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River Sands Used in South Togo Physical Characterization

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ABSTRACT

This study aims to characterize river sands used in construction in the regions of southern Togo in order to know their properties and possible uses. Sand samples are taken and subjected to identification tests such as particle size analysis, apparent and absolute densities, the equivalent of sand. The river sands of southern Togo are mostly suitable for making concrete because they are fairly clean and medium. They have a tight particle size and are generally poorly graded. The fine sands identified can be used for masonry. The sands studied can be used for the filtration of wastewater. Use as a filtering material for drinking water requires sieving and calibration.

Keywords: river sand, filtration material, concrete, masonry.

INTRODUCTION

Sand is a natural element coming from quartz and flint and consists of fairly fine grains, with dimensions varying between 1 and 6.3 mm. [1] Its name varies according to its size (fine sand, coarse sand and gravelly sand). It can be natural (river sand, quarry sand, sea sand and leaf sand) or artificial (sand for crushing slag blocks in blast furnaces). Sand and gravel are essential materials for the construction of public works and buildings and must meet criteria to ensure the quality of the work. Sand is also essential in wastewater or drinking water treatment plants where it serves as a filtration material.

In Togo, since the ban on the use of sea sand in 2011, the use of quarry sands and river sands in the construction of structures has increased. It is question in this study of listing rivers sand quarries in the regions of southern Togo in order to know if these sands are suitable for construction without any risk or usable as a filtration material. For this, a mapping of these sands is established followed by their physical characterization by carrying out identification tests on samples of these sands. Finally, the potential for using these sands during construction or for water filtration are analysed.

MATERIALS & METHODS

This study concerns the characterization of rivers sands in "Maritime" and the "Plateaux" regions of southern Togo. Togo is a country in West Africa divided into five administrative regions: "Maritime" region, the "Plateaux" region, "Centrale" region, the "Kara" region and the "Savanes" region.

A total of 45 river sands sampling sites (18 in "Maritime" region and 27 in the "Plateaux" region) have been identified in these regions as shown in Table 1 and Figure 1.These sites are the main sampling points for sandy materials used for construction by the populations.

Table 1: Sampling sites

Region	Sampling sites	Latitude (°North)	Longitude (°East)
"Maritime" region	Gati Agodou	6.499083	1.321000
	Gapé Kpodji	6.674567	0.969550
	Dalavé	6.385883	1.243083
	Adétikopé	6.322850	1.217217
	Aveta	6.272717	1.288467
	Agbétiko	6.496917	1.711033
	Tovégan	6.568600	0.897583
	Badja	6.375183	0.986200
	Agbadjanaké	6.482767	0.827000
	Agbéti kopé	6.242917	1.093483
	Togblé	6.517250	1.336983
	Sedome	6.764917	1.574267
	Tabligbo	6.583300	1.500000
	Aneho	6.227980	1.591900
	Tsévié	6.420000	1.210000
	Adakpamé	6.167780	1.286940
	Zébé	6.250000	1.616670
	Bé	6.137200	1.212000
The "Plateaux" region	Kavé	7.545600	1.482500
	Amakopé	7.340433	1.118867
	Ahassomé	7.238150	1.504000
	Toko	7.116233	0.834883
	Wahala	7.175133	1.165317
	Amakpapé	6.779383	1.179783
	Djékloe	6.891050	1.233750
	Siyime	6.973100	1.470200
	Konta	8.406767	1.613550
	Sassanou	7.277950	0.656933
	Akaba gare	7.940450	1.049850
	Akata	7.083330	0.716667
	Anie	7.760633	1.193133
	Hiheatro	7.538067	1.106583
	Azafi	7.571050	1.038333
	Bassa kopé	7.246100	1.004300
	Avédjé	7.463450	1.135517
	Notse	6.950000	1.166670
	Tohoun	7.033330	1.616670
	Haho	6.958650	1.172467
	Kpalimé	6.900000	0.633333
	Agbonou	7.516670	1.150000
	Amoutchou	7.533300	1.083300
	Badou	7.583330	0.600000
	Elavagnon	8.000000	1.300000
	Adjassiwoewoe	7.722534	1.099750
	Amlamé	7.466670	0.900000

Table 2: Uniformitycoefficient interpretation [6-7]

Appreciation	Intervals
very tightly grained material	$Cu < 2$
tight-grained material	$2 \leq Cu < 5$
semi-tight grain material	$5 \leq Cu < 20$
spread grain material	$20 \leq Cu < 200$
very wide grain size material	$Cu \geq 200$

Table 3: Sand graduation appreciation [6-7]

Appreciation	Intervals
well graded sand (SW)	$Cu > 6$ et $1 < Cc < 3$
poorly graded sand (SP)	$Cu \leq 6$ ou $Cc \leq 1$ ou $Cc \geq 3$

Table 4: Sand equivalent appreciation [1]

Sand Equivalent (SE)	Nature of sand	Sand appreciation
SE<30	Purely clay sand	To be rejected for making concrete.
30<SE<60	Clay sand	Risk of shrinking or swelling. To be rejected for quality concrete.
60<SE<70	Slightly clay sand	Permissible property for standard quality concrete when there is no particular fear of shrinkage.
70<SE<80	Clean sand	Low percentage of fine clay. Suitable for high quality concrete.
SE>80	Very clean sand	Almost total absence of fine clay. Risk of causing a plasticity defect.

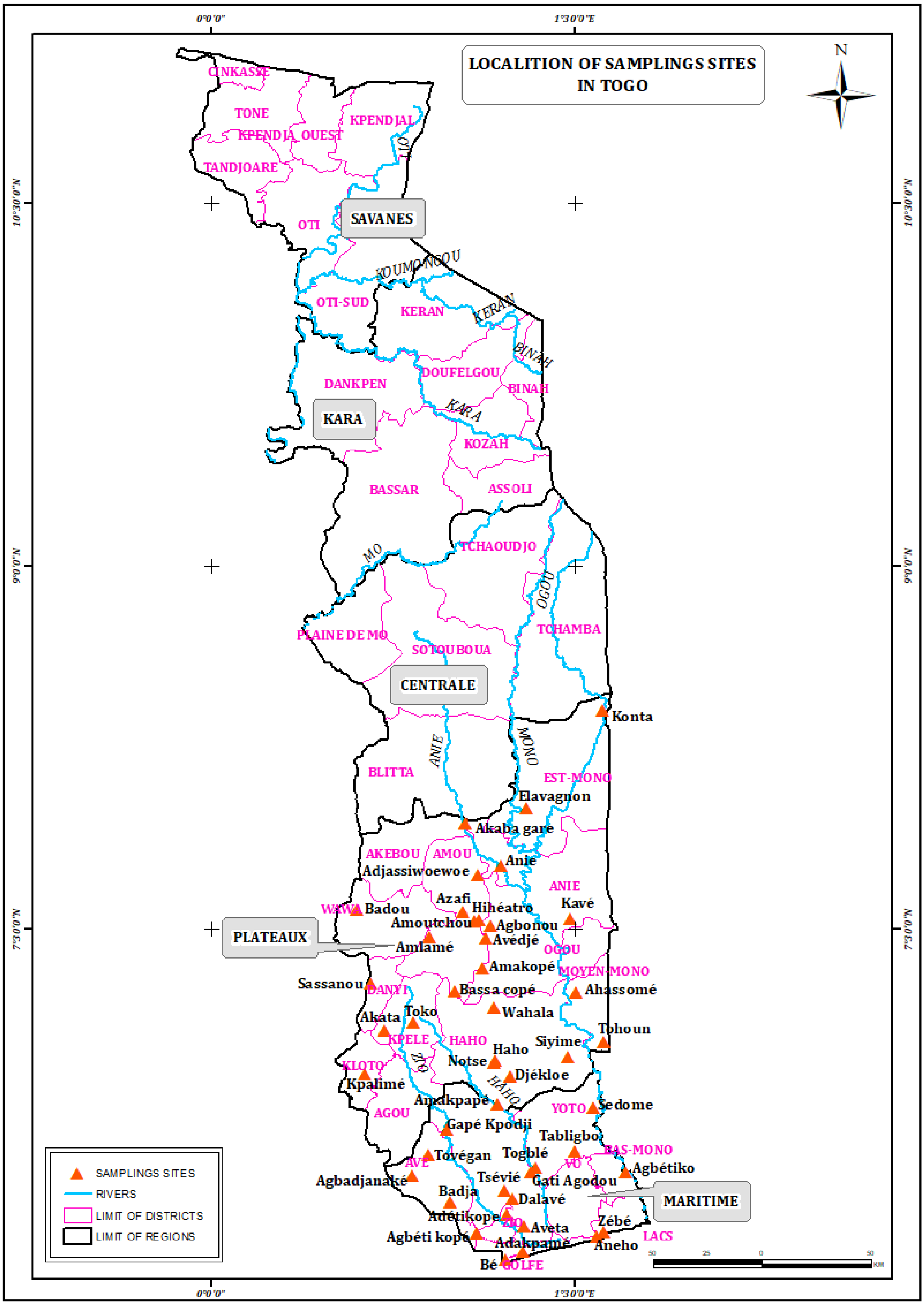

Figure 1: Sampling sites location on Togo map

The sand samples taken on these sites are subjected to the following tests:

- measurement of apparent density in accordance with standard NF EN 1097-3; [2]
- sand equivalent test according to standard NF EN 933-8 + A1; [3]
- measurement of absolute density in accordance with standard NF EN 1097-6; [4]

- grain size analysis according to standard NF EN ISO 17892-4. [5]

To assess the grain size of these sands, the following parameters are determined:
- minimum and maximum sand diameters;
- grains effective diameter which is the diameter leaving 10% of the grains to pass;
- passers-by in the 80 µm sieve;
- fineness module; [1, 6-7]
- curvature coefficient (Cc) and uniformity coefficient (Cu) given by: [6-7]

$$c_c = \frac{(d_{30})^2}{d_{10} \times d_{60}} \quad (1)$$

$$c_u = \frac{d_{60}}{d_{10}} \quad (2)$$

where d_{10}, d_{30} and d_{60} are the diameters leaving respectively 10%, 30% and 60% of the grains to pass.

The parameters and characteristics determined make it possible to assess the quality and to conclude on the possible use of these sands as construction materials based on Tables 2 to 5.

Table 5: Fineness modulus appreciation [1]

Use in concrete	Nature of sand	fineness modulus	Observations
Unauthorized sands	Sand too fine	<1.8	
Eligible sands	Sand a little too fine	1.8 to 2.2	Sands usable if one seeks in particular the ease of implementation to the probable detriment of resistance
	Medium sand (preferential)	2.2 to 2.8	Sands which are well suited to obtain satisfactory workability and good resistance with limited risks of segregation
	Sand a little too coarse	2.8 to 3.2	Sands that can be used to find high strengths, but poor workability and risk of segregation
Unauthorized sands	Sand too coarse	> 3.2	

The assessment of the use of sand as a filtration material is made mainly based on the effective diameter (Table 6), the uniformity coefficient and the apparent density.

Table 6: Sand use for a type of filtration according to effective diameter [8]

Type of filtration	Intervals of effective diameter d_{10}
Slow filtration and very fast filtration under pressure (25 m/h or even 50 m/h) of swimming pools, lightly loaded water, coagulation on filter	d_{10} between 0.1 mm and 0.5 mm
Filtration without prior settling with or without coagulation on filter: speed of 7 m/h (lightly charged water)	d_{10} between 0.6 mm and 0.8 mm
Direct filtration of lightly loaded raw water, floor filter washable with water and air, speed from 15 m/h to 20 m/h	d_{10} between 0.9 mm and 1.35 mm
Roughing of industrial water, pre-filtration before slow filtration	d_{10} between 1.35 mm and 2.5 mm
Use as a support or roughing layer	d_{10} between 3 mm and 25 mm

The uniformity coefficient of filter sands for use relating to the production of drinking water must have a maximum value must be between 1.5 and 1.8. [9-10] For wastewater treatment, this limit is between 3 and 6. [11]

The apparent density of filter sands should generally be between 1.4 and 1.7 and the absolute density between 2.5 and 2.8. [9]

RESULTS AND DISCUSSION

The characteristics and parameters of identification of the sand samples studied are presented in Table 7. Table 8 presents the assessment of each sand for use as a building or filtration material.

Table 7: Characteristics of river sands of "Maritime" and the "Plateaux" regions

Region	Sampling sites	Passant à 80 µm	d10	dmin	dmax	Cu	Cc	MF	Dap	dabs	ES
"Maritime" region	Gati Agodou	0.5	0.14	0.08	6.3	2.86	0.94	1.62	1.57	2.59	78
	Gapé Kpodji	0	0.09	0.16	6.3	5	0.89	1.61	1.48	2.6	70
	Dalavé	28.26	0.11	0.16	5	3.73	0.89	1.56	1.50	2.63	78
	Adétikopé	2.27	0.17	0.63	12.5	2.35	0.99	1.65	1.50	2.64	82
	Aveta	1	0.14	0.08	2.5	2.79	0.89	1.50	1.43	2.72	81
	Agbétiko	1.2	0.2	0.08	5	2.95	0.87	2.22	1.37	2.63	82
	Tovégan 2	40	0.14	0.16	6.3	3.79	1.13	1.89	1.47	2.63	71
	Badja	80	0.9	0.16	6.3	0.66	0.15	1.96	1.50	2.63	56
	Agbadjanaké	20	0.2	0.16	5	3	1.2	2.22	1.41	2.63	69
	Agbéti kopé	10	0.21	0.16	5	2.81	1.1	2.38	1.52	2.64	83
	Togblé	20	0.14	0.16	5	3.71	0.86	1.91	1.46	2.62	80
	Sedome	0.7	0.32	0.08	6.3	2.31	0.86	2.59	1.50	2.67	91
	Tabligbo	0	0.36	0.16	8	2.5	1.07	2.98	1.48	2.64	80
	Aneho	0.7	0.2	0.08	10	2.95	1.1	2.12	1.44	2.67	68
	Tsévié	0.2	0.31	0.08	12.5	2.9	0.93	2.71	1.47	2.65	94
	Adakpamé	6.6	0.16	0.16	5	2.38	0.98	1.77	1.47	2.65	69
	Zébé	0	0.18	0.16	5	3.5	1.14	2.22	1.50	2.64	83
	Bé	15	0.13	0.14	6	2.68	0.94	1.56	1.47	2.61	62
The "Plateaux" region	Kavé	3.06	0.17	0.08	16	3.59	0.756	2.25	1.65	2.68	68
	Amakopé	0	0.29	0.16	5	2.45	0.9	2.46	1.44	2.64	85
	Ahassomé	10	0.23	0.16	5	3.43	1.07	2.54	1.48	2.64	80
	Toko	6	0.14	0.08	5	2.64	0.93	1.49	1.36	2.62	65
	Wahala	0	0.33	0.16	8	3.3	0.9	3.02	1.47	2.68	70
	Amakpapé	2.54	0.2	0.08	12.5	3.95	1.12	2.52	1.45	2.60	75
	Djékloe	1.4	0.19	0.08	10	3.84	1.04	2.46	1.46	2.61	74
	Siyime	0.5	0.2	0.08	10	3	1.08	2.27	1.50	2.63	89
	Konta	10	0.34	0.16	5	4.41	0.83	2.70	1.48	2.65	85
	Sassanou	3	0.11	0.16	5	3.55	0.84	1.62	1.38	2.63	53
	Akaba gare	0	0.18	0.16	5	2.72	1.02	2.06	1.42	2.64	83
	Akata	50	0.17	0.16	5	7.35	1.27	2.85	1.58	2.60	56
	Anie	3.45	0.25	0.16	8	2.72	1.23	1.95	1.42	2.64	88
	Hiheatro	31.8	0.12	0.16	5	3.92	1.2	1.78	1.42	2.63	61
	Azafi	0	0.18	0.16	5	2.78	0.81	2.12	1.44	2.64	50
	Bassa kopé	0.5	0.24	0.08	10	2.5	1.06	2.47	1.43	2.62	85
	Avédjé	1.8	0.13	0.08	12.5	3.69	0.85	1.79	1.59	2.62	81
	Notse	10	0.32	0.16	8	2.63	0.82	2.64	1.46	2.64	71
	Tohoun	10	0.24	0.16	8	2.21	1.14	2.16	1.44	2.64	83
	Haho	0	0.23	0.16	12.5	2.61	1.05	2.4	1.49	2.66	85
	Kpalimé	50	0.18	0.16	5	6.94	1.16	2.85	1.58	2.60	56
	Agbonou	6.07	0.15	0.16	5	2.67	0.88	1.77	1.44	2.64	83
	Amoutchou	0.4	0.17	0.08	12.5	2.18	0.64	1.92	1.64	2.72	71
	Badou	0.8	0.27	0.08	5	5.56	0.59	3.06	1.76	2.64	92
	Elavagnon	10	0.21	0.16	5	2.81	1.05	2.27	1.48	2.66	86
	Adjassiwoewoe	0.74	0.32	0.063	16	3.44	0.71	3.093	1.59	2.67	76
	Amlamé	0.6	0.3	0.08	20	2.03	0.92	2.84	1.43	2.58	91

d_{10}: effective diameter; dmin: minimum diameter; dmax: maximum diameter; Cu: uniformity coefficient; Cc: curvature coefficient; dap: apparent density; dabs: absolute density; FM: fineness modulus; SE: sand equivalent

Table 8: Assessment of studied river sands quality

Region	Sampling sites	Sand equivalent	Finesse modulus	Uniformity coefficient	Graduation	Effective diameter
"Maritime" region	Gati Agodou	CS	STF	TG	SP	SF
	Gapé Kpodji	CS	STF	STG	SP	SF
	Dalavé	CS	STF	TG	SP	SF
	Adétikopé	VCS	STF	TG	SP	SF
	Aveta	VCS	STF	TG	SP	SF
	Agbétiko	VCS	MS	TG	SP	SF
	Tovégan	CS	SLTF	TG	SP	SF
	Badja	SC	SLTF	VTG	SP	DF
	Agbadjanaké	SCS	MS	TG	SP	SF
	Agbéti kopé	VCS	MS	TG	SP	SF
	Togblé	VCS	SLTF	TG	SP	SF
	Sedome	VCS	MS	TG	SP	SF
	Tabligbo	CS	SLTC	TG	SP	SF
	Aneho	SCS	SLTF	TG	SP	SF
	Tsévié	VCS	MS	TG	SP	SF
	Adakpamé	SCS	STF	TG	SP	SF
	Zébé	VCS	MS	TG	SP	SF
	Bé	SCS	STF	TG	SP	SF

The "Plateaux" region	Kavé	SCS	MS	TG	SP	SF
	Amakopé	VCS	MS	TG	SP	SF
	Ahassomé	CS	MS	TG	SP	SF
	Toko	SCS	STF	TG	SP	SF
	Wahala	CS	SLTC	TG	SP	SF
	Amakpapé	CS	MS	TG	SP	SF
	Djékloe	CS	MS	TG	SP	SF
	Siyime	VCS	MS	TG	SP	SF
	Konta	VCS	MS	TG	SP	SF
	Sassanou	SC	STF	TG	SP	SF
	Akaba gare	VCS	SLTF	TG	SP	SF
	Akata	SC	SLTC	STG	SW	SF
	Anie	VCS	SLTF	TG	SP	SF
	Hiheatro	SCS	STF	TG	SP	SF
	Azafi	SC	SLTF	TG	SP	SF
	Bassa kopé	VCS	MS	TG	SP	SF
	Avédjé	VCS	STF	TG	SP	SF
	Notse	CS	MS	TG	SP	SF
	Tohoun	VCS	SLTF	TG	SP	SF
	Haho	VCS	MS	TG	SP	SF
	Kpalimé	SC	SLTC	STG	SW	SF
	Agbonou	VCS	STF	TG	SP	SF
	Amoutchou	CS	SLTF	TG	SP	SF
	Badou	VCS	SLTC	STG	SP	SF
	Elavagnon	VCS	MS	TG	SP	SF
	Adjassiwoewoe	CS	SLTC	TG	SP	SF
	Amlamé	VCS	SLTC	TG	SP	SF

VCS : very clean sand; CS: clean sand; SCS: slightly clay sand; SC: clay sand ; STF : sand too fine ; SLF : sand a little too fine; MS : medium sand; SLC : sand a little too coarse; STC: sand too coarse; TG : tight-grained material; STG : semi-tight grain material; VTG: very tightly grained material; SW: well graded sand; SP : poor graded sand; SF: slow filtration and very fast filtration under pressure of swimming pools, lightly loaded water, coagulation on filter; DF: direct filtration of lightly loaded raw water, floor filter washable with water and air

Table 8 shows that the sands of "Maritime" region are poorly graded and can be used for slow or very rapid filtration under pressure of swimming pools, lightly charged waters, or for coagulation on a filter except the Badja sand. 61.11% of these sands are admissible for making concrete with regard to the fineness modulus with risks of segregation for some (Tabligbo sand) and loss of strength for others (22.22%). Apart from Badja sand, all the sands of "Maritime" region can make quality concrete with regard to their cleanliness with risks of shrinkage for some (22.22%) and lack of plasticity for others (44, 44%). 38.89% of the sands in this region are too fine and clean enough to be used as a mortar, but must be mixed with other coarse sands before use in the manufacture of concrete. These sands have a predominantly tight particle size (88.89%). For use as a filtration unit for drinking water, a correction of the grain size is necessary in order to reduce the uniformity coefficients which are high compared to the standard. The apparent and absolute densities are suitable for use as filter sand.

The sands studied in the "Plateaux" region are poorly graded except Kpalimé and Akata sands which are well graduated. Regarding their effective diameter, they can all be used for slow or very rapid filtration under pressure of swimming pools, lightly charged water, or for coagulation on a filter. The use of these sands as a wastewater filtration material is possible except for Kpalimé and Akata sands which have a uniformity coefficient greater than 6. However, a use for the filtration of drinking water will only be possible after sieving and sizing these sands since their uniformity coefficient is greater than 1.8. 81.48% of the sands studied in the "Plateaux" region are eligible for making concrete with the risk of lack of workability for 22.22% of these sands and falling resistance for 18.51% of them. 18.52% of these sands are too fine but clean and can be used as masonry mortar but must be mixed with other sands before serving as concrete sand. 14.81% of the sands in this region cannot be used to make quality concrete because they are clayey (sand equivalent less than 60). The remaining 85.19% can be used in the manufacture of quality concrete with risk of shrinkage for 11.11% of these sands and plasticity defect for 48.15%. The sands of the "Plateaux" region are tightly grained (88.89%) or semi-tight.

CONCLUSION

This study initially made it possible to establish the map of river sands sampling points in "Maritime" and the "Plateaux" regions of southern Togo. Then, from the tests carried out on the samples of these sands, the possibilities of use are defined. The sands studied are of tight grain size and can be used as a wastewater filtration material. Their use for the filtration of drinking water can only be envisaged after sieving and calibration. The sands studied are mostly admissible for making concrete because they are at least clean and have a finesses modulus between 1.8 and 3.2. The minority made up of fine sands can be used for masonry.

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