MODEL TESTS ON LITTORAL SAND TRANSPORT RATE

by

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ABSTRACT:

This paper is an analysis of two sets of experimental results on littoral sand transport. A littoral sand transport expression is proposed, relating littoral transport rate to surf similarity parameter and hence to wave energy dissipation rate. The expression indicates that the 'constant' in the CERC formula is dependent on the mobile bed beach slope and on the breaker index. The expression is also compared with some of the few published field measurements.

INTRODUCTION

One of the most important problems facing the engineer involved in coastal protection and harbour design is that of estimating the littoral sand transport along a shoreline. Usually, field measurement data are not available or not of sufficient accuracy and most empirical formulas do not take into account all the wave and sediment parameters in a satisfactory fashion.

Littoral sand transport tests were performed at Queen's University in a three-dimensional mobile bed coastal model with two different types of sand. Earlier tests by Readshaw (1979), and reported by Kamphuis and Readshaw (1978) used sand with a median diameter of 0.56 mm. The longshore sediment transport rate was found to be dependent on the beach profile characteristics and the rate of wave energy dissipation, as well as on the usual wave and sediment parameters.

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The present series of tests was performed in the same wave basin under similar test conditions. A finer sand of median diameter 0.18 mm was used. The results of these tests in combination with the earlier tests are the topic of this paper.

More details regarding both sets of experimental results may be found in Sayao (1982) and Sayao and Kamphuis (1983).

EXPERIMENTAL EQUIPMENT AND PROCEDURE

The three dimensional wave basin at the Coastal Engineering Research Laboratory, of Queen's University at Kingston is shown in Figure 1.

Monochromatic waves were produced with a piston type wave generator. Wave filters and splitters, were placed immediately in front of the wave generator to prevent formation of transverse standing waves and to filter out high frequency components. Wave guide walls were constructed and aligned along wave orthogonals calculated from refraction theory. Openings were cut in these training walls at several locations to facilitate filling and draining of the central test basin and the reservoir surrounding the central testing area. Three capacitance-type wave probes were used to measure the wave heights in the constant depth portion of the test basin, between the toe of the beach and the wave filters. Wave heights in the breaking zone and at any other location along the beach profile were measured with a fourth capacitance-type wave probe mounted on a transversely travelling trolley placed on the beach side of the travelling carriage. Beach profiles were measured with a blunt-ended point gauge mounted on a separate trolley also placed on the beach side of the travelling carriage. An initial model beach was shaped twice during the present test series by screeding and compacting sand to a thickness of 0.13 m. over a sloped concrete floor. The grain size distribution curves for the materials used for both sets of tests are shown in Figure 2.

The present experiments consisted of a total of 14 series of tests, each of several seasons of a predetermined duration varying from 15 to 110 minutes. The wave parameters were changed after every series and could be paired together to form a regular seasonal cycle as described in Kamphuis and Readshaw (1978). Although the beach initially had a uniform slope of 1:10, a beach profile was allowed to "develop" with time and each subsequent test was started on the beach profile remaining from the previous test. Slow, continuous recession of the shoreline was observed and at the end of series 5, after approximately 83 model hours of profile development, the initial slope of 1:10 was reshaped. Testing then resumed for another 87 model hours up to the end of test series 14.

During the experimental investigation the alongshore sediment transport rate was recorded continuously. Other data measured included breaker characteristics such as the breaker height H_b, the

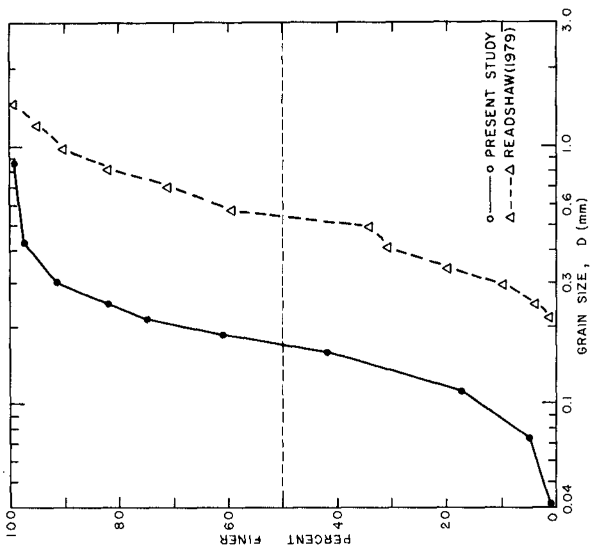

FIG. 2 GRAIN SIZE DISTRIBUTIONS

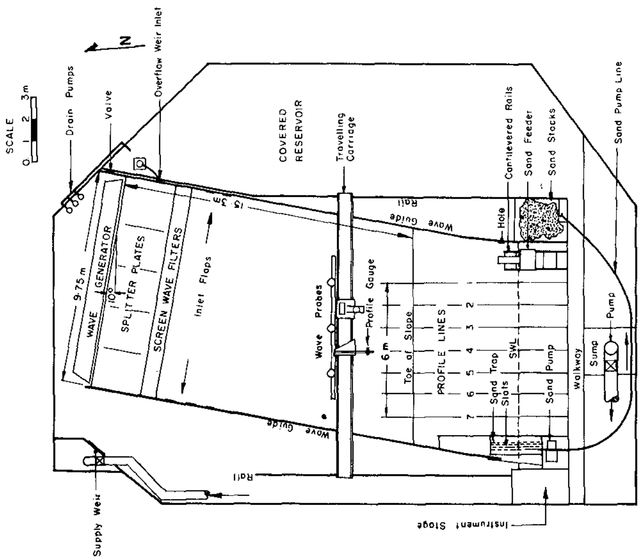

FIG. 1 PLAN VIEW OF THE WAVE BASIN

depth below still water level at the breaking point d_b, the breaker distance λ_b measured from the still water level shoreline, the velocity of wave propagation at the breaking point C_b and the incident angle of breaking α_b. Analysis of the measured breaker characteristics have been reported in detail in Sayao and Kamphuis (1982). It is to be noted that all these parameters have been evaluated for beach profiles rather than for plane beaches.

EXPERIMENTAL RESULTS

The experimental results are summarized in Table 1. A more detailed description of the present tests as well as Readshaw's (1979) data may be found in Sayao (1982) and Sayao and Kamphuis (1983).

Dimensional Analysis

Dimensional analysis for littoral transport rate yields:

$$\Pi_{Q_s} = \phi_{Q_s}\left(\frac{H_b}{L_o}, m, \frac{H_b}{D}, \frac{\rho_s}{\rho}\right) \qquad (1)$$

where

$$\Pi_{Q_s} = \frac{Q_s}{\rho H_b^2 (H_b/T) \frac{1}{2} \sin 2\alpha_b} \qquad (2)$$

Q_s is the dry mass littoral sediment transport rate, in kilograms per unit of time, ρ the water density, ρ_s the sediment density, H_b the wave height, L_o the deep water wave length, T the wave period, D the particle size and m the beach slope. The definition of beach slope m for mobile bed models has been the subject of considerable debate. From the present experiments - Sayao and Kamphuis (1983) - it was found that the most convenient form of beach slope definition,

$$m = \frac{d_b}{\lambda_b} \qquad (3)$$

was also the definition which described surf zone phenomena, including littoral drift rate most accurately. This definition is called "mobile bed beach slope" throughout this paper.

Relationship between Beach Slope and Relative Grain Size

Figure 3 shows the mobile bed beach slope as a function of relative grain size parameter for the combined data set of the present tests and Readshaw's (1979) tests. Even though the data are scattered, a definite relationship between these two parameters is evident. From regression analysis the curve fitted through the data

TABLE 1

EXPERIMENTAL RESULTS (SAYAO, 1982)

Model Material: Sand of D_{50} = 0.18 mm

Wave Basin Depth of Water: 0.51 m

First Run: Test Series S1 to S5

Test Number	H_o (m)	H_b (m)	L_o (m)	d_b (m)	λ_b (m)	α_b (o)	$\bar{Q}_s$ (kg/hr)
S1L04	0.129	0.151	3.513	0.139	1.85	5.5	-
SIL08	0.120	0.135	3.513	0.128	1.788	5.5	-
S1L12	0.125	0.154	3.513	0.160	2.075	5.5	-
S2S04	0.044	0.060	2.137	0.074	0.75	4.0	17.4
S2S08	0.048	0.064	2.137	0.088	1.20	4.0	19.2
S2S12	0.047	0.058	2.137	0.088	1.163	4.0	16.2
S2L04	0.119	0.151	3.513	0.155	2.088	2.5	144.0
S2L08	0.131	0.150	3.513	0.143	2.038	2.5	132.0
S2L12	0.128	0.158	3.513	0.201	3.013	2.5	150.0
S2L14	0.127	0.147	3.513	0.202	3.038	2.5	150.0
S2L17	0.128	0.152	3.513	0.192	3.15	2.5	120.0
S2L20	0.128	0.162	3.513	0.184	3.138	2.5	120.0
S3S04	0.041	0.051	2.137	0.075	0.725	3.5	14.4
S3L06	0.119	0.144	3.513	0.170	2.963	2.5	150.0
S4L04	0.039	0.057	6.434	0.081	0.40	1.0	9.6
S4S07	0.043	0.064	2.137	0.078	0.738	2.5	14.4
S4L10	0.032	0.050	6.434	0.081	0.513	1.0	7.8
S4S13	0.040	0.049	2.137	0.089	0.80	2.5	15.0
S5L03	0.065	0.101	3.513	0.131	2.013	3.5	21.6
S5L06	0.074	0.103	3.513	0.130	1.963	3.5	21.0
S5S03	0.088	0.113	1.656	0.150	3.225	3.5	69.6
S5S06	0.084	0.110	1.656	0.152	3.35	3.5	46.8

TABLE 1 (continued)

Second Run: Test Series AS6 to S14

Test Number	H_o (m)	H_b (m)	L_o (m)	d_b (m)	λ_b (m)	α_b (o)	$\bar{Q}_s$ (kg/hr)
S6L05	0.092	0.108	2.845	0.087	1.25	6.5	120.0
S6L09	0.093	0.103	2.845	0.123	1.625	6.0	132.0
S6L15	0.093	0.106	2.845	0.128	1.788	7.0	114.0
S7S03	0.058	0.071	2.137	0.096	1.338	5.5	35.4
S7L04	0.045	0.063	2.845	0.063	0.975	6.5	13.2
S7S06	0.058	0.071	2.137	0.098	1.775	6.0	34.2
S7L07	0.047	0.064	2.845	0.077	1.425	7.0	6.6
S8S04	0.057	0.060	1.656	0.083	1.613	6.5	24.0
S8S08	0.055	0.074	1.656	0.104	2.40	6.5	21.0
S8S12	0.055	0.071	1.656	0.095	2.263	6.5	22.8
S8L04	0.093	0.113	3.560	0.160	2.825	7.5	60.0
S8L08	0.092	0.109	3.560	0.166	2.775	7.5	94.2
S8L12	0.096	0.111	3.560	0.129	2.288	7.5	75.0
S9S03	0.063	0.084	2.137	0.103	1.388	6.5	18.0
S9L04	0.077	0.095	2.845	0.118	1.80	6.5	38.4
S9S06	0.062	0.082	2.137	-	-	5.5	30.0
S9S07	0.063	0.083	2.137	0.079	0.838	5.5	19.8
S9L08	0.081	0.098	2.845	0.123	2.513	8.0	43.2
S9L09	0.078	0.098	2.845	0.126	2.425	8.0	42.6
S10L2	0.093	0.108	2.845	0.139	2.65	7.5	34.2
S10L6	0.096	0.107	2.845	0.143	2.60	7.5	37.8
S11L4	0.102	0.110	2.845	0.162	3.00	6.5	41.4
S11L8	0.102	0.112	2.845	0.155	2.963	8.0	39.6
S11S4	0.061	0.078	1.656	0.113	1.95	6.5	17.4
S11S7	0.061	0.078	1.656	0.112	2.075	6.0	20.4
S12L4	0.057	0.074	2.845	0.089	0.975	8.0	35.4
S12L8	0.054	0.073	2.845	0.102	1.575	7.5	34.8
S14L1	0.100	0.127	3.560	0.151	2.95	6.5	46.2
S14S2	0.073	0.093	2.137	0.132	2.675	5.5	48.6
S14L4	0.101	0.124	3.560	0.145	2.875	7.5	36.0
S14S4	0.071	0.078	2.137	0.098	1.213	?5.5	61.2
S14S5	0.075	0.089	2.137	0.117	1.963	5.5	58.8

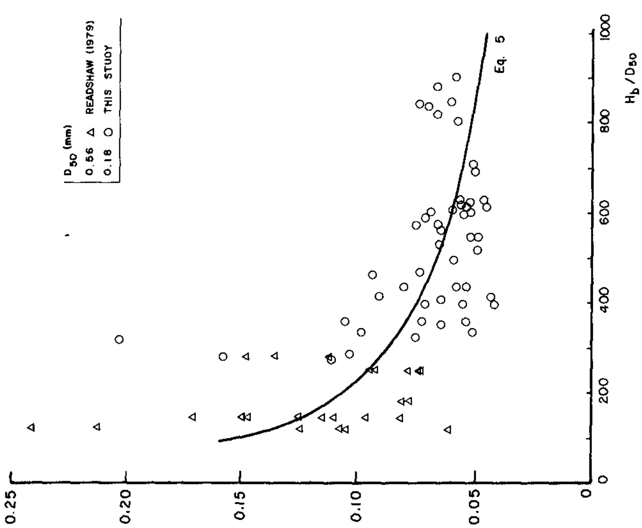

FIG. 3 MOBILE BED BEACH SLOPE AS A FUNCTION OF RELATIVE GRAIN SIZE

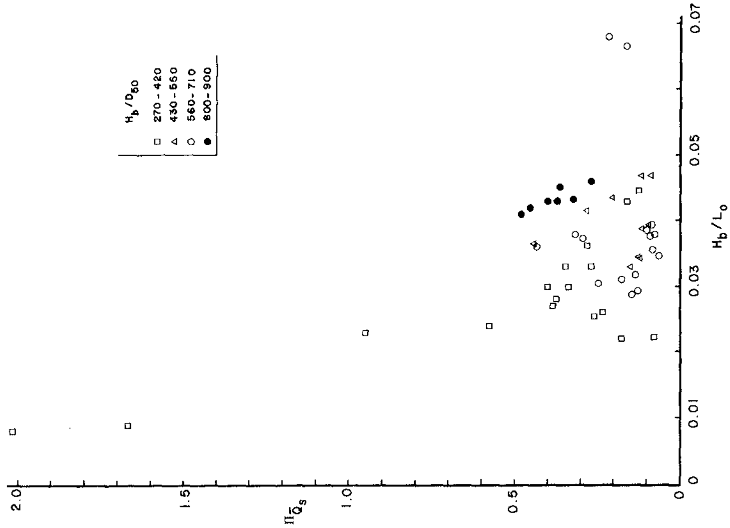

FIG. 4 AVERAGE DIMENSIONLESS TRANSPORT RATE AS A FUNCTION OF BREAKER STEEPNESS

is:

$$m = 1.5 \left(\frac{H_b}{D_{50}} \right)^{-1/2} \qquad (4)$$

with $r^2 = 0.42$. The scatter of the data is further reduced if the wave steepness is included as a parameter, see Sayao (1982). It may be concluded that:

$$m \sim \sqrt{\left(\frac{D_{50}}{H_b} \right)} \qquad (5)$$

for medium and fine sands. This result agrees with earlier findings by other authors, reviewed in Sayao and Kamphuis (1982a) and with the well known fact that steeper beach slopes are formed by coarser sediments.

From the above analysis it may be concluded that the mobile bed beach slope m as a dimensionless variable for littoral transport includes much of the influence of relative grain size and hence the two are not completely independent as required by dimensional analysis. Thus, relative grain size and beach slope should not both be included in Equation 1. It was decided to retain beach slope in the relationship. Grain size can be re-introduced at a later stage to account for additional effect of grain size.

Since the model experiments were conducted using sand as the model material in order to avoid serious scale effects resulting from incorrect modelling of the density ratio (see Kamphuis 1975), Equation 1 may be rewritten in simplified form as:

$$\Pi_{Q_s} = \phi_{Q_s} \left(\frac{H_b}{L_o}, m \right) \qquad (6)$$

Figures 4 and 5 show the dimensionless average mass rate of littoral transport ($\Pi_{\bar{Q}_s}$) as a function of each of the dimensionless variables of Equation 6, the wave steepness and the mobile bed beach slope. "Average" refers to sediment transport rate averaged over a test with constant incident wave conditions. Both the present set of results as well as Readshaw's (1979) results are plotted.

For Readshaw's tests, the depth at the breaking point d_b and the breaker distance λ_b had not been measured directly and these quantities were determined by measurement from his published beach profiles. Figure 4 shows a decrease in $\Pi_{\bar{Q}_s}$ with breaker steepness. Also for the same value of the breaker steepness, Readshaw's coarser

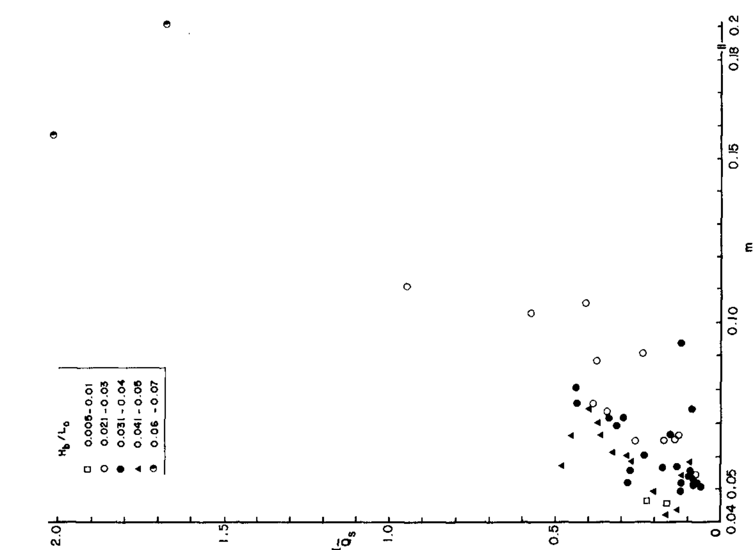

FIG. 5 AVERAGE DIMENSIONLESS TRANSPORT RATE AS A FUNCTION OF BEACH SLOPE

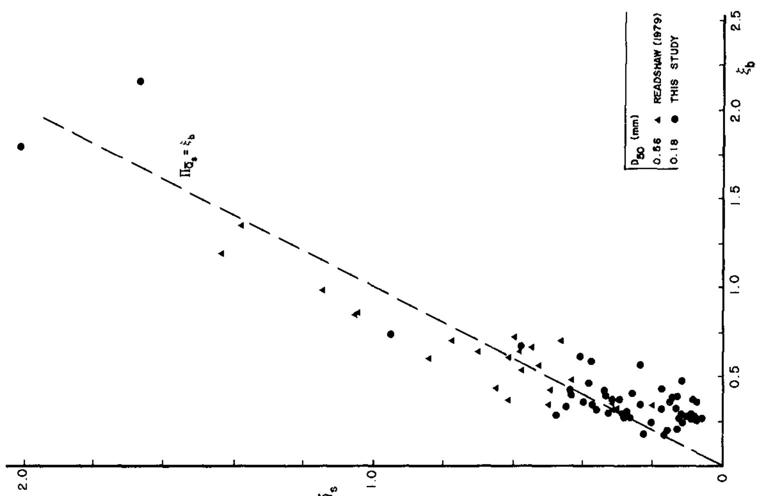

FIG. 6 AVERAGE DIMENSIONLESS TRANSPORT RATE VS SURF SIMILARITY PARAMETER, MEDIUM AND FINE SAND

material produced higher dimensionless littoral transport rates, and two distinct curves for $\Pi_{\bar{Q}_s}$ versus H_b/L_o could be drawn. Figure 5 shows an increase of $\Pi_{\bar{Q}_s}$ with mobile bed beach slope.

Figures 4 and 5 indicate that some of the variation in $\Pi_{\bar{Q}_s}$ resulting from the breaker steepness may be compensated by the change in $\Pi_{\bar{Q}_s}$ resulting from the beach profile slope. The influence of the breaker steepness and beach slope on the dimensionless average mass rate of littoral transport might therefore well be expressed by:

$$\Pi_{\bar{Q}_s} \sim \frac{m}{\sqrt{(H_b/L_o)}} = \xi_b \quad (7)$$

where ξ_b is the surf similarity parameter.

Kamphuis and Readshaw (1978) first proposed that dimensionless littoral transport rate is related to the rate of energy dissipation in the breaking zone and hence to the surf similarity parameter.

Littoral Transport Rate and the Surf Similarity Parameter

Figure 6 shows the dimensionless average mass rate of littoral transport as a function of surf similarity parameter, for the present results with fine sand and for Readshaw's (1979) results with the coarser material. The surf similarity parameter was defined from Equations 3 and 7 as:

$$\xi_b = \frac{m}{\sqrt{(H_b/L_o}} = \frac{d_b/\lambda_b}{\sqrt{(H_b/L_o)}} \quad (8)$$

A strong straight line relationship between the dimensionless average mass rate of littoral transport and the surf similarity parameter may be seen and hence a good approximation of Equation 6 is:

$$\Pi_{\bar{Q}_s} = \kappa \cdot \xi_b \quad (9)$$

where κ is a dimensionless constant. Numerical values for κ were found from regression analysis and are given in Table 2. Some variation in κ was noted possibly depending on grain size.

TABLE 2

VALUE OF κ

Experimental Data	Number of Points	Regression Analysis r^2	κ
Readshaw (1979)	24	0.83	1.09
Present results	50	0.83	0.84
Combined data set	74	0.81	0.94

Substitution of Equations 5 and 8 into Equation 9 yields:

$$\Pi_{\bar{Q}_s} = \kappa \cdot \xi_b \sim \frac{\sqrt{(D_{50}/H_b)}}{\sqrt{(H_b/L_o)}} \qquad (10)$$

This implies that the dimensionless littoral transport rate is proportional to the square root of the grain size, for medium and fine sands which agrees with Bajorunas (1970) and Castanho (1970). Laboratory tests conducted by Larras and Bonnefille (1965), reviewed in Sayao and Kamphuis (1982a) revealed that littoral transport rate goes through a maximum when related to the grain size, Lepetit (1972) and Bonnefille (1976). Thus for very coarse sands, Equation 10 will not be valid, and in the limit, for large rocks, the fluid is no longer capable of moving any material.

Equation 10 also shows that dimensionless average mass rate of littoral transport is inversely proportional to the square root of the breaker steepness. This inverse proportionality has been proposed earlier by Saint-Marc and Vincent (1954), Larras (1957) and Le Méhauté and Brebner (1961).

RELATIONSHIP BETWEEN LABORATORY AND FIELD DATA

Immersed Weight, Dry Mass and Alongshore Energy Flux Factor

An attempt to compare the present method and Equation 9 with field data is now presented. Unfortunately, at the present time, only few field data have been published and the quality of these few field data sets was questioned by Greer and Madsen (1978) and Bruno et al (1981). The relationship for dimensionless average mass rate of littoral transport (Equation 9) may be rewritten as:

$$\frac{g\,\bar{Q}_s}{\rho g\, H_b^{\,2}\, (H_b/T)\, \frac{1}{2}\, \sin 2\alpha_b} = \kappa \cdot \xi_b \tag{11}$$

The average dry mass transport rate $\bar{Q}_s$ may be converted to immersed weight littoral transport rate I_ℓ by the following relation:

$$I_\ell = \frac{\rho_s - \rho}{\rho_s}\, g\, \bar{Q}_s \tag{12}$$

For quartz sand with $\rho_s/\rho = 2.65$ and using the small amplitude expression for wave energy

$$I_\ell = \frac{8\kappa}{1.6}\, \frac{H_b\, \xi_b}{T}\, E_b\, \frac{1}{2}\, \sin 2\alpha_b \tag{13}$$

Substitution of Equation 8 into Equation 13 yields

$$I_\ell = \frac{5\kappa}{\sqrt{2\pi}}\, m\, \sqrt{gH_b}\;\; E_b\, \frac{1}{2}\, \sin 2\alpha_b \tag{14}$$

Longshore wave energy flux factor P_ℓ , is normally defined as follows:

$$P_\ell = \frac{1}{16}\, \rho g\, H_b^{\,2}\, n_b\, C_b\, \sin 2\alpha_b \tag{15}$$

Using $n_b \approx 1$ for shallow water and C_b as given by small amplitude theory, shown to be correct in Sayao and Kamphuis (1982), P_ℓ becomes:

$$P_\ell = \sqrt{gd_b}\;\; E_b\, \frac{1}{2}\, \sin 2\alpha_b \tag{16}$$

Now I_ℓ and P_ℓ may be related using Equations 14 and 16:

$$I_\ell = \frac{5\kappa}{\sqrt{2\pi}}\, m\, \sqrt{\gamma_b}\;\; P_\ell \tag{17}$$

Equations 9, 14 and 17 are simply different expressions of the same relationship for littoral transport rate proposed in the light of the present findings. Equation 17 may be written in dimensionless form as:

$$K_p = \frac{I_\ell}{P_\ell} = \frac{5\kappa}{\sqrt{2\pi}}\, m\, \sqrt{\gamma_b} = 2\,\kappa \cdot m\, \sqrt{\gamma_b}\,. \tag{18}$$

which shows that the value of K_p is not constant as expressed in the

CERC formula - U S Army Corps of Engineers (1977) - but varies as a function of the mobile bed beach slope and the breaker index. Figure 7 shows a plot of K_p versus $m\sqrt{\gamma_b}$ for the combined results of Readshaw (1979) and the present tests. Figure 7 is equivalent to Figure 6, but contains a little more scatter. Using a value for $\kappa \approx 1$ (see Table 2), the curve fitted in terms of K_p becomes:

$$K_p = 2\, m \sqrt{\gamma_b} \qquad (19)$$

which was found valid for the model data, with $r^2 = 0.78$.

Preliminary Comparison of Experiments with Field Data

Existing field data on littoral drift have been compiled by Das (1971). The measurements were expressed in terms of immersed weight transport rate and longshore wave energy flux factor. Komar and Inman (1970) found

$$K_p = \frac{I_\ell}{P_{\ell r}} = 0.77 \qquad (20)$$

where $P_{\ell r}$ is P_ℓ evaluated using H_{rms}. The present CERC formula in which Komar's data as well as other available field data sets are used finds K_p equal to 0.78 (Bruno et al, 1981). If the significant wave height is used to calculate P_ℓ, then the comparable value for the CERC formula 'constant' becomes:

$$K_p = \frac{I_\ell}{P_{\ell s}} = 0.39 \qquad (21)$$

assuming the wave heights near breaking to be Rayleigh distributed. Equation 21 is also shown in Figure 7.

A comparison will be made between the present model results and the field data of Komar (1969), see also Komar and Inman (1970). For this comparison of field and model data it is assumed that the monochromatic model wave height H may be compared with the significant wave height H_s in the field. This has become a common assumption in the past for mobile bed model studies performed at Queen's University, as well as at other hydraulics laboratories.

Unfortunately, for Komar's field data, only typical beach profiles for each location were given (see Komar, 1969). For Silver Strand beach the wave data were collected at the same time as the

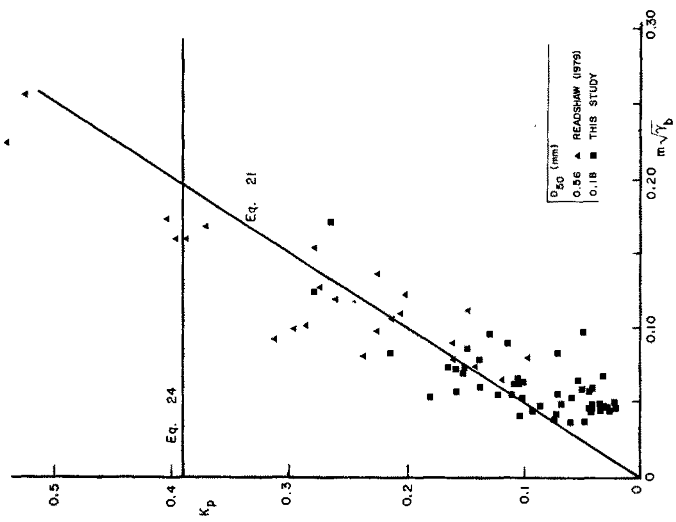

FIG. 7 VARIATION OF COEFFICIENT IN THE CERC FORMULA WITH BEACH SLOPE AND BREAKER INDEX

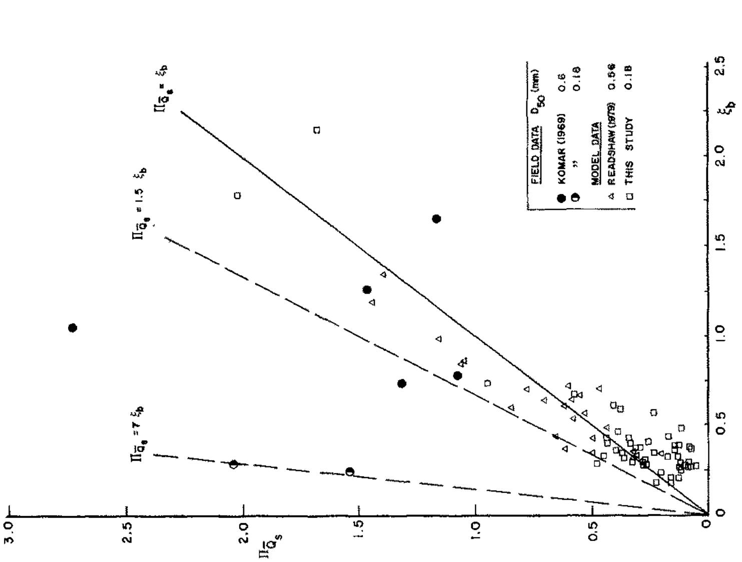

FIG. 8 COMPARISON OF FIELD AND MODEL DATA ON LITTORAL TRANSPORT RATE

beach was surveyed. For El Moreno, the wave climate was considered for this study to vary on a seasonal basis, i.e. it was assumed that the profile surveyed in May 1968 was also valid for Komar's measurements of May 1966 and May 1967. Out of the 14 orginal data points only seven can be used in the present comparison. Table 3 shows the parameters used for calculating $\Pi_{\bar{Q}_s}$ based on Komar's (1969) own field measurements using

$$\Pi_{\bar{Q}_s} = \frac{1}{5} \frac{\sqrt{g d_b}}{H_b/T} \frac{I_\ell}{P_{\ell s}} \tag{25}$$

TABLE 3

FIELD MEASUREMENTS FROM KOMAR (1969)

No	Site	Date	m		$(H_b)_{rms}$	α_b	I_ℓ	$(\xi_b)_s$	$(\Pi_{\bar{Q}_s})_s$	κ
				(s)	(m)	(°)	(N/s)			
	(1)		(2)	(3)	(4)	(3)	(5)	(6)	(6)	
1	SSB	4 Sep 68	1/55	11.10	0.528	5.8	47.1	0.29	2.04	7.03
2	SSB	5 Sep 68	1/55	9.50	0.565	4.3	37.9	0.24	1.54	6.42
3	EMB	4 May 66	1/7	2.72	0.316	10.0	45.1	0.73	1.31	1.79
4	EMB	5 May 66	1/7	3.28	0.398	14.0	84.4	0.78	1.08	1.38
5	EMB	22 May 67	1/7	4.72	0.317	9.8	28.7	1.25	1.46	1.17
6	EMB	23 May 67	1/7	5.88	0.287	5.3	7.5	1.65	1.17	.71
7	EMB	11 May 68	1/7	3.75	0.285	4.1	20.8	1.06	2.72	2.56

(1) SSB: Silver Strand beach, D_{50} = 0.18 mm
EMB: El Moreno beach, D_{50} = 0.6 mm
(2) From typical beach profiles given in Figure 9 of Komar (1969)
(3) Averaged daily values from data given in Appendix IV of Komar (1969)
(4) Averaged daily root mean square values from data given in Appendix IV of Komar (1969)
(5) Averaged daily values given in Table 1 of Komar (1969)
(6) Calculated using significant breaker height

The results were plotted in Figure 8 for which $\Pi_{\bar{Q}_s}$ was calculated using $(H_b)_s$ for the field data points (i.e. $(H_b)_{rms}$ was multiplied by $\sqrt{2}$). It may be seen from Figure 8 that Equation 9 is also valid for the field results, but that the value of κ based on the model results would underestimate the littoral transport rate by a factor of about 7 when compared with the Silver Strand field results and by a factor of about 1.5 when compared with the widely scattered El Moreno field results.

The fact that Equation 9 is valid for the field results is not surprising since there is no reason why field sediment transport rates should not be related to rate of energy dissipation. The fact that κ for the field results is higher than for the model is also reasonable. In the model (and on prototype beaches of large grain size), the sand is moved almost solely by bed load transport. For finer sands in the field, additional transport results from material suspension. In the model and the coarse material prototype, the driving force is related to shear stress. In the finer material prototype, additional consideration must be given to stirring of material into suspension by the turbulent breaker, to the settling mechanisms and fall velocity and to the effect of excess pore water pressures in the beach at the breaking zone, locally causing liquefaction of the sand mass and much higher rates of sediment transport.

The model results indicate that as D increases, m increases, ξ increases and hence Q_s increases. But the suspension and liquefaction mechanisms would indicate that as D increases, concentration of particles in suspension decreases and hence Q_s decreases. The first mechanism is taken into account with ξ , the second with κ . Further field comparisons are obviously necessary to prove the above preliminary hypothesis to be correct. No better comparisons can be made until more field measurements of littoral sand transport rate become readily available in which wave characteristics and beach profiles are simultaneously recorded.

For the sake of completeness a simple dimensional plot of I_ℓ versus $P_{\ell s}$, as suggested by the CERC formula (U S Army Corps of Engineers, 1977), is also produced in Figure 9. No strong relationship is evident.

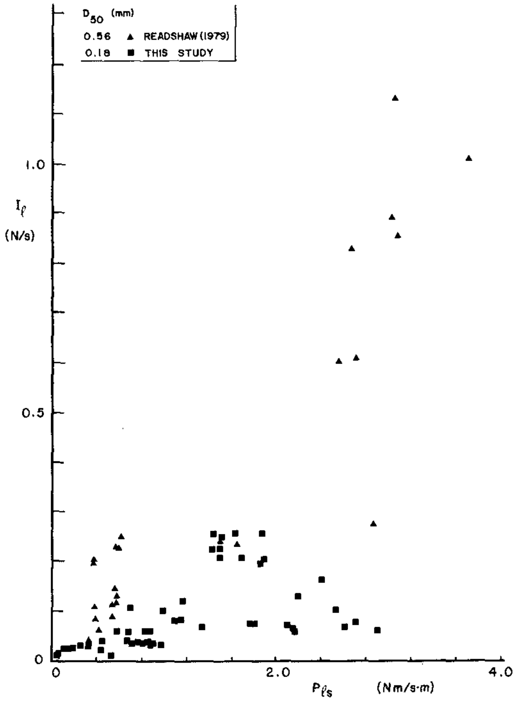

FIG. 9 I_ℓ VERSUS $P_{\ell S}$, FOR MODEL DATA OF MEDIUM AND FINE SAND

CONCLUSIONS

a. Littoral transport rate for medium and fine sand models may be expressed as

$$\Pi_{\bar{Q}_s} = \kappa \, \xi_b \tag{9}$$

or

$$\frac{\bar{Q}_s}{\rho \, H_b^2 \, (H_b/T) \, \frac{1}{2} \sin 2\alpha_b} = \kappa \frac{m}{\sqrt{H_b/L_o}} \tag{26}$$

where κ was found to be approximately equal to one for the model studies.

b. The beach slope to be used for calculations of littoral transport rate in mobile bed models is

$$m = \frac{d_b}{\lambda_b} \tag{3}$$

which was found to be related to grain size

$$m \sim \sqrt{\frac{D_{50}}{H_b}} \tag{5}$$

c. Another form of Equation 26 is:

$$I_\ell = 2 \, \kappa \, m \sqrt{\gamma_b} \, P_{\ell_s} \tag{27}$$

which indicates that the "constant" in the CERC formula is not constant but varies with beach slope and breaker index.

d. Preliminary analysis of some field results indicates that Equation 9 is also valid for prototype beaches but that the value of sediment transport (and κ) for the field results is higher than for the model. This is hypothesised to be a result of additional transport in the field by material suspension.

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NOTATION

General

b	(as a subscript) at the breaker
C	velocity of wave propagation
C_b	velocity of wave propagation in the breaking zone
C_g	group velocity
D	sediment grain size
D_{50}	sediment grain size corresponding to sieve size retaining 50% of a sediment sample
d	local water depth, related to still water level
d_b	water depth at breaking, related to still water level
E	energy density in a wave ($= 1/8 \rho g H^2$)
E_b	energy density at time of breaking
g	acceleration due to gravity
H	wave height
H_b	breaker height
H_o	deep water wave height
H_{rms}	root mean square wave height
H_s	significant wave height
I_ℓ	immersed weight littoral sand transport rate
K_p	empirical dimensionless littoral transport coefficient
L	local wave length
L_b	wave length at point of breaking
L_o	deep water wave length
m	mobile bed beach slope ($= d_b/\lambda_b$)
m	(as a subscript) model

N	model distortion
n	energy propagation factor ($= C/C_g$)
n	model scale
p	(as a subscript) prototype
P_ℓ	longshore wave energy flux factor
P_{ℓ_r}	P_ℓ evaluated using H_{rms}
P_{ℓ_s}	P_ℓ evaluated using H_s
Q_s	mass rate of littoral sediment transport
$\bar{Q}_s$	average mass rate littoral transport during one test
r	correlation coefficient
T	wave period
x	horizontal
y	vertical
α	angle of incidence between waves and shoreline
α_b	angle α measured at the breaking point
γ_b	breaker index ($= H_b/d_b$)
ξ_b	surf similarity parameter evaluated at the breaking point ($= m/\sqrt{(H_b/L_o)}$)
Π_A	dimensionless version of a property A
ϕ	dimensionless function
κ	empirical dimensionless constant
λ_b	breaker distance, measured between the breaking point and the shoreline, at still water level
ρ	density of water
ρ_s	sediment density