American Journal of Applied Sciences

Original Research Paper

Characterisations of Parameters of Granularity of Sediments from Togolese Littoral: Granular Potential

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Article history
Received: 11-07-2018
Revised: 14-07-2018
Accepted: 10-10-2018

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Abstract: The present study aims at analysing the dimensional distribution of granulate grains all along the Togolese littoral and identifying the law of their longitudinal distributions. In this regard two hundred and ten (210) samples are collected all along the Togolese littoral from the Togo-Ghana border up to Togo-Benin border and another ten (10) samples on each side of a spike located at 37.5 PK. Samples dried at 105°C for 20 h are then subjected to screening test. Their longitudinal size distributions, uniformity coefficients and bendings are then specified. It is apparent that the sediments of the Togolese littoral consist of grains of category ''F_3'' that are getting bigger and bigger, less and less tight, badly graduated and more open in accretion and erosion zones in the direction of the littoral drift. Natural and artificial works all along the Togolese littoral enable to identify three categories of sediment (fine, medium-size and big) corresponding to properly determined usages in the concrete.

Keywords: Sediment, Togolese Littoral, Longitudinal Distribution, Size Distribution

Introduction

Most of civil engineering works, completed in Togo are in concrete which is a composite material made generally of granulates, binders and water. The choice of the size of granulates depends on expected results for concrete (desired features) such as Watertight concrete, shockproof concrete, hard wearing, compression resistant, bending resistant and impact resistant concrete, permeable concrete, workability of concrete: These are the features that are found for a concrete (Aitcin, 1998). The fundamental perimeter that influences the physical aspect of concrete is the granulate form characterized by its size distribution.

Various types of sands are used in Togo as granulates: Sea sands, river sands, sands from crushing of rocks and continental dunes. In order to meet sand demands projects are completed in Lomé and in the Togolese littoral areas. In the course of these projects sands from the Togolese littoral are very often used without knowing their different characteristics depending on their transversally and longitudinally geographical position.

The aim of this study is to find out the law of the size and longitudinal distribution through parameters of differential distribution, coefficients of Hazen, uniformity and granulate class of the littoral sediments of Togo. The determination of granulate properties of sandy sediments is being searched on the samples all along the Togolese littoral on 50 km from the border with Ghana (PK0) up to Benin border (PK50) in order to specify the potentials of each profile in granulates for concrete. Which will enable the optimization of this material in the civil engineering construction and therefore the optimization of the extraction of these sandy sediments.

Basic Equations

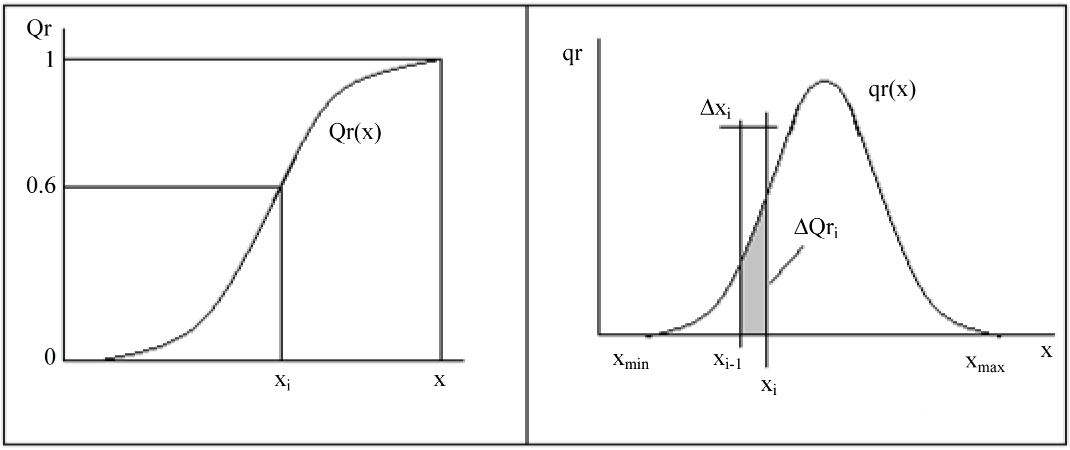
The typical, cumulative standard distribution $Q_r(x)$ of a distribution illustrated through Fig. 1 lies between 0 and 1, i.e., between 0% and 100%. Its expression is given by the following equation (NF ISO 9276-1, 1998):

$$Q_{r,i} = \sum_{v=1}^{i} \Delta Q_{R,v} = \sum_{v=1}^{i} \bar{q}_{r,v} \Delta x_v \quad (1)$$

With $1 \le v \le i \le n$.

The differential distribution $q_r(x)$ (Fig. 1) is obtained by the equation:

$$q_r(x) = \frac{dQ_r(x)}{dx} \quad (2)$$



(a) (b)

Fig. 1: Curves of cumulative and differential distributions (NF ISO 9276-1, 1998) (a) Cumulative distribution Qr(x) (b) Differential distribution qr(x)

Table 1: Classification of materials according to coefficients of Hazen (of uniformity)

Nature of soil	Value of Cu
Material with a highly tight grain size	Cu < 2
Material with a tight grain size	2 ≤ Cu < 5
Material with a highly semi-tight grain size	5 ≤ Cu < 20
Material with a stretched grain size	20 ≤ Cu < 200
Material with a highly stretched grain size	Cu ≥ 2

Table 2: Identification of the graduation of materials

Nature of soil	Value of Cc
Case of gravel	
Well graduated and clean material (GW)	Cu > 4 and 1 < Cc < 3
Badly graduated material (GP)	Cu ≤ 4 or Cc ≤ 1 or Cc ≥ 3
Case of sand	
Well graduated and clean material (SW)	Cu > 6 and 1 < Cc < 3
Badly graduated material (SP)	Cu ≤ 6 or Cc ≤ 1 or Cc ≥ 3

The evaluation of the granular surface area can be measured by coefficients of uniformity Cu and curve Cc the expressions of which are given by (Tchouani Nana and Callaud, 2004):

$$Cu = \frac{x_{60}}{x_{10}} \quad (3)$$

$$Cc = \frac{(x_{30})^2}{x_{10} \times x_{60}} \quad (4)$$

The parameters of these two equations are defined by:

x_{60}: The screening correspondent to qr_{60}
x_{30}: The screening correspondent to qr_{30}
x_{10}: the screening correspondent to qr_{10}

Following the values of Cu et Cc the sediments can be classified according to Table 1 and 2.

The granulates are also charactrised by the diameter of the smallest grain « d » and that of the biggest grain « D » and are expressed by d/D and called granular class of a granulate. For sands, given the very small value of d, the NF standard recommends to write 0/D (NF EN 12620, 2002**)** (Bresson, 1996).

In practice, this condition is seldom observed. The standard has then required criteria of acceptation of a granulate. For a superposition of sieve of stitch 1.56D-D-d and 0.63d, this criteria is expressed by the system of the following equations (Amey, 2006):

$$\begin{cases} q_r(D) + q_r(0.63d) \le \begin{cases} 15\% \text{ if } D \ge 1.56d \\ 20\% \text{ if } D \le 1.56d \end{cases} \\ q_r(1.56D) = 0 \\ 100 - Q_r(0.63d) \le \begin{cases} 30\% \text{ if } D > 5mm \\ 5\% \text{ if } D \le 5mm \end{cases} \end{cases} \quad (5)$$

Materials and Methods

Collections of samples of sediment are carried out on thirty-five (35) profiles from the border Togo -

Ghana up to Togo – Bénin (Fig. 2). Table 3 shows the numbers of profiles that are surveyed as well as their distance with regard to the border with Ghana (PK).

On each of the profiles, sediments are collected on the low-foreshore (Bas-E), the semi- foreshore (Mi-E), the high-foreshore (Haut-E) and on the aerial beach at 5 m of high- foreshore (Début -PA), 10 m the high -foreshore (Mi-PA) and at the end of aerial beach (Fin-PA) as shown on Fig. 3.

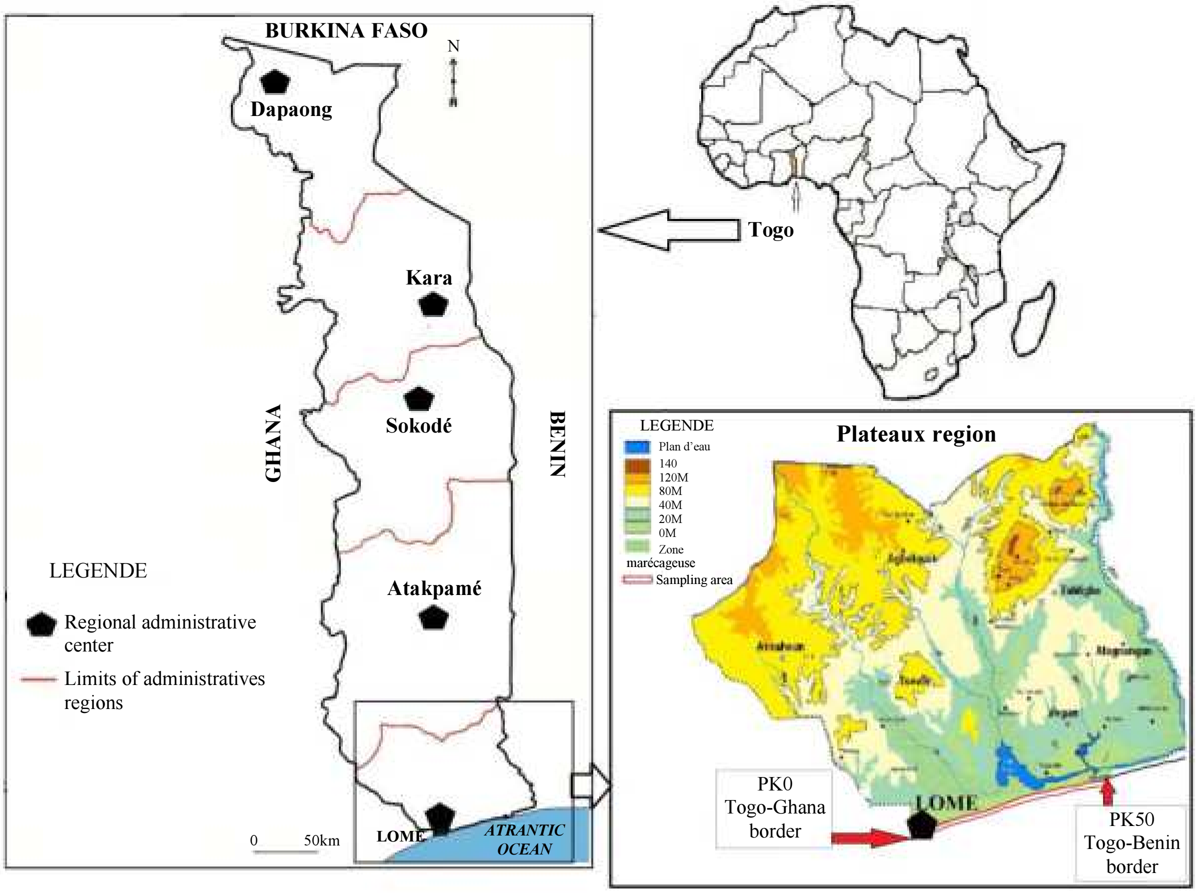


Fig. 2: Location of Togolese beach

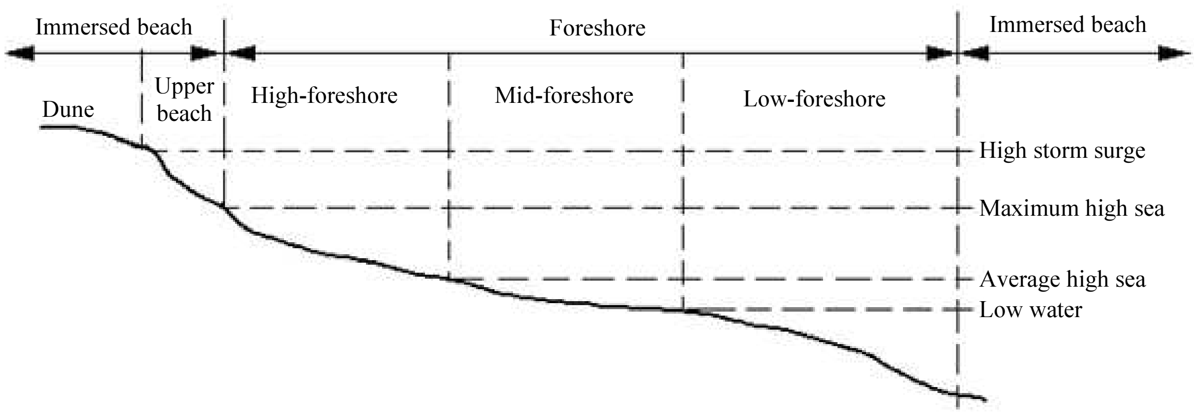


Fig. 3: Profile through a beach showing the foreshores and the aerial beach

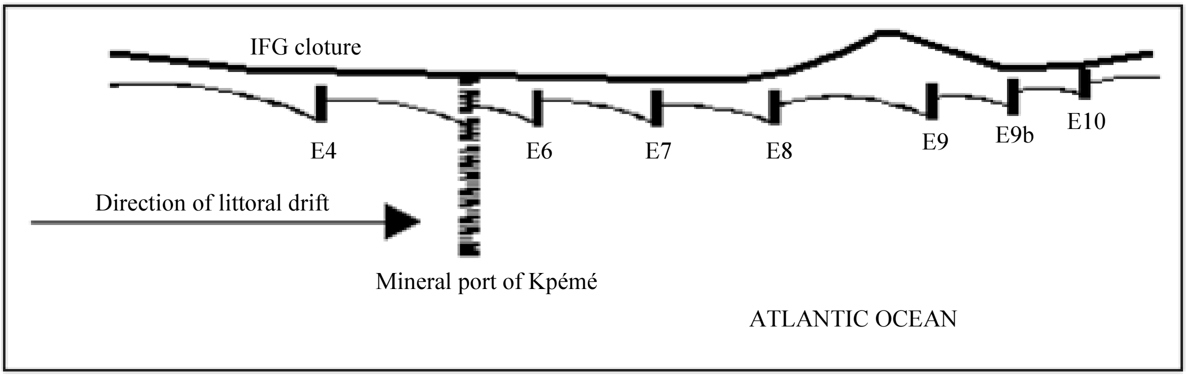


Fig. 4: Positions of the spikes on the coast

Table 3: Positions of the different profiles

Profile	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Distance: PK (km)	0	2	4	5	6	7	8	9	10	12	16	18	20	24	28	29	30	32
Profile	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	
Distance: PK (km)	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	

Table 4: Positions of profiles with regard to the spike E4

Positions	Western of the spike E4					Eastern of the spike E4				
Profile	1	2	3	4	5	6	7	8	9	10
Distances with regard to the spike (m)	400	300	200	100	10	10	100	200	300	400

Ten (10) other collections are carried out on the low – foreshore on each side of the spike E4 located near PK37.5 (Table 4 and Fig. 4) of following characteristics:

- Glassy coastline: -0.01 m
- Length: 70 m

The collected sands are dried in a proofer at a temperature of 105°C for 20 h (NF EN 933-1, 1997). The dried samples are subject to a test of sifting on the stitch sieves 0.08 mm - 0.125 mm - 0.25 mm - 0.5 mm - 1 mm - 2 mm - 4 mm et 5 mm (NF EN 933-2, 1996).

And then, the granular parameters are determined: size distribution, the coefficients of Hazen and uniformity and the granular class

Results

Longitudinal Differential Distribution

The Fig. 5 and 6 show the longitudinal grain-size distributions of sand all along the Togolese littoral and on each side of the spike E4. The differential distributions are the average of the samples of the 6 points of collection by profile.

From the curves on Fig. 5 and 6 it is apparent that:

- The sea sand contains practically no grains under 0.125 mm and over 4 mm (proportions under 1%) (Fig. 5)
- The grains of 0.5 mm, 1 mm, 2 mm et 4 mm are generally of growing proportions of PK0 (profile 1) at PK 50 (profile 35). However, the grains of 0.125 et 0,25 mm present an average differential distribution q_{rm} decreasing (Fig. 5)

The equations from the smooth curves that illustrate these behaviours are given by:

$$q_{r<0.08}(x) = 0.0015x + 0.0035 \quad (6a)$$

$$q_{r0.08}(x) = 0.0052x + 0.1424 \quad (6b)$$

$$q_{r0.125}(x) = -0.1031x + 7.3247 \quad (6c)$$

$$q_{r0.25}(x) = -0.1064x + 43.502 \quad (6d)$$

$$q_{r0.5}(x) = 0.0851x + 37.004 \quad (6e)$$

$$q_{r1}(x) = 0.0702x + 9.9796 \quad (6f)$$

$$q_{r2}(x) = 0.039x + 1.806 \quad (6g)$$

$$q_{r4}(x) = 0.0099x + 0.2478 \quad (6h)$$

$$q_{r5}(x) = 0.001x + 0.0023 \quad (6i)$$

DOI: 10.3844/ajassp.2018.399.408

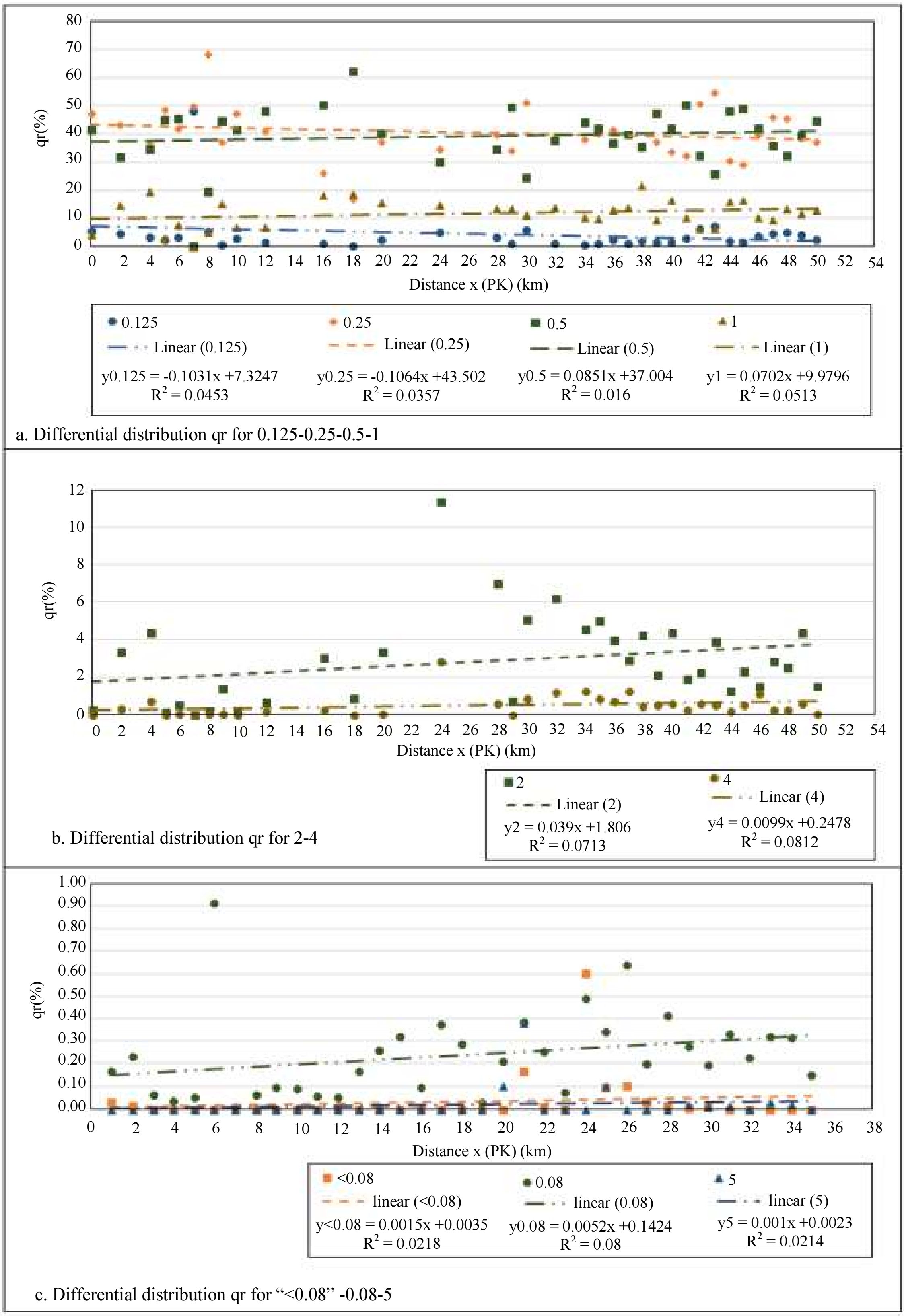


Fig. 5: Differential distributions of the particle size according to the profiles

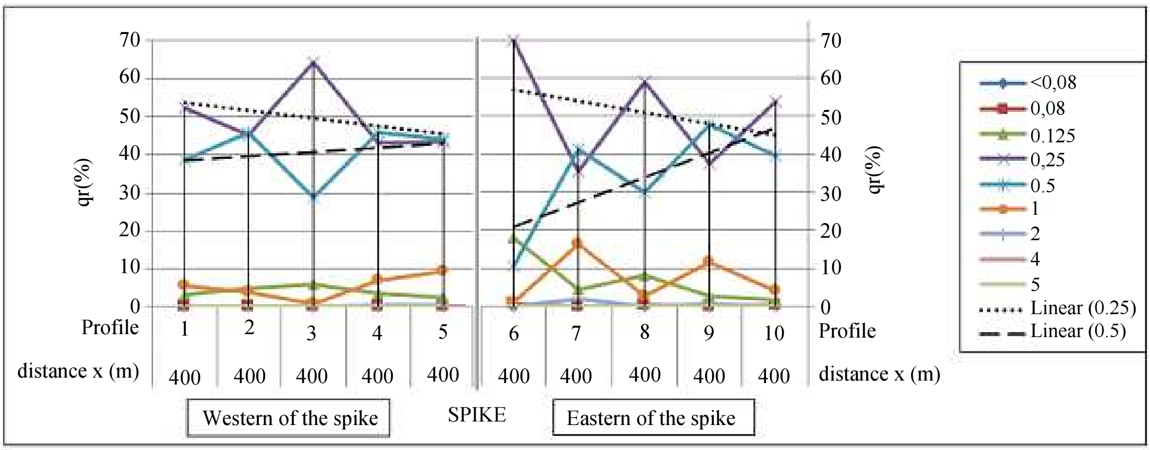


Fig. 6: Differential distributions of the grain size on each side of the spike E4

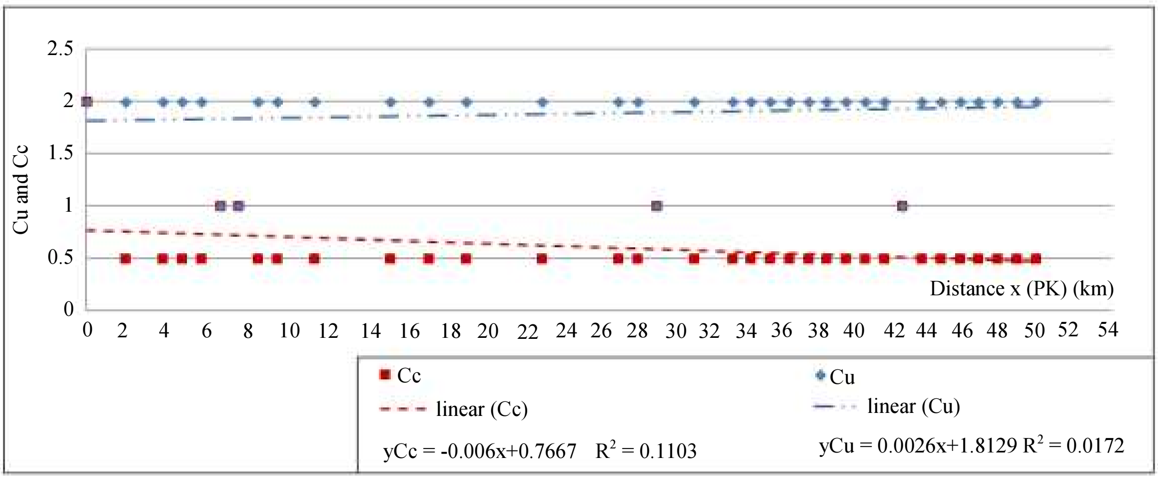


Fig. 7: Development of coefficients of uniformity (Cu) and of bending (Cc) according to profiles

In these equations q_{ri} shows the differential distribution at sieve *i* and *x* the distance in *km* with regard to the point of reference called *PK0* at the border Togo-Ghana:

- From Fig. 6 it is apparent that around the spike E4, whereas the sediments get rich in grains of 0.5 mm (growth of curves trends) following the direction of littoral drifting, those of 0.25 mm are getting poor in the sediments (decrease of trend curves). In the immediate vicinity of the spike E4, the grains of 0.5 mm are more important in the accretion zone than in the erosion zone. The reverse phenomenon happens for the grains of 0.25 mm

Classification of Sediments

The different coefficients of uniformity and bendings of 35 profiles are given by Fig. 7 whereas those of each side of the spike E4 are given by Fig. 8. From this it is apparent that:

- The coefficients of uniformity (C_u) are all equal to 2 except for KP7 (profile 6), PK8 (Profile 7), PK30 (profile 17) et PK43 (profile 28) that have a C_u equal to 1. Generally, this coefficient is increasing of PK 0 (profile 1) at KP50 (profile 35). As for coefficients of bending (C_c), they are included between 0.5 and 1. It presents an decreasing trend all along the littoral

  This behaviour of coefficients can be illustrated by the smooth curves the equations of which are given by:

$$C_c(x) = -0.006x + 0.7667 \tag{7a}$$

$$C_u(x) = 0.0026x + 1.8129 \tag{7b}$$

with:

C_c and C_u = Respectively the coefficients of bending and uniformity.
x = Given as previously.

- On each side of the spike E4, the coefficient of uniformity is constant; as for the coefficient of bending, it is constant in the accretion zone, decreasing in the erosion zone

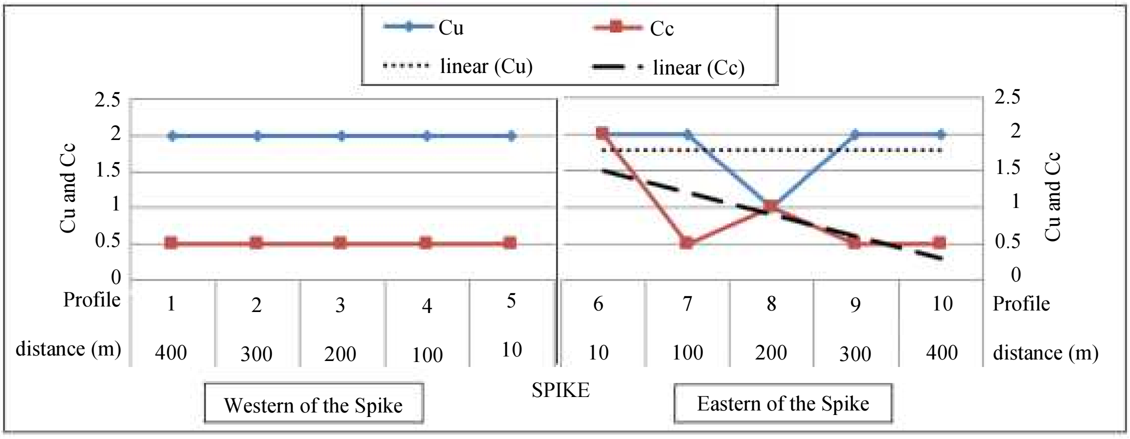


Fig. 8: Development of coefficients of uniformity (Cu) and of bending (Cc) on each side of the spike E4

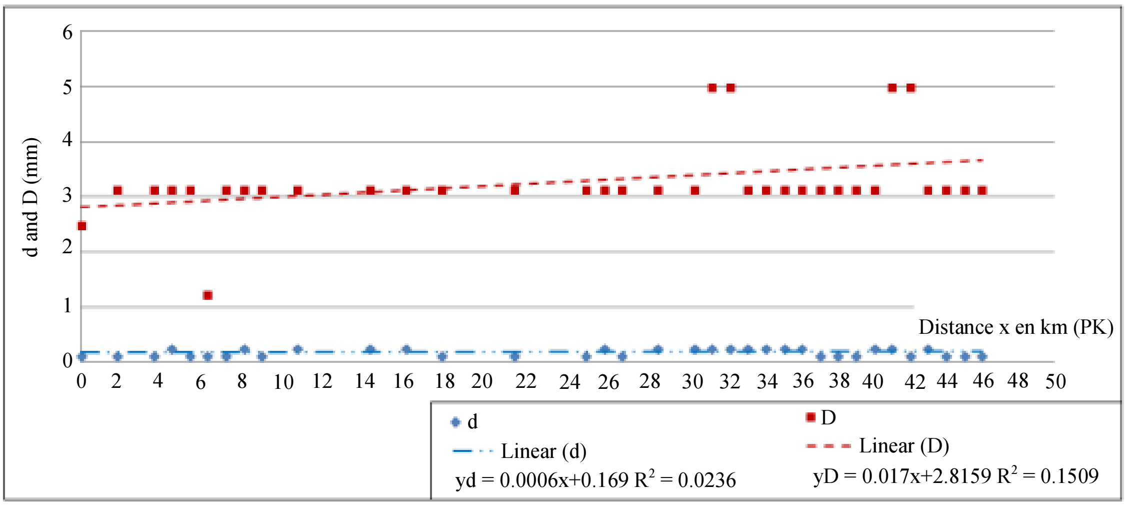


Fig. 9: Longitudinal distribution of d and D

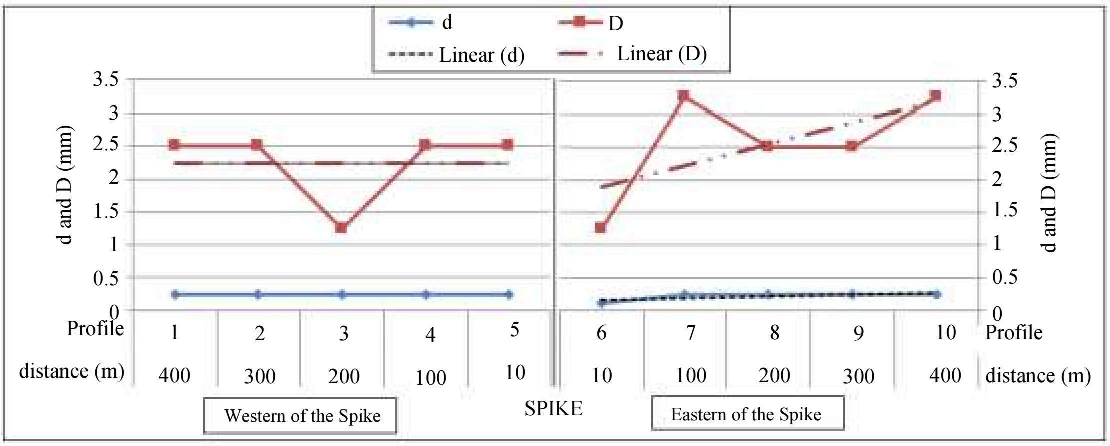


Fig. 10: Distribution of d and D on each side of the spike E4

Longitudinal Distribution of Granular Class

Based on the system of Equation 5, the granular class of sediments by profile are calculated. Figure 9 and 10 provide the curves expressing the values d and D according to profiles. The curves of Fig. 9 and 10 show that:

- The smallest grain (d) is practically constant all along the profiles (0.125 mm < d < 0.2 mm). As for the biggest grain (D), it is constant (D = 3.15 mm) on all the profiles except for PK0 (profile 1) (D = 2.5 mm), at PK7 (profile 6) (D = 1.25 mm) and at PK 35, 36, 45 et 46 (profiles 20, 21, 30 et 31) for which D is 5 mm. But, in general it is increasing all along the littoral
  This behaviour can be illustrated par the following smooth curves:
  The smooth curves that illustrate this behaviour are given by the following equations:

$$d(x) = 0.0006x + 0.169 \quad (7a)$$

$$D(x) = 0.017x + 2.8159 \quad (7b)$$

  with
  d and D respectively the smallest and the biggest grains of sand
  x is given as previously.

- The smallest grain (d) is practically constant on each side of the spike. Whereas in the accretion zone the biggest grain (D) is constant, in the erosion zone, it is getting bigger and bigger as one is moving away from the spike

Discussion

It emerges from this study that sediments from the littoral are made up of grains that are getting bigger and bigger in the accretion zones (western of the spike) and erosion zone (eastern of the spike) in the direction of the littoral drifting. These sediments are less and less tight, badly graduated and more opened in the direction of the littoral drift. These observations are valid on the entire littoral for which the size of sediments increases in the direction of their transportation and gets richer in big particles of 0.5 mm, 1 mm, 2 mm and 4 mm, with a more open size that is more and more badly graduated. In the immediate vicinity of the spike the grains are bigger in the accretion zone than in the erosion zone. This behavior of sediments is consistent with the results based on the study on the transversal development of differential distributions, the granular class (Amey, 2005) and the longitudinal distribution of medium-sized grains, sorting index and skweness (Amey, 2007) of Togolese littoral's sediments.

This highly tight grain size, which becomes less and less tight following the direction of the littoral drift and enriched in bigger particles, can be explained by the presence of natural works on the littoral that modifies the hydrodynamic behavour (Blivi, 1993) of sediments' particles.

In fact, the accretion zones of works receive waves with all their energy (important speediness) that carry sediments' elements. Which enables the rejection of big grains on the foreshore by transport. In the erosion zones, waves collide with the spike E4, lose their energies. The close downstream of the spike is then a water zone that is practically stagnant (Fig. 11). The biggest particles of the grains in this zone can no longer be transported by the low-energy waves. These particles settle then in the immerged beach. By going away from the work in the erosion zone, the low-energy waves carry the fine sand in suspension and medium sand by transport up to foreshore.

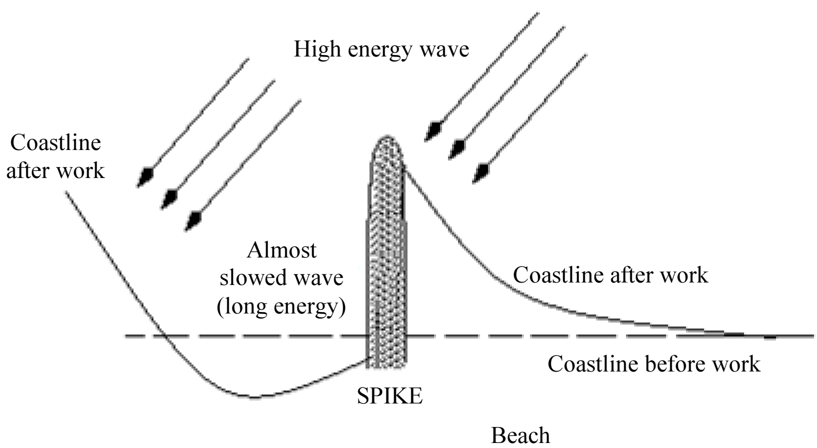


Fig. 11: Principle of sedimentary additions by waves at the level of spike E4

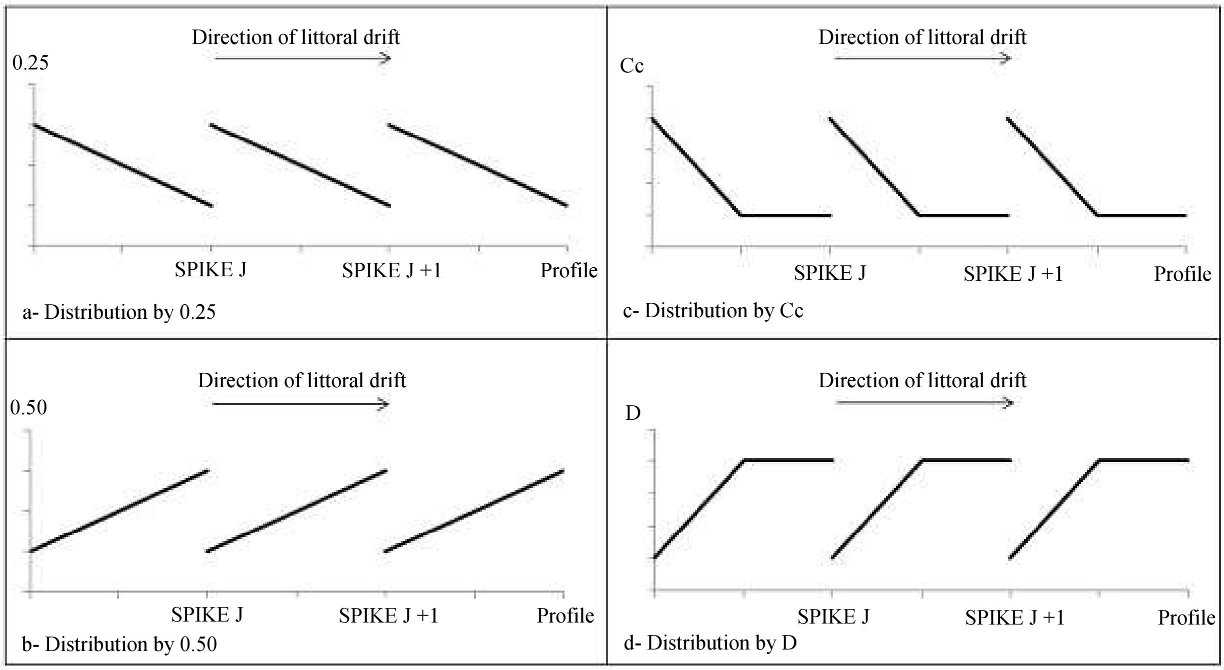


Fig. 12: Principle of distribution of sizes for a succession of the spike

The distribution of sediments 0.25 and 0.5 mm, of coefficients of Hazen and of bending, of the granular class for a succession of spikes can then be illustrated by Fig. 12.

Conclusion

From 210 samples collected all along the Togolese littoral and 10 on each side of the spike that are subjected to size analysis, it emerges that sediments of Togolese littoral are in general getting bigger and bigger in the direction of their transport from west to east (border Togo-Ghana and Togo-Benin). The spikes cause the creation of zones in erosion with fine sediments and of zones in accretion with big sediments. The sediments are sands of category "f_3" with highly tight grain size, badly graduated (Sm), that get increasingly rich in big grains and become more open and badly graduated in the direction of the littoral drift. The natural or artificial works along the Togolese littoral (Lomé harbor, Kpémé wharf, spikes and beach-rock) make it possible to get the following categories of sands on the Togolese littoral:

- Fine sands in the accretion zones far from works and in the erosion zones in the immediate vicinity of the work
- Medium-sized sands close to the works in the accretion zones and erosion zones
- Big-grain sands very close to the works in the accretion zones and far from the works in the erosion zones

As concrete materials, sands from Togolese littoral provide a huge granular potential:

- Medium-sized sands (0.25 and 0.5 mm) and big-grain sands (over 1 mm) are more appropriate for the construction of concretes the resistance of which is highly wanted and can be obtained from PK0 to PK50 except for PK7 and the accretion zones
- As for fine sands (0.125 and 0.25 mm) they can be obtained in PK7 and in the erosion zones. They are wanted for coating works and for concrete the cladding aspect of which is very asked
- Because of its tight feature, the sand from Togolese littoral becomes a granulate providing a concrete that is less compact porous with a risk of segregation

Acknowledgement

This work could be done without formal logistic and financial support from FORMATEC we express our sincere gratitude to.

Funding Information

FORMATEC financed the research of materials and consumables necessary for the various tests.

Author's Contributions

Amey Kossi Bollanigni: Preparation of study samples, study realization, results processing and manuscript writing.

DOI: 10.3844/ajassp.2018.399.408

Neglo Koumah: Project manager, conceptual contributions on the research.

Ethics

There are no ethical worries or concerns regarding this paper.

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