}$ on $\Delta D\rho g/\mu\tau_r$ is

$$S = 0.22\ D(\tau_c/\rho)^{1/2}\ e^{-0.19 \frac{\Delta D\rho g}{\mu\tau_r}} \qquad (4)$$

and the regression line for all data with regression of $\Delta D\rho g/\mu\tau_r$ on $\log S/D(\tau_c/\rho)^{1/2}$ is:

$$S = 1.95\ D(\tau_c/\rho)^{1/2}\ e^{-0.33 \frac{\Delta D\rho g}{\mu\tau_r}} \qquad (5)$$

In the original formula of Frijlink the coëfficient in the exponent of e was 0.27 (ref. 6). With this exponent the formula becomes

$$S = 0.74\ D(\tau_c/\rho)^{1/2}\ e^{-0.27 \frac{\Delta D\rho g}{\mu\tau_r}} \qquad (6)$$

The fact that the coëfficient 0.74 is much lower that the coëfficient in Frijlink's formula, which was 5, has most likely to be attributed to the fact that Frijlink discussed prototype data, whilst the data used in the present paper are obtained from a relatively narrow sand trap, which does not catch the whole transport (ref. 2).

After the completion of these tests, further tests were performed, viz. with waves the crests of which make in still water an angle of 25° with the direction of the current, having a component in the direction of the current and having a component against the direction of the current (ref. 2). Due to streamrefraction, the angle becomes in these two cases respectively 27° to 28° and 22° to 23°.

Using the coefficient 0.27 in the exponent of e, the value of b has been calculated for the various cases. The sand has been captured in a sand trap which has been divided in several compartiments. The sand trap had a total length of 0.93 m measured in the direction of the current. The computations have been carried out for the material captured in the complete trap (wide trap) and in the foremost 0.15 m (narrow trap). The results are represented in table I.

Table I Values of b

	current ←	current ← and waves ↙ $\varphi = 28^o$	current →	current → and waves ↙ $\varphi = 22^o$
Narrow trap	0.4 ± 0.2	0.4 ± 0.2	0.2 ± 0.1	0.2 ± 0.1
Wide trap	1.3 ± 1.0	1.1 ± 0.8	1.0 ± 0.6	0.6 ± 0.2

The following test results were obtained.

(i) The scatter in the results with the wide trap is very great. The reason is most likely that, in the lower layers of the flow, part of the material is moved in suspension (saltation). It is quite to be expected that a great variation will occur in the quantities of this portion of the material caught in the trap. This is supported by the fact that the values of b, computed with the quantities measured in the wide trap with waves and current combined, are slightly smaller than for current only. This may be explained by the fact that the turbulence for the combination of waves and current is greater than for current only, so that a smaller part of the total quantity of material transported will be trapped.

(ii) The quantities transported in the two different directions for current only, differ significantly, assuming that the values of b, as calculated by this procedure, are distributed like stochastic variables around their mean values. The reason may attributed to the fact that, although sand of the same diameter was applied, the packing of the sand at both sides of the sand trap was different. A different explanation may be that, although the mean velocity was equal, the upstream conditions for the two current directions were unequal. This results in a different vertical velocity distribution and hence, in a different bed shear. Although from visual judgement, the ripple patterns and heights for both situations were equal, a slight change in ripple coëfficient might also cause this difference in the values of b. Since it was not possible to predict the difference in the ripple coëfficient beforehand, it has not been introduced in the calculations.

(iii) For both wide and narrow sand traps the values of b for current only and for the combination of current and waves, are not significantly different. Since b is computed with formula (6) which takes into account the increased bed shear by the wave motion, the conclusion may be drawn, that the transport of material is increased by the waves, independently of the fact whether the waves are propagating obliquely with the current, or against the current.

The main conclusions, drawn from the tests described above and discussed in full in the author's paper "Some considerations about scales of coastal models with movable bed" (ref. 2) are the following:

(i) The transport of a combination of waves and current may be written as:

$$S = b.D \frac{v}{C} g^{1/2} e^{-0.27 \frac{\Delta DC^2}{\mu v^2 \left(1 + \frac{1}{2}\left(\xi \frac{u_o}{v}\right)^2\right)}} \qquad (7)$$

where $\xi = 0.45 \, K \, C/g^{1/2} = 0.0575 \, C$, or:

$$S = b.D(\tau_c/\rho)^{1/2} e^{-0.27 \frac{\Delta D \rho g}{\mu \tau_r}} \qquad (8)$$

(ii) The principal difference of this equation with the original one of Kalinske-Frijlink is, that the ripple factor is operative only in the stirring parameter, and not in the transport parameter. Keeping in mind the definition of the ripple factor, as defining that part of the bed shear which is not used to overcome bedform resistance, it is physically more justified to introduce this factor only in the stirring parameter. Once the material is stirred up, it is moved with the current velocity. Hence, a ripple factor seems here to have less sense.

(iii) A rather important variation may occur in the factor b. For the time being, the value of 5 seems the most appropriate.

(iv) Another source of uncertainties is the value of the resistance coëfficient C. The advantage of the described procedure is, however, that the origin of the uncertainties becomes visible.

3. COMPUTATION OF LITTORAL DRIFT

Using the formula derived in paragraph 2 in combination with a formula for the longshore current, it should be possible to compute the littoral drift generated by a wave motion approaching the coast obliquely.

For the longshore current the equation as given by Eagleson is applied:

$$v_L^2 = \frac{3}{8} \left(\frac{g H_b^2 m_b}{h_b}\right) \frac{\sin \alpha \sin \varphi_b \sin 2\varphi_b}{f} \tag{9}$$

where v_L = the value of the longshore current velocity, H_b = the breaker height, h_b = the breaker depth, m_b = ratio of group velocity c_g to wave celerity = $\frac{1}{2}\left[1 + \frac{4 \pi h/L}{\sin h(4 \pi h/L)}\right]$, α = beach slope, φ_b = angle between breaker crests and coast line and f = Darcy Weisbach resistance coëfficient = $8g/C^2$ (ref. 4).

The study of Eagleson does not give values for the distance from the coast over which this current occurs, particularly not outside the breakerzone. For a first approximation the current will be assumed invariable with the distance from the coast. Due to the increasing depth, the transport will presumably drop at some distance from the coast to a negligible value.

Since the bed load transport should be calculated with formula (7) and (8), using the ratio between orbital velocity and main current velocity, the values of the orbital velocity in the breaker region have to be evaluated. From tests by Iversen, which are summarized in table II, it becomes evident that orbital velocities computed with the first-order theory from waves breaking according to the solitary wave theory, are in reasonable agreement with actual measured orbital velocities at the point of breaking (ref. 7). According to the solitary wave theory $h_b = 0.45 (H_o T)^{2/3}$, and with these values and the tables of Tech. Rep. 4 of C.E.R.C. the data of table II have been obtained (ref. 1).

Table II

Beach slope	T_o sec	L_o m	H_o m	breaker depth calculated from solitairy wave theory H_oT m s	h_b m	normal theory $\frac{h_b}{L_o}$	H_b m	u_o m/s	tests u_o m/s
1/10	1.51	3.56	.073	.11	.103	.0290	.082	.38	.30
1/10	1.98	6.10	.043	.085	.087	.0142	.057	.29	.39
1/50	1.74	4.72	.061	.106	.101	.0214	.074	.35	.33
1/50	2.65	10.95	.071	.188	.148	.0135	.095	.38	.32

The above figures show a mean deviation between calculated and observed values of 20% to both sides. In view of the inevitable inaccuracy of the tests of Iversen, the author accepted to use the calculated values of the orbital velocity for the computation of u_o/v, for the calculation of ξ.

Since expecially in the breaker zone the transport of suspended load will be considerable, this transport will also be calculated. For this calculation the procedure of Einstein will be applied (ref. 5). One of the difficult points in this computation procedure is the determination of the concentration of suspended load immediately above the bed. The best procedure seems to be to take this concentration equal to that of the bed load transport, assuming an even distribution of this transport over half the ripple height. According to unpublished work of van Breugel, the fictitious bed may be assumed to be at half the ripple height (ref. 3). Since the fictitious roughness is equal to half the ripple height, the suspended load concentration is derived from the bed load by assuming that this bed load will be transported in a layer immediately above the bed with a thickness equal to that of the fictitious bed roughness.

The mean velocity in this layer is, with the well-known assumption that $v(y) = (v_*/\kappa) \ln 33\, y/r$;

$$\bar{v}_{o-r} = \frac{\int_{er/33}^{r} v(y)dy + 1/2\, v_{er/33}\, er/33}{r} = \frac{2.54\, v_*}{\kappa} = 6.35\, v_* \tag{10}$$

The expression for the suspended load transport is,

$$S_s = \int_a^h c(y)\, \bar{v}(y)\, dy \tag{11}$$

The concentration c(y) may be written as:

$$\frac{c(y)}{c_a} = \left(\frac{h-y}{y} \cdot \frac{a}{h-a}\right)^z \tag{12}$$

in which $$z = w/\kappa v_* \tag{13}$$

in which w = fall velocity of the grains. In the case of a combination of current with waves for v_* the increased v_*' due to the wave motion should be introduced, which has the value $v_*' = \left[1 + \frac{1}{2}(\xi \frac{u_o}{v})^2\right] v_*$.

In this equation c_a is the concentration of suspended load immediately above the bed and this may be written according to the reasoning given above as

$$c_a = S_b/6.35\, v_*\, r\ , \tag{14}$$

under the assumption that the suspended load is transported with the velocity of the fluid.

The formula for the total transport of suspended load according to Einstein may be written now as follows:

$$S_s = 1.83\, S_b \left[I_1 \ln 33\, h/r + I_2 \right] \tag{15}$$

with: $$I_1 = 0.216 \frac{(a/h)^{z-1}}{(1 - a/h)^z} \int_{a/h}^{1} \left(\frac{1 - y}{y}\right)^z dz \tag{16}$$

and $$I_2 = 0.216 \frac{(a/h)^{z-1}}{(1 - a/h)^z} \int_{a/h}^{1} \left(\frac{1 - y}{y}\right)^z \ln y \; dy \tag{17}$$

In his paper, Einstein suggests that $S_b = 11.6\, v_* \, c_a \, a$, where "a" is a layer of 2 grain diameters. Since, according to the author's opinion, this set up is not in complete agreement with the physical phenomenon of bed load transport over a bed with ripples or dunes and moreover, the factor 11.6 is based upon one limited series of measurements only, he suggests the approach discussed on page 9 leading to formula (14).

4. COMPUTATION OF LITTORAL DRIFT ALONG THE COAST OF IVORY COAST

According to the available estimates, the littoral drift along Ivory Coast is 10^6 m^3/year = 0.032 m^3/s. If the wave period is assumed to be 12 s and, the wave height in deep water H_o is assumed to be 1.6 m, with the angle φ_o between wave crests in deep water and the coastline equal to 13°, the littoral drift as calculated by the formula of the C.E.R.C. is just about 0.032 m^3/s (ref. 1). For this computation the version of this formula as presented by the author is used, viz.:

$$S = 1.4 \; 10^{-2} \; H_o \; c_o \; K^2 \sin \varphi_b \cos \varphi_b \tag{18}$$

in which c_o = wave velocity in deep water, K = refraction coëfficient = square root of ratio of distances between wave orthogonals in deep water and at the breaker region (ref. 2).

The longshore current velocity according to Eagleson has an equilibrium value as given by equation (9) (ref. 4).

For the coast of Ivory Coast the following data hold:

$$\alpha = 1/14 = 4^o, \quad \varphi_b = 4\tfrac{1}{2}^o \quad (\varphi_o = 13^o).$$

$$D_{50} = 0.5 \text{ mm}, \quad D_{90} = 0.9 \text{ mm} \quad \Delta D = 1.65 \;\; 5 \; 10^{-4} = 8.25 \; 10^{-4} \text{ m}$$

$$w = 0.08 \text{ m/s}, \quad v_*{}^1 = v_* \sqrt{1 + 1\tfrac{1}{2}(\xi \frac{u_o}{v})^2}$$

The resistance coëfficient of Chezy C = 42 $m^{1/2}$/s, which corresponds to a fictitious apparent bottom roughness of 0.17 m at the breaker depth of 3.2 m. This results in $f = 8g/C^2 = 0.045$.

$$m_b = \frac{1}{2}\left(1 + \frac{4\pi h_b/L_b}{\sinh 4\pi h_b/L_b}\right) = 0.97 \tag{19}$$

From this follows:

$$v_L^2 = \frac{3}{8}\left(\frac{g\ 2.5^2\ 0.97}{3.2}\right)\frac{0.07\ \ 0.078\ \ 0.156}{0.045} = 13.2\ 10^{-2}\ m^2/s^2 -$$

$$v_L = 0.36\ m/s.$$

With these data the following computations will be performed in the tables III through VII.

Table III $v_e = 0.36$ m/s

h	C	ξ	$C_{d_{90}}$	μ	C^2	$\frac{v}{C}\sqrt{g} = v_*$	$5\ Dv_*$ $5\ D\frac{v}{C}\sqrt{g}$
1	42	2.42	74	0.43	1760	$2.7\ 10^{-2}$	$67\ 10^{-6}$
3	42	2.42	83	0.36	1760	$2.7\ 10^{-2}$	$67\ 10^{-6}$
5	46	2.65	87	0.38	2110	$2.45\ 10^{-2}$	$61\ 10^{-6}$
7	49	2.82	90	0.40	2400	$2.3\ 10^{-2}$	$57.5\ 10^{-6}$
9	51	2.94	92	0.41	2600	$2.2\ 10^{-2}$	$55\ 10^{-6}$
11	52	3.00	93	0.42	2700	$2.15\ 10^{-2}$	$54\ 10^{-6}$
13	54	3.11	95	0.43	2910	$2.1\ 10^{-2}$	$52\ 10^{-6}$
15	55	3.17	96	0.43	3020	$2.05\ 10^{-2}$	$51\ 10^{-6}$
17	56	3.22	97	0.44	3120	$2.0\ 10^{-2}$	$50\ 10^{-6}$

For different values of the depth, h, the resistance coëfficient C, the coëfficient ξ, the ripple coëfficient and the parameter $5\ Dv_* = 5\ D\ \sqrt{g}\ v/C$ are computed.

For the above mentioned depths, the ratios of wave heights at this depth to deep water wave height, if not influence by refraction, H'/H_o are computed and, via the refraction coëfficient, the actually occurring wave height H. From this value the amplitude of the orbital velocity at the bottom u_o and the ratio u_o/v is computed.

Table IV

h	$\frac{h}{L_o}$	$\frac{H'}{H_o}$	K	$K\frac{H'}{H_o}$	H	$\sinh \frac{2\pi h}{L}$	u_o	$\frac{u_o}{v}$
1	.0045	1.74	.99	1.72	0.78	.170	1.20	3.33
3	.0134	1.34	.99	1.33	2.13	.30	1.86	5.15
5	.0222	1.20	.99	1.19	1.90	.395	1.26	3.5
7	.0312	1.12	.99	1.11	1.77	.473	0.98	2.72
9	.040	1.06	.99	1.05	1.68	.55	0.80	2.22
11	.049	1.02	.99	1.01	1.62	.62	0.68	1.89
13	.058	1.00	.99	0.99	1.58	.69	0.60	1.67
15	.067	0.98	.99	0.97	1.55	.76	0.54	1.50
17	.076	0.96	.99	0.95	1.52	.82	0.49	1.36

Table V

h	$(\xi \frac{u_o}{v})^2$	$1 + \frac{1}{2}(\xi \frac{u_o}{v})^2$	$v^2\ 1 + \frac{1}{2}(\xi \frac{u_o}{v})^2$	ζ $\frac{0.27\ \Delta D C^2}{\mu v^2 \left[1+\frac{1}{2}(\xi \frac{u_o}{v})^2\right]}$	$e^{-\zeta}$	$S_b \cdot 10^{-6}\ m^2/s$
1	65	33	1.84	0.21	0.81	54
3	156	79	3.69	0.11	0.90	60
5	86	44	2.17	0.22	0.80	49
7	74	38	1.97	0.27	0.76	44
9	49	26	1.38	0.42	0.66	36
11	36	19	1.03	0.58	0.56	30
13	27	14	0.78	0.83	0.44	23
15	22	12	0.61	1.10	0.33	17
17	19	11	0.63	1.10	0.33	16

From the results of tables III and IV the factor $1 + \frac{1}{2}(\xi\ u_o/v)^2$, by which the bed shear of the current is increased due to the wave motion, is computed and with these results the stirring factor, and finally the total bed load transport S_b. These transports are computed for belts, parallel to the coast, ranging in width from 0-2, 2-4, 4-6 m etc, the mean depths of these belts, viz.: 1, 3, 5 m, etc. respectively.

The values of the transports, as given in this table, are the transports per unit of width. The total transport in each belt can be obtained by multipliing the transport per unit of width with the width of the belt, that is 2 . 14 = 28 m, since the beach slope is 1:14.

Table VI

h	$v_*^1 = v_* \left[1+\frac{1}{2}\left(\xi\frac{u_o}{v}\right)^2\right]$	$\frac{w}{0.4\, v^1}$	$v_{0.17} = 8.75\, v_*$	$c_a = \frac{S_b}{0.17\, \bar{v}_{0-0.17}}$	$\bar{v}_{0-0.17} = \frac{2.54}{\kappa} v_* = 6.35\, v_*$
1	0.155	1.30	0.235	$1.9\ 10^{-3}$	0.17
3	0.24	0.84	0.235	$2.1\ 10^{-3}$	0.17
5	0.16	1.25	0.215	$1.9\ 10^{-3}$	0.155
7	0.14	1.43	0.20	$1.8\ 10^{-3}$	0.145
9	0.11	1.82	0.19	$1.5\ 10^{-3}$	0.14
11	0.095	2.10	0.19	$1.3\ 10^{-3}$	0.135
13	0.08	2.5	0.185	$1.0\ 10^{-3}$	0.13
15	0.07	2.86	0.18	$0.8\ 10^{-3}$	0.13
17	0.065	3.07	0.175	$0.8\ 10^{-3}$	0.125

The necessary values for the computation of the suspended load transport are calculated.

Table VII

h	$A = a/h$	$\ln \frac{33h}{r}$	I_1	$I_1 \ln \frac{33h}{r}$	$-I_2$	$I_1 \ln \frac{33h}{r} + I_2$	$1+1.83(I_1 \ln \frac{33h}{r} + I_2)$	S_{b+s} 10^{-6} m^2/s	S_{tot} 10^{-3} m^3/s
1	.17	5.26	.18	0.95	0.23	0.72	2.32	125	3.5
3	.057	6.36	.55	3.50	0.90	2.60	5.75	345	13.2
5	.034	6.87	.38	2.61	0.84	1.77	4.05	198	19.1
7	.024	7.21	.33	2.38	0.83	1.55	3.85	169	22.4
9	.019	7.46	.22	1.64	0.68	0.96	2.77	100	26.3
11	.016	7.67	.18	1.38	0.60	0.78	2.43	73	28.3
13	.013	7.84	.14	1.10	0.51	0.59	2.08	48	29.5
15	.011	7.98	.11	0.88	0.45	0.43	1.79	30	30.5
17	.010	8.1	.10	0.81	0.42	0.39	1.71	27	31.3

Table VIIa a = 0.1 m

h	$A = a/h$	$\ln \frac{33h}{r}$	I_1	$I_1 \ln \frac{33h}{r}$	$-I_2$	$I_1 \ln \frac{33h}{r} + I_2$	$1+1.83(I_1 \ln \frac{33h}{r} + I_2)$	S_{b+s} 10^{-6} m^2/s	S_{tot} 10^{-3} m^3/s
1	0.1	5.80	.24	1.39	.38	1.01	2.84	170	4.7
3	0.033	7.53	.69	5.20	1.30	3.90	8.12	511	19.1
5	0.02	7.46	.44	3.28	1.10	2.18	5.0	290	27.3
7	0.014	7.75	.32	2.48	.96	1.52	3.77	196	33.9
9	0.011	8.00	.22	1.76	.80	0.96	2.76	127	36.1
11	0.009	8.20	.17	1.39	.67	0.72	2.32	93	39
13	0.008	8.37	.13	1.09	.54	0.55	2.0	68	40.6
15	0.007	8.50	.12	1.02	.53	0.49	1.9	61	42.5
17	0.006	8.63	.11	0.95	.51	0.44	1.8	52	44.0

Table IIIa

$$v_L^2 = \frac{3}{8}\left(\frac{g\ 2.5^2\ 0.97}{3.2}\right)\left(\frac{0.07\quad 0.078\quad 0.156}{0.019}\right) = 31{,}2 \quad 10^{-2}\ m^2/s^2$$

$f = 8g/C^2 = 0.019$ $v_L = 0.56$ m/s

h	C	ξ	$C_{d_{90}}$	μ	C^2	$v_* = (v/C)\sqrt{g}$	$5\ D\ V_*\ 10^{-6}$
1	64	3.68	74	0.81	4100	2.7 10^{-2}	67
3	64	3.68	83	0.68	4100	2.7 10^{-2}	67
5	68	3.91	87	0.69	4630	2.6 10^{-2}	65
7	71	4.08	90	0.70	5020	2.5 10^{-2}	63
9	73	4.20	92	0.71	5310	2.4 10^{-2}	60
11	74	4.25	93	0.71	5490	2.35 10^{-2}	59
13	76	4.36	95	0.72	5790	2.3 10^{-2}	58
15	77	4.43	96	0.72	5920	2.3 10^{-2}	57
17	78	4.49	97	0.72	6080	2.25 10^{-2}	56

Table IVa

h	$\frac{h}{L_o}$	$\frac{H'}{H_o}$	K	$K\frac{H'}{H_o}$	H	$\sinh\frac{2\pi h}{L}$	u_o	$\frac{u_o}{v}$
1	.0045	1.74	.99	1.72	0.78	.170	1.20	2.15
3	.0134	1.34	.99	1.33	2.13	.30	1.86	3.31
5	.0222	1.20	.99	1.19	1.90	.395	1.26	2.25
7	.0312	1.12	.99	1.11	1.77	.473	0.98	1.75
9	.040	1.06	.99	1.05	1.68	.55	0.80	1.43
11	.049	1.02	.99	1.01	1.62	.62	0.68	1.22
13	.058	1.00	.99	0.99	1.58	.69	0.60	1.06
15	.067	0.98	.99	0.97	1.55	.76	0.54	0.96
17	.076	0.96	.99	0.95	1.52	.82	0.49	0.87

Table Va

h	$(\xi \frac{u_o}{v})^2$	$1+\frac{1}{2}(\xi \frac{u_o}{v})^2$	$\mu v^2 \left[1+\frac{1}{2}(\xi \frac{u_o}{v})^2\right]$	$\gamma = \frac{0.27\ \Delta D C^2}{\mu v^2 \left[1+\frac{1}{2}(\xi \frac{u_o}{v})^2\right]}$	$e^{-\gamma}$	$S_b\ 10^{-6}$ m^2/s
1	63	32	8.15	0.11	0.90	60
3	149	75	16.00	0.06	0.94	63
5	77	39	8.49	0.12	0.89	58
7	51	26	5.73	0.20	0.82	52
9	36	19	4.25	0.28	0.76	46
11	27	14	3.13	0.39	0.68	40
13	21	11	2.49	0.52	0.59	34
15	18	10	2.26	0.58	0.56	32
17	15	9	2.04	0.66	0.52	29

Table VIa

h	v_*'	$\frac{w}{0.4\ v_*'}$	$v_{0.17} = 8.75\ v_*$	$c_a = S_b/0.17\ \bar{v}_{0-0.17}$	$\bar{v}_{0-0.17} = \frac{2.54}{\kappa} v_* = 6.35\ v_*$
1	0.15	1.33	0.235	2.1 10^{-3}	0.17
3	0.23	0.87	0.235	2.2 10^{-3}	0.17
5	0.16	1.25	0.230	2.1 10^{-3}	0.165
7	0.13	1.54	0.22	1.9 10^{-3}	0.16
9	0.105	1.90	0.24	1.8 10^{-3}	0.15
11	0.09	2.22	0.205	1.6 10^{-3}	0.15
13	0.076	2.64	0.20	1.4 10^{-3}	0.145
15	0.073	2.74	0.20	1.3 10^{-3}	0.145
17	0.0675	2.95	0.195	1.2 10^{-3}	0.14

Following the procedure described in ref. 5 the total transport, being the sum of suspended load and bed load transport, is computed, using the slightly modified formula (15), viz.:

$$S_{b+s} = S_b(1 + 1.83\left[I_1 \ln 33h/r + I_2\right]) \qquad (20)$$

These transports are computed for the various belts. Finally, also the integrated total transport for belts from 0-2, 0-4, 0-6, etc. indicated by S_{tot}, are given. From these data it is clear indeed that the total littoral drift does not increase very much when the depth to be taken into consideration is greater than some 11 m. If it is assumed that the longshore current velocity outside the breaker zone decreases rapidly, the total transport could be obtained by taking into account only the values upto the 6 m depth contour. The total transport is in this case 0,019m^3/s.

In order to study the influence of the assumed bed roughness on the results, the same computations have also been executed for a roughness of 0.1 m. The resistance coefficient C at the breaker depth of 3 m is in this case 64 $m^{1/2}/s$. From this follows for the longshore velocity, according to Eagleson, the value v_L = 0.56 m/s. The results are given in tables IIIa through VIIa. The total littoral drift is in this case 0.044 m^2/s which does not differ very much from the value of 0.032 obtained with a bed roughness of 0.17 m. The total transport within the 6 m depth contour is in this case 0.027 m^3/s.

From this result the conclusion may be drawn that, although the total transport is of course influenced by the assumed bed roughness, uncertainties in this value do not invoke too great complications.

DISCUSSION

The method of computation of littoral drift discussed in this paper is based upon two basic assumptions, viz.:

(i) The longshore current velocity, resulting from the waves approaching coast obliquely, should be calculated. For the time being the formula of Eagleson is used. In this formula no velocity gradient perpendicular on the coast line is given, nor a width of the belt over which this current does occur. From the results it appears that this is perhaps not a very serious drawback since the transport of material decreases rather quickly with increasing depth, hence with the distance from the shore. It may be expected, however, that for these reasons the values of the transports are too high. The approach of Svasek, who relates the littoral drift to the energy loss of the waves approaching the coast, may be useful also for determining the longshore current.

(ii) Starting from the longshore current, and taking into account the effect of the wave motion on the bed shear due to this current, the littoral drift is calculated. For this calculation it is necessary to take also the suspended load into account, since this will be normally rather high under these conditions. This introduces another point of inaccuracy into the results as the relationship between suspended load and bed load is still rather vague.

The possible advantage of the present procedure over the existing littoral drift formulae is, however, that this approach shows more clearly the origins of possible inaccuracies in the results. Further study may, moreover, solve the unknown points.

A second advantage is the fact that with this procedure it is also possible to take into account a longshore current that is not generated by the waves.

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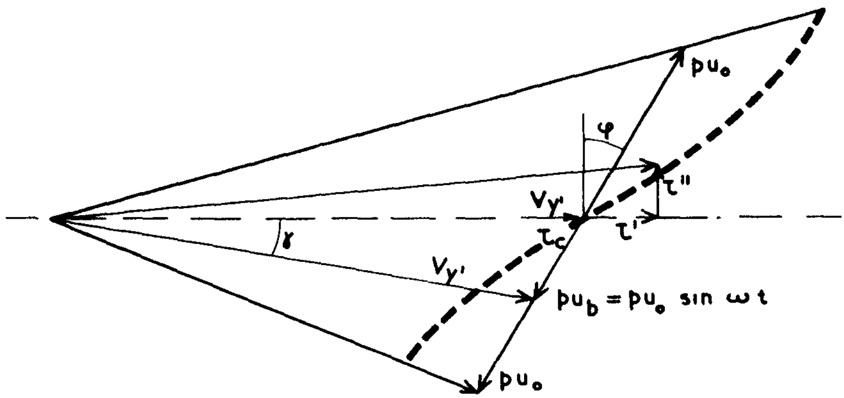
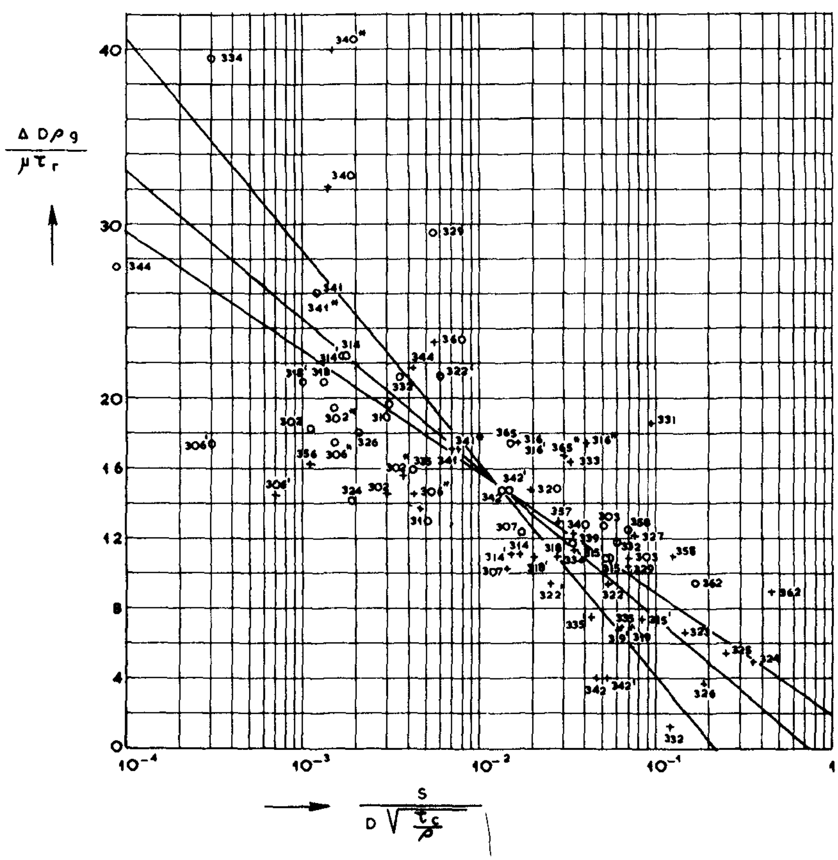


ρu_o
φ
τ''
$V_{y'}$
τ_c
τ'
γ
$V_{y'}$
$\rho u_b = \rho u_o \sin \omega t$
ρu_o

FIG. 1



$\frac{\Delta D \rho g}{\mu \tau_r}$
$\frac{S}{D\sqrt{\frac{\tau_c}{\rho}}}$

FIG. 2