CONTRIBUTION TO THE PHYSICAL AND MECHANICAL CHARACTERIZATION OF TILES IN MICRO-CONCRETE MADE LOCALLY WITH THE GUM ARABIC.

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ABSTRACT
The main objective of the present study is the validation of the use of a binder vegetable (gum Arabic) as matrix in the elaboration of the building materials of the semi-structural or structural components in the field of the cover of the works. It makes the synthesis of a set of results obtained on this binder and the structural elements made with this binder. Scientific and technical reference information of practical use will be put in the measure of the tile makers and the inhabitants of the dry and hot zones of the Sahel and Sahara for the production of quality tiles. We want to help these inhabitants to cover easily and at a lower cost their works.

The interest of this study lives in the possibility of realizing through various experimental methods or digital simulation of the appropriate and relatively simple physical and mechanical tries on the semi-structural components (tiles) to know their behavior.

KEYWORDS: *binder vegetable, cover of the works, gum Arabic, matrix, quality tiles and semi-structural components.*

1. INTRODUCTION

The gum Arabic, also known under the name of gum Senegal (L.)Willd in substitution of the cement was used for the manufacturing of tiles in micro-concrete[1]. For that purpose, the natural properties (solubility in the water and the viscosity) [1] of this raw material and the experimental method of "trials and errors" served respectively for the determination of the mass optimal relationship of the water on the gum Arabic (E: G) and of the volume optimal relationship of the solution of the gum Arabic on the sand (G: S). Optimal mixtures as for them, were determined by the experimental method of the tries said by "development"("clarification") of three various types of mixtures [2]. With these relationships and optimal mixtures so determined, the experimental tries of physical control and control of mechanical resistances were made on the Romanic tiles of experiments of size 500x250x10 mm^3 [3]. A trial device of mechanical resistances was beforehand designed and validated.

The results of these tries show us that with regard to tiles in cement (TMV), tiles with the gum Arabic are beautiful and good resistant. For the mechanical resistances, the linear static analysis and the modal dynamic analysis by digital simulation on laptop computer confirm the experimental results in 10 % near. Besides, they assure good heat insulation and they are less heavy. What implies an economy on the skeleton of the cover. Their physical aspect raises no problem also. However, during their production, we notice that: tiles with the only gum Arabic are resistant and stable provided that we make a good drying of tiles for the sun or in a hairdryer and a high-temperature cooking in an oven local tunnel in approximately 1000°C. It raises the important problem of the energy consumption (generally some charcoal) and thus of the deforestation.

2. MATERIAL AND METHODS

2.1 MATERIAL

We present the characteristics of the various raw materials used for the preparation of mortars in micro-concrete.

2.1.1 Sands

Naming and nature: lagunaires sands of siliceous nature
Origin / site of extraction: lagoons of DEKOUNGBE (Benin)
Physical characteristics in 28°C :

PICTURE 1*: values of the physical characteristics of sands*

PHYSICAL CHARACTERISTICS	NORME	FORMULA	VALUES	UNITY
- Density of the water ρ_w	-	-	1.00	
- Absolute density ρ_a	NF EN 1097-6	$\rho_a = \rho_w \times M_4 / (M_4 - (M_2 - M_3))$	2.73	
- Real density ρ_{rd}		$\rho_{rd} = \rho_w \times M_4 / [M_1 - (M_2 - M_3)]$	2.69	T/m^3 or g/cm^3
- Density saturated surface dries ρ_{ssd}		$\rho_{ssd} = \rho_w \times M_1 / M_4 / [M_4 - (M_2 - M_3)]$	2.11	
- Coefficient of absorption of water WA	NF EN 1097-6	$WA=100 \times (M_1-M_4) / M_4$	0.6	% of the dry mass
- Flakiness Index en anglais FI (Coefficient d'aplatissement A)	NF EN 933-3	$FI=M_5 / M_6$	5	-

With:

- M_1: saturated Mass surfaces sandbank ; M_2: Mass of the pycnomètre + sample after 12 pm in a bath of water
- M_3: Mass of the pycnomètre filled only with water; M_4: constant Mass in the steam room after 12 pm in 105°C
- M_5: Masses of the aggregate of every class d_i / Di getting through the railing with crack corresponding to the class (D_i / 2).; M_6: the Somme of the masses of the elementary aggregates d_i / D_i.

Chemical characteristics: the chemical compounds of used sands are:

S_iO_2	T_iO_2	Al_2O_3	Fe_2O_3	C_aO	M_gO	$N_{a2}O$	K_2O	SO_3	S	Cl

To characterize sands which were of use to the manufacturing of tiles, we realized the following tries: the grading analysis by sieving and the tries of cleanliness of sands.

[1]Association of binder, sand and water.

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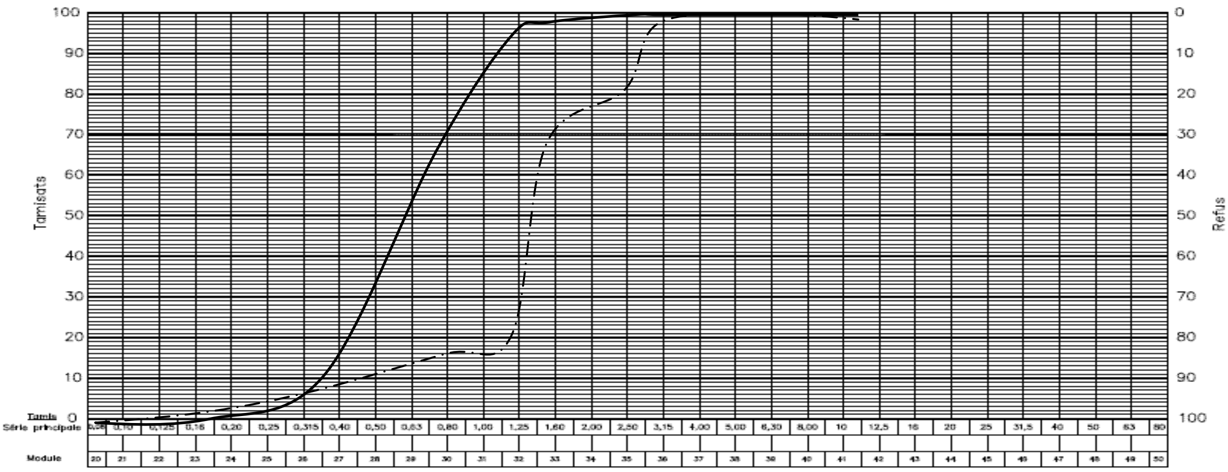
A) <u>The grading analysis by sieving</u>

Two sizes grading of sands are used in this work:

- A fine sand (0/2 mm): indicated by SF, tamisat obtained by sieving of the sand on the normalized sieve 2 mm in diameter of stitches (Module 34, AFNOR(FRENCH NATIONAL ORGANIZATION FOR STANDARDIZATION)).
- An unrefined sand (2/5 mm): indicated by SG corresponds to the tamisat on sieve 5 mm in diameter of stitches (Module 38, AFNOR) normalized and in the refusal on sieve 2 mm in diameter of stitches normalized after sieving.
- The average sand (0/5 mm): indicated by SM is a mixture of sands 0/2 and 2/5.

PICTURE 2: *results of the grading analysis of the fine and unrefined sand*

Date	22/03/2012			
Réf.	**SF001-** lagunaires sands of siliceous nature of DEKOUNGBE			
	Trial taking (g) =	1280		
N° Sieve AFNOR	**Mesh (mm)**	**reserved Weight (g)**	**Refusal (%)**	**Tamisat (%)**
40	8.00	0	0	100
38	5.00	0	0	100
35	2.50	0	0	100
34	2.00	0	0	100
32	1.25	12.37	0.98	99.02
31	1.00	57.04	4.52	95.48
29	0.63	430.34	34.10	65.90
26	0.315	1105.51	87.6	12.40
23	0.160	1238.65	98.15	1.85
20	0.08	1261.50	99.96	0.04
	TOTAL = 1261.50		100	
	Loss % = 1.45			
	ω% = 0.15		**C_u = 0.5**	
Date	24/03/2012			
Réf.	**SG001-** lagunaires sands of siliceous nature of DEKOUNGBE			
	Trial taking (g) =	1310		
N° Sieve AFNOR	**Mesh (mm)**	**reserved Weight (g)**	**Refusal (%)**	**Tamisat (%)**
40	8.00	0	0	100
38	5.00	0	0	100
35	2.50	23.31	1.80	98.2
34	2.00	227.92	17.60	82.40
32	1.25	405.72	31.33	68.67
31	1.00	1010.75	78.05	21.95
29	0.63	1085.21	83.80	16.20
26	0.315	1186.22	91.60	8.40
23	0.160	1250.71	96.58	3.42
20	0.08	1293.06	99.85	0.15
	TOTAL = 1293.06		100	
	Loss % = 1.29			
	ω% = 0.12		**C_u = 0.5**	



REPRESENT 1: *grading Curves of fine and unrefined sands*

The grading analysis by sieving is realized according to the NF standard P 18-560 (in September, 1990) which gives the distributions of grains presented in picture 1. They are illustrated by the grading curves of it represent1.

After treatment and analysis of the results of this try, it turn out that the coefficients of uniformity of these two sands are equal: $C_u = 0.5$.

Analysis and Interpretation of the results: it is the proof that every curve is uniform because $C_u < 2$. It means that in the classes 0/2 and 0/5 obtained after sieving, it not no irregularity of the distribution of the size of particles and consequently, with regard to the size grading, these sands are good for the manufacturing of tiles.

B) The equivalent of sand E_s

E_s or content in clay is realized according to the NF standard P 18-598 (in October, 1991). The results of the tries gave to us on average $E_S = 72.5\%$.

Analysis and Interpretation of the results: the sand is not thus rather clean because the standard requires one E_S minimum between 85 and 90 %. That is why we washed sands and obtained E_S one = 87.5 %.

C) The content in organic matters Mo

She must be realized according to the NF standard P 18-586. But, the simple test based on colors is enough for verifying the presence of the content in organic matters. Indeed, the color of the solution determining the content in organic matters is:

- ***Clearly in light yellow****: contains few organic matters: the sand suits from the point of view of the content in impurities;*
- ***Dark yellow****: contains organic matters: reduction from 10 to 20 % of the resistance of the final mixture;*
- ***Yellow red*****:** *sand to be rejected: reduction from 50 % to 80 % of the final resistance of the mixture.*

Analysis and Interpretation of the results: by the dark yellow color of the sand after stay of 24 hours (12 pm) in a solution to 3 % of soda NaOH or CaOH in some distilled water, the results indicate us that these sands contain organic matters. These can cause the reduction from 10 to 20 % of the resistance of the final mixture. It is thus necessary to wash sands to make leave these impurities.

2.1.2 Cement

Naming of the cement: SCB Lafarge classifies CPJ 35

Origin / site of extraction: ONIBOLO (Benin)

Physical characteristics:

- Density: 3.1 g / cm^3 or 3.1 T / m^3
- Specific Surface: 3200 cm^2 / g
- Median Diameter: 16 µm
- Packaging: 50 kg bags

Chemical characteristics:

PICTURE 3: *chemical Constituents of the cement CPJ 35*

Chemical constituent in %									Compound anhydrous of the clinker in %			
S_iO_2	Al_2O_3	Fe_2O_3	C_aO	M_gO	CO2	K_2O	SO_3	RI	C_2S	C_3S	C_3A	C_4AF
16.99	4.78	2.62	62.40	1.06	6.56	1.21	3.14	1.24	42.93	16.34	8.25	7.95

2.1.3 Gum arabic

Other naming: Gum Senegal (L). Willd.

Origin / site of extraction: Ati (Chad)

Description: in the form of powder of light yellow color

Physical properties:

- Solubility: in the water and Insoluble in the alcohol.
- Density: 1.35 T / m^3.
- Toxicity: can cause asthma attacks if it is inhaled.

Chemical properties: mass molar = 240 000.daltons

REPRESENT 2: *exuded of gum Arabic of a locust tree and a gum Arabic in the form of not ground crystals of rounded off shape. [Ref. Web-free].*

2.1.4 Water of mixing

Origin / choice of the water: water of the drinkable water distribution system ONEB of Benin. She is clean and exempt from any aggressive material towards mixtures. The quality of the water is tested according to the NF standard P 18-303.

Quantity: to obtain a statutory consistency of 26 cms, The mass dosage Water on Cement (E: C) is close to 0,5 and rarely exceed 0,65.

2.1.5 The mechanical Resistances. [4]

During the realization of every try of mechanical resistances (flexion, shocks and drive of the heel), comparators are placed in the neighborhood of the point of application of the load and below the tile. Comparators register the deflections of the tile.

A) Fold resistance 3 points

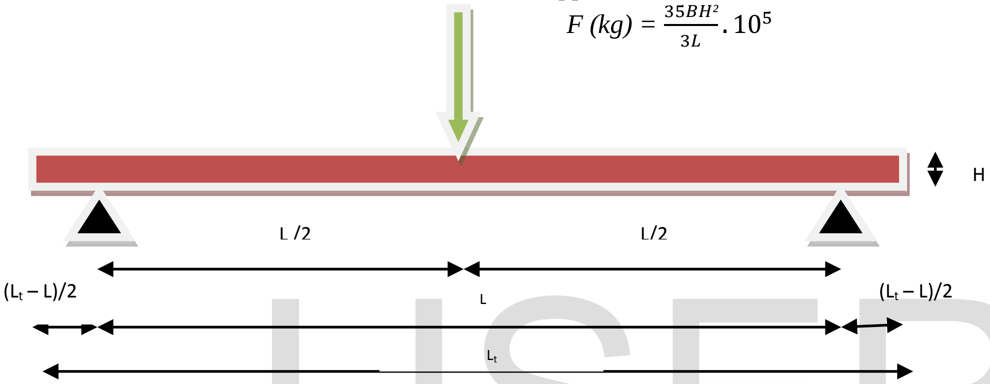
For the present analysis, we retain the configuration of flexion three points type1, the most binding of three types of configuration of flexion three points which exist [5]. It is about the configuration among which boards-supports and boards-loads are flat. The geometrical characteristics of the tile and the conditions in the limits are presented on the plan below.

- ***L*** : Distance between supports, is calculated from the formula:

$$L = \frac{7}{10} x L_t \quad (1)$$

- ***F*** **:** Normative minimal load applied in the middle of the tile. It is obtained from the formula :

$$F\ (kg) = \frac{35BH^2}{3L}.10^5 \quad (2)$$

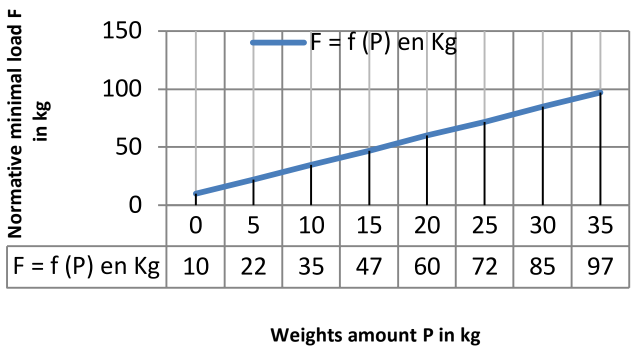


REPRESENT 3: *general configuration of the fold resistance three (3) typical points 1*

REPRESENT 4: *view of the trial device of fold resistance 3 points*

Determination of the equivalent weight P

- Calculation of the spacing of supports L. Relation (1)
- Calculation of the normative minimal load F. Picture (4) or Relation (2);
- We determine by linear interpolation the value of the equivalent weight P by means of the diagram (Represent. 5).



REPRESENT 5 : *bend normative minimal Load F - Weights amount P in kg*

- The tile is put on two (2) supports spaced out by L cms of the device of flexion;
- A lever provided with a device of load if support in the middle of the tile;

- From the normative equivalent weight, we make vary the load in the rear free of the lever until the break of the tile;
- We find the maximal weight of break P_r in daN or kg in the rear free of the lever;
- We determine by interpolation by means of the represent 5 the breaking load F_r passed on by the lever in the middle of the tile in daN or kg.

PICTURE4: *values of the normative loads according to the thickness of tiles*

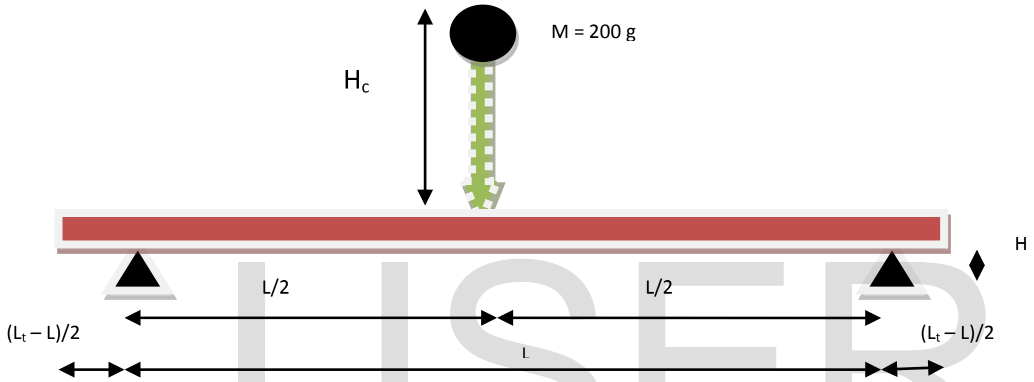
Thickness (mm)	6	8	10
Load (daN or kg)	30	50	80

Conditions and results

- The tile does not have to break. Tiles 250 mm in width must be capable of resisting the normative loads determined from the values of loads according to their thickness.

B) The Resistance in the impact or in the shocks

- I : slowness of the tile $I = 12.99\ cm^4$ (3)
- Y : static deflection of the tile
  $Y = [(M \times L^3) / 48.\ E.\ I]$ (4)
- µ : dynamic Coefficient of striking on tile
  $\mu = [(2.H_C)/ Y \times (1+ (0{,}5M_t / M)]^{0,5}$ (5)
- F_f : Strike force on tile
  $F_f = \mu \times M$ (6)



REPRESENT 6: *general configuration of the shock resistance*

REPRESENT 7: *view of the trial device of shock resistance*

- The tile is put in dish on the table below the trial device of shocks;
- 0n settle the device at a normative height of 20 cms above the table;
- A normative ball of 200 g is put on said device in 20 cms above the tile; we bring down the ball on the tile thanks to a lever which we turn;
- From the normative height Hc = 20 cms, we make vary the height of fall of the ball until the break of the tile or the appearance of cracks. Then we raise the height Hr of break of the tile: if Hr = 20 cms: bad result (notes 0/2), if 20 cms Hr = 50 cms: average result (notes 1/2), if Hr > 50 cms: good result (notes 2/2).

If the tile has to resist more important shocks (hail, diverse objects, fruits, etc.), the distance ball - *surface of the tile(blow) must be carried in 500 mm.*

Conditions and results

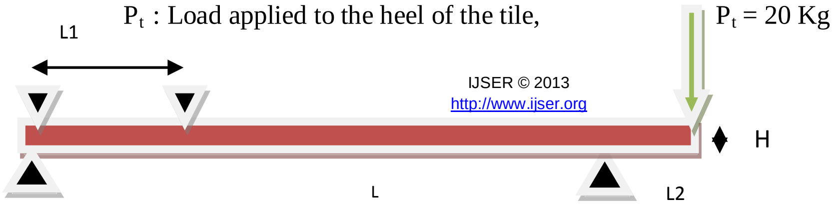
- The shock does not have to cause of cracks on the tile. The test of tone allows making sure of it.

C) Traction resistance of the heel

$$L_1 = \frac{1}{5} x\ L_t \quad (7)$$

$$L_2 = \frac{1}{10} x\ L_t \quad (8)$$

P_t : Load applied to the heel of the tile,



REPRESENT 8: *general Configuration of the traction resistance of the heel*

REPRESENT 9: *view of the trial device of traction resistance of the heel*

- The tile rests on the edge of the table of the device. Near the heel, she overflows 5 cms of the table.
- Carries Him- in forgery is thus equal to 5 cms. The heel is near the ground.
- The tile is maintained against the table by a device fixed to the table.
- From the normative weight P_t = 20 kg, we make vary the weight of the traction test on the heel until break of the tile.
- Then we raise the weight in the break of the heel P_r in daN or kg.

Conditions and results

- The tile has to remain intact, the heel and the tie do not have to break.

D) Test of tone

Principle

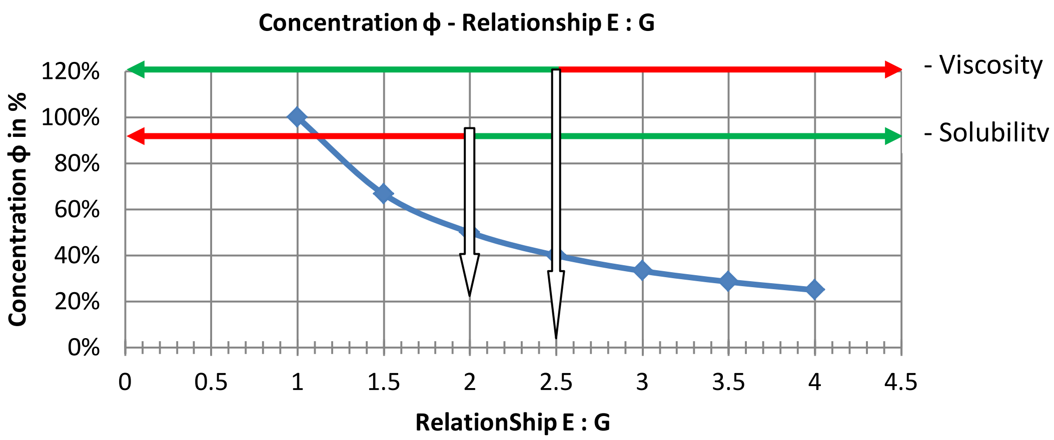
- Seize the tile by the heel;
- Strike the surface of the tile by small knocks by means of a metallic room.

Results

- The struck tile has to produce a clear sound;
- If the produced sound is matt, microcracks are present;
- Rejection of the not satisfactory tiles.
-

2.2 METHODS

2.2.1 Determination of the relationship E: G



REPRESENT 10: *concentration according to E: G*

Hypotheses: the gum Arabic is about completely soluble in twice its body of water and even in concentration from 30 to 40 %, the gum Arabic remains little viscous.

Conclusion: to obtain a solution or viscous glue for which the gum Arabic is completely dissolved in some water, the weight ratio E : G must be understood between 2 and 2.5.

2.2.2 Determination of the relationship G : S

It is a question of determining the quantity of the solution (water + gum Arabic) noted G which it is necessary for the conglomeration and the envelope of a volume of noted sand S after drying. For lack of information on this subject, we adopted the method of trials and errors. We compose:

- volume of unrefined sand 2/5;
- 2 volumes of fine sand 0/2;
- Addition of the viscous solution G some gum by making vary the ratio [G:S] of [0.2: 3] in [1: 3]. We determine at the same time for every variation of ratio, the consistency of the mixture.
- For the ratio [G:S] = [0.2: 3], the mixture is stiff and is difficult to mold. When [G:S] = [1: 3], the mixture flows simply.

To conclude, the best ratio is situated around [0.45: 3], is 15 % and we obtain a 26 cm consistency which recommends the existing standard.

2.2.2 Optimization of mixtures

For this study, two types of mixtures indicated respectively by the figure 1, 2 are considered. These mixtures are established of

- TYPIFY 1: cement, sands and water of mixing;
- TYPIFY 2: solution of the Arabian and sand-colored gum.

A) Methodology of the tries of development(“clarification”)

The methodology of the tries of "development"("clarification") [6] summarized in ten (10) points below is used to optimize these two (2) various types of mixture res. She gives at the same time the description of samples and their ratios.

1) We select the sand with the characteristics indicated to the sub-paragraph 2.1.1 and we fit the sieve to obtain sands of classes 0/2 and 2/5;
2) For every type of mixtures, we make 10 trial series indicated respectively by letters A, B, C, D, E, F, G, a Hour, I, J according to the volume ratios presented in boards 5 and 6;
3) Every trial series concerns the production of five (5) tiles by leaving of a standard mixture and then variations on the standard mixture;
4) The standard mixture is the series A which is established of:
   - 1 volume of binder (cement or gum Arabic);
   - 2 volumes of fine sand;
   - 1 volume of unrefined sand;
   - 1 vibration of 30 seconds;
   - 1 consistency of the mixture Ø = 26 cms.
5) Four (4) parameters of study which the variations concern are:
   1. The ratio [C:S] or [G:S]; the series F, A, G are mixtures containing more or less of cement or solution of the gum Arabic or both;
   2. The ratio [SF: SG]; series: H, A, I, J are mixtures containing more or less of unrefined sand;
   3. The consistency Ø in centimeters; the Series D, A, E are mixtures more or less liquid;
   4. The time of vibration in seconds; the series: B, A, C are mixtures which undergoing more or less of vibration.
6) For the sand to select, we have 5 tiles by series, that is 50 tiles for a sand;
7) Every tile of every trial series will be considered on its weight, its tone and its aspect: dimensions, pores and cracks of surface and their locations (Picture 8);
8) On every series we take 4 remaining tiles to make a try of fold resistance, a try of resistance in the impact, a try of traction resistance of the heel and a try of impermeability;
9) For every trial series we proceed to a weight analysis by considering:- Results of the tries; The sensibility of the mixture in the variations of volume of binder, the vibration, the consistency of the mixture and the percentage of the unrefined sand on some fine sand;
10) The weight analysis is made by multiplying the results obtained by a stabilizing coefficient (Picture 9) according to the importance given to the criterion in the evaluation and by adding up all the obtained points. The best mark on all the ten (10) trial series indicates the dosage which it is necessary to retain for the selected sand.

PICTURE 5: *ratios of typical mixtures 1*

<table>
<tr><th>Séries</th><th>Ratio C : S</th><th>Ratio SF: SG</th><th>Consistency in cms</th><th>Vibration in seconds</th></tr>
<tr><td>A</td><td rowspan="5">1 :3</td><td rowspan="5">2 :1</td><td rowspan="3">26</td><td>30</td></tr>
<tr><td>B</td><td>15</td></tr>
<tr><td>C</td><td>60</td></tr>
<tr><td>D</td><td>24</td><td rowspan="2"></td></tr>
<tr><td>E</td><td>30</td></tr>
</table>

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F	1 :3.5			
G	1 :2.5			
H	1 :3	3 :1	26	30
I		1 :1		
J		1 :2		

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PICTURE 6: *ratios of typical mixtures 2*

<table>
<tr><th>Séries</th><th>Ratio G : S</th><th>Ratio SF : SG</th><th>Consistency in cms</th><th>Vibration en seconds</th></tr>
<tr><td>A</td><td rowspan="5">0.45 :3</td><td rowspan="7">2 :1</td><td rowspan="3">26</td><td>30</td></tr>
<tr><td>B</td><td>15</td></tr>
<tr><td>C</td><td>60</td></tr>
<tr><td>D</td><td>24</td><td rowspan="7">30</td></tr>
<tr><td>E</td><td>30</td></tr>
<tr><td>F</td><td>0.45 :3.5</td><td rowspan="5">26</td></tr>
<tr><td>G</td><td>0.45 :2.5</td></tr>
<tr><td>H</td><td rowspan="3">0.45 :3</td><td>3 :1</td></tr>
<tr><td>I</td><td>1 :1</td></tr>
<tr><td>J</td><td>1 :2</td></tr>
</table>

B) Implementation of mixtures

The weather situation to be watched is:

- The ambient temperature;
- The relative humidity;
- The action of the wind.

Mixture typifies 1

The ideal weather conditions are: ambient temperature around 25 °C, time soft and light break.

The process consists in:

1. At first kneading of the cement and the sands (SF and SG) during two (2) minutes in speed 130 rpm then, introduction of the water in the mixture;
2. Kneading with speed 260 rpm during 4 minutes;
3. Stop to scrape edges then, strong kneading during 15 minutes in 700 rpm;
4. Finally slow kneading during 15 minutes in 260 rpm.

Mixture typifies 2

the ideal weather conditions for the impregnation of the sand by the solution of the gum Arabic are: ambient temperature of at least 35 °C, a dry weather with breeze.

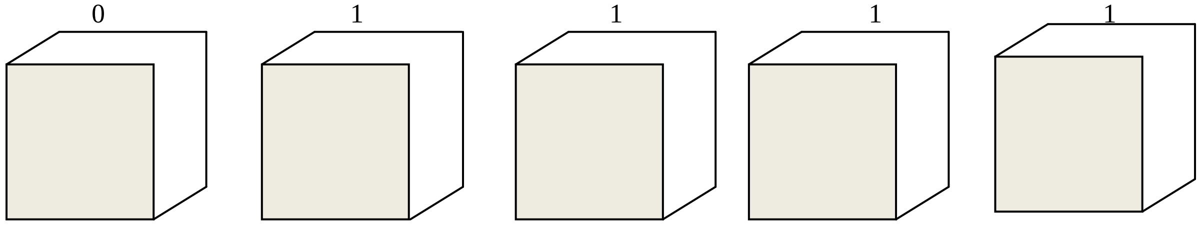
The process consists in:

1. Beforehand mixture of the water and the gum Arabic in complete dissolution of the gum in the water and the obtaining of a viscous and sticky solution;
2. Mixture of the sands (SF and SG), then addition of a quantity of the gum in previously realized solution;
3. Kneading until homogenization of the sand-colored set and the solution of the gum Arabic.

C) Production of experimental tiles

REPRESENT 11: *images of molds, vibrating table and tiles of experiment*

D) Index card of the results of 5 tiles of a series of tries (copy)
N° OF TRIAL SERIES: A
Analysis of the aspect of 5 tiles:
PICTURE 7: *copy of the results of 5 tiles of a trial*

Weight in kg	2,1	2,4	2,4	2,3	2,4
Pores Ø > 2 mm (1)	0	0	1	1	1
Pore Ø > 5 mm (2)	0	0	2	2	0
Crack > 5 mm (3)	2	0	2	2	2
Localisation (4)	0	1	1	1	1
					
Tone (5)	1	2	1	2	2

NOTATION
(1) : 0 so more than 6 pores, 1 so less than 6 pores and 2 if no pores.
(2) : 0 if pores Ø > 5 mm and 2 if no pores.
(3) : 0 if cracks > 5 mm and 2 if no cracks
(4) : 0 if in the grey zone, 1 if in the white zone and 2 if absence of any problem.
(5) : 0 if his deaf person, 1 if his means and 2 if his light;
(6) : 0 if the result is bad, 1 if average result and 2 if good result
Proceed to the following calculations:

- Middleweight in kg: 2.32
- Weighty distance 0.3
- Average Aspect (0, 1 or 2): 1
- Tone averages ((0, 1 or 2): 2

Analysis of the resistance (1 tile by try):

- Resistance in the impact or the shock (6): 1
- Impermeability (6): 2
- Traction resistance of the heel in kg: 22.4
- Fold resistance in kg: 120

E) Index card of the results of a series of tries (copy)

N° OF TRIAL SERIES: **A**
WEIGHT ANALYSIS OF THE TRIAL RESULTS: we multiply every result with the weight of the criterion presented in the picture below.
PICTURE 8: *values of the coefficients of weighting*

CRITERIA	**RESULT**	**WEIGHT**	**TOTAL**
− Middle weight in kg	2.32	× **0.4**	0.93
− Weighty distance in kg	0.3	× **10**	3
− Average Aspect	1	× **5**	5
− Tone	2	× **5**	10
− The Resistance in the impact	1	× **3**	3
− Impermeability	2	× **5**	10
− Traction resistance of the heel	22.4	× **0.5**	11.2
− Fold resistance	120	× **0.2**	24
		Total Notes	**67.13**

F) Choice of the best mixture
Retain ten (10) trial series, series for which the total mark is the highest. Indeed, mixture corresponding to this trial series is the optimal mixture.

2.2.4 Digital simulation [7]
The method of finished elements classic, based on the three-dimensional formulation of the principle of the virtual works and using approximations of low degrees, is applied to tiles considered as a plate of thin structure.

The resolute general equation expresses himself by: ***M U " + C U ' + K U = F (t) - f (t, U).*** [8]

With: K - Matrix of rigidity; C - matrix of the amortization; M - matrix of the masses; U - Movements; U '-speeds; U "-accelerations; F (t) - vector of the outer efforts; f (t, U) - Vector of the unbalanced efforts.

The particular cases are:

- Linear static Analysis: K_0 U = F. [9]
- Modal dynamic Analysis: if ***U (t) = U sin (ω t)*** *then* ***(K_0 - ω² M) U = 0.*** [10,11,12]

3. RESULTS AND DISCUSSION

PICTURE 9: *results of the determination of the typical optimal mixture 1*

Séries	Middle weight in kg	Weighty distance in kg	Average Aspect	Tone	the Resistance in the impact	Impermeability	Traction resistance of the heel	Fold resistance	Total Notes
A	**0.93**	**3.0**	**5**	**10**	**3**	**10**	**11.2**	**24.0**	**67.13**
B	0.96	3.0	5	10	3	5	10.5	22.8	60.26
C	0.96	3.1	5	10	3	10	9.8	2208	64.66
D	0.92	3.0	5	5	3	10	9.9	22.7	59.52
E	0.94	3.2	5	5	3	10	10.0	22.8	59.94
F	0.96	3.2	5	5	3	10	10.4	21.7	59.26
G	0.94	3.1	5	10	3	5	10.2	22.4	59.64
E	0.95	2.9	5	5	3	5	10.4	22.6	54.85
I	0.92	2.9	5	5	3	10	10.0	22.1	58.92
J	0.92	3.0	5	5	3	10	11.1	22.8	60.82

Analysis of the results: the mixture for which the total note is the highest corresponds to the series A. With regard to the physical characteristics, there is a problem at the level of the weight of the tiles which we can neglect because the distance with regard to the average of the distances gives only a 1.3 % value.

PICTURE 10: *results of the determination of the typical optimal mixture 2*

Séries	Middle weight in kg	Weighty distance in kg	Average Aspect	Tone	the Resistance in the impact	Impermeability	Traction resistance of the heel	Fold resistance	Total Notes
A	0.70	2.0	5	5	3	10	14.8	21.88	62,38
B	0.70	2.0	5	5	3	10	15.4	23.10	64,20
C	**0.72**	**1.1**	**5**	**5**	**6**	**10**	**16.1**	**26.40**	**70.22**
D	0.70	1.4	5	5	3	10	15.1	22.42	62.62
E	0.68	2.0	5	5	6	10	14.1	23.40	66.18
F	0.68	2.0	5	5	6	10	15.0	25.10	68.78
G	0.71	1.6	5	5	6	10	15.2	23.46	66.97
E	0.71	1.4	5	5	6	10	14.8	23.55	66.46
I	0.68	2.0	5	5	3	10	15.0	25.11	65.79
J	0.68	1.0	5	5	3	10	13.9	24.84	63.42

Analysis of the results: the mixture for which the total note is the highest corresponds to the series C. Tiles made with this mixture is physically fit to be seen and mechanically resistant. However, we have to stay up the implementation. This mixture is consequently the ideal of mixtures.

PICTURE 11: *ratios of typical optimal mixtures 1 and 2*

Type	Serial	RATIO [C : S]	RATIO [G : S]	RATIO [SF : SG]	CONSISTENCY in cm	TIME OF VIBRATION in Seconds	Total Note
1	A	1/3	-	2/1	26	30	**67,13**
2	C	-	0.45/3			60	**70,22**

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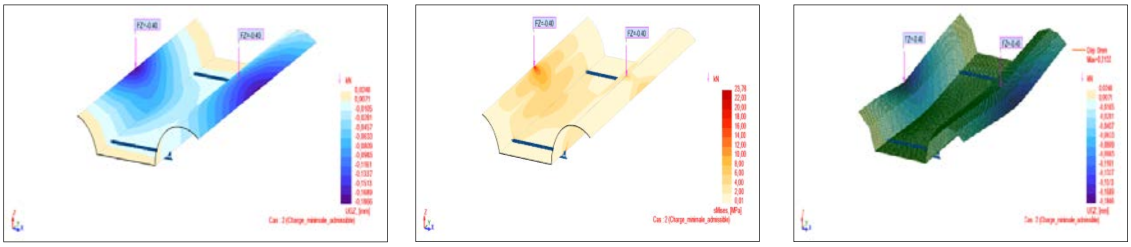
PICTURE 12: *physical and mechanical Properties of typical mixtures 1 and 2*

Typical optimal mixtures	1	2
Density is similar Mva g / cm^3	2.00	1.44
Porosity opened in %	5.1	2.2
Tore resistance in compression sc in Mpa	4 à 25	4 à 28
Module of YOUNG E in Mpa	30 000±1000	20 000±1000
Threshold of putting in flow τ_0 in Pa	35	40
Viscosity µ in Po	1.636	0.984
Thermal conductivity in W.m-1. K-	0.51	0.31

PICTURE 13: *results of the tries of fold resistance 3 points*

Romanic tile 500 x 250 x 10 mm^3 TYPIFIE	1	2
Normative minimal load F in kN (Picture 4)	**0.80**	
Compound constraint in Mpa	16.01	16.23
Deformation in %	0.54	0.81
Deflections on comparator in µm (experiment)	- 194.5	- 258.4
Deflections calculated in µm (simulation)	- 181.8	- 276.1
Distance	**6.5%**	**6.8%**
Rotations (R_{XX}) in 10^{-3}Rad Rotations (R_{YY}) In 10^{-3}Rad	- 3.6 - 1.3	- 6.0 - 2.0
Load in the break Fr in kN	**1.20**	**1.32**
Maximal compound constraints in Mpa	24.02	26.78
Maximal Deformation in %	0.80	1.34
Maximal deflections on comparator in µm	- 254.6	- 428.4
Maximal deflections calculated in µm	- 272.7	- 455.6
Distance	**7.1%**	**6.3%**
Maximal rotations (RXX) in 10-3Rad Maximal rotations (RYY) in 10-3Rad	- 5.5 - 1.9	- 9.2 - 3.2



REPRESENT 12: *fold resistance 3 points* - shock resistance **-** respectively, diagrams of the movements (mm), the composed constraints (Mpa) and deformations (%)

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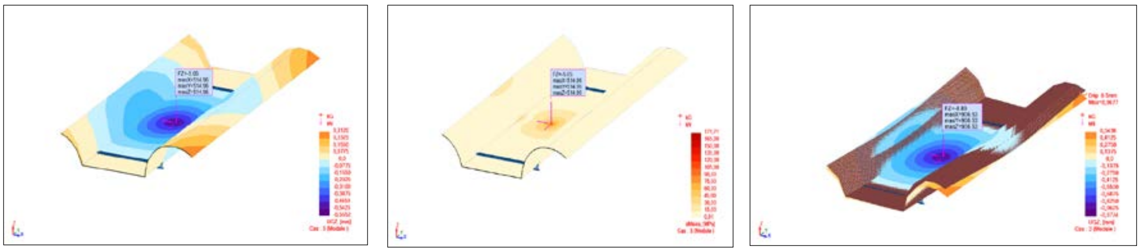
PICTURE 14*: results of the tries of shock resistance*

Romanic tile 500 x 250 x 10 mm^3 TYPIFIE	**1**	**2**
Forces of normative striking F_F in KN	**5.05**	**3.59**
Frequencies Clean oscillations in Hz	89.19	86.7
Compound constraints in Mpa	108.41	77.07
Deformations in %	3.61	3.85
Deflections on comparator in µm (experiment)	-515.6	-587.3
Deflections calculated there in µm (simulation)	-535.9	-571.4
Ecart	**3.9%**	**2.7%**
Rotations (R_{XX}) in 10^{-3}Rad	-7.5	-7.9
Rotations (R_{YY}) in 10^{-3}Rad	-4.3	-4.6
Strike forces in the break Fr in KN	8.89	6.79
Maximal frequencies Nm of the clean oscillations in Hz	67.22	62.81
Compound constraints maximal in Mpa	190.85	145.77
Maximal Déformations in ‰	6.36	7.29
Maximal dynamic deflections in µm on comparator	-978.6	-1112.5
Maximal Dynamic deflections calculated in µm	-943.4	-1080.8
Distance	**3.6%**	**2.8%**
Maximal rotations (R_{XX}) in 10^{-3}Rad	-13.1	-15.0
Maximal rotations (R_{YY}) I in 10^{-3}Rad	-7.5	-8.6



REPRESENT 13: shock resistance - respectively, diagrams of the movements (mm), the composed constraints (Mpa) and deformations (%)

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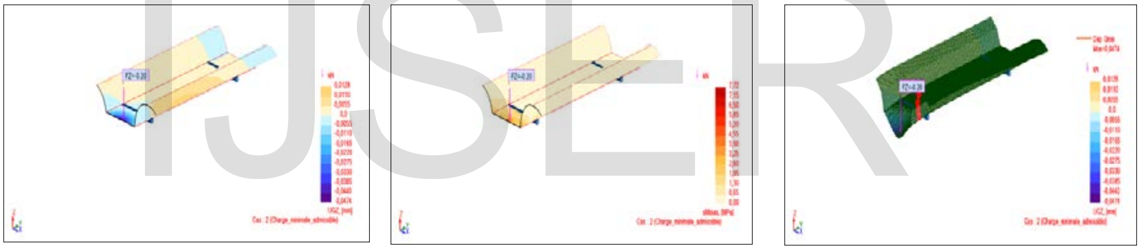
PICTURE 15: *results of the tries of traction resistance of the heel*

Romanic tile 500 x 250 x 10 mm^3 TYPIFIE	1	2
Charge minimale normative F_t en kN	**0.20**	**0.20**
Compound constraint in Mpa	5.22	5.47
Déformations in ‰	0.17	0.27
Deflections on comparator in µm (experiment)	-32.5	-48.5
Deflections calculated in µm (simulation)	-29.5	-45.8
Ecart	**9.2%**	**5.6%**
Rotations (R_{XX}) in 10^{-3}Rad	-0.5	-0.8
Rotations (R_{YY}) In 10^{-3}Rad	-0.6	-1.0
Load in the break Fr in kN	**0.22**	**0.32**
Compound constraints maximal in Mpa	5.74	8.76
Maximal Déformations in ‰	0.19	0.44
Maximal deflections on comparator in µm	-37.8	-78.5
Maximal deflections calculated in µm	-32.4	-73.2
Distance	**6.9%**	**6.8%**
Maximal rotations (R_{XX}) in 10^{-3}Rad	-0.6	-1.3
Maximal rotations (R_{YY}) I in 10^{-3}Rad	-0.6	-1.6



REPRESENT 14: *traction resistance of the heel* **-** *respectively, diagrams of the movements (mm), the composed constraints (Mpa) and deformations (%)*

Summarize of the analysis and some discussion of the results

After examination of the experimental results and those of the digital simulation were presented in the previous pages, we notice that:

⇨ **To produce quality tiles with the gum Arabic, it is necessary**::

- Beforehand, make the solution of the gum Arabic (water + gum) noted G according to the weight ratio [E: G] understand between 2 and 2.5. With this relationship, the gum Arabic is supposed completely dissolved in the water and the solution must be viscous and sticky;
- Add a quantity of the solution of the gum Arabic G to sands following a volume relationship [G:] around [0.45: 3] is 15 % before kneading; a ratio [SF: SG] of [2 1] and one time of compaction (vibration) longer (60 seconds); a hot and dry climate with a light breeze; an appropriate hairdryer according to the thickness of the tile and a good cooking (approximately 1000 °C) of the tile to make it stable towards the bad weather and towards the efforts of all kinds.

⇨ **During the maturation of tiles**: contrary to the grip and to the hardening of mixtures with the gum Arabic, the maturation of mixtures in cement is not a simple drying and a cooking of the dough after addition of the water and the molding. It is a question of a set of chemical reactions of hydration allowing the passage of the dough of cement of the state liquid in the solid state. The dough of hydrated cement is the result of chemical reactions between the water and the compounds of the cement C3S, C2S, C3A, and C4AF. It is about a complex process in which these main things consisted of some cement react to train new insoluble compounds (silicates of calcium hydrated (C-S-H), of the portlandite ($C(OH)_2$) and of the ettringite (Ca(OH)2) (CaO)6 (Al2O3)(SO3)3, 32H2O)) who pull the grip and the progressive hardening of the material. Consequently, during the preparation of mixtures, weather conditions required in trial protocols must be strictly respected for a good maturation of tiles.

⇨ **Of the point of seen the mechanical resistances**: the tiles of gum Arabic resist better with regard to the tiles of cement TMV::

- In the static loads of flexion and drive because they deform widely with rotations around axes X and Y before the pictures 13 and 15;
- In the dynamic loads of shocks because they reduce considerably the strike force of objects to fall on the cover and deform widely also with rotation around axes X and Y before the picture 14.

⇨ **Of the point of seen physical aspect and thermal comfort**: they are aesthetically fit to be seen and waterproof pictures 9 and 10; the results of measure of the thermal conductivity picture12 is a proof that they assure a good heat insulation (approximately 40 %) with regard to) the TMV.

3. CONCLUSION

Globally, following a profound analysis and an interpretation of the results, it turns out that the technology of tiles in micro-concrete is scientifically and technically well indicated to some conditions near for the production of the tiles of good quality gum Arabic. It is going to need thus to worry about the economic aspect. If the technology does not raise problem, the insufficiency of raw materials such as the gum Arabic and the cooking of tiles are left by severe problems. For the first problem, it is enough to plant locust trees and to protect them. As for the second problem, a study must be led to avoid the use of charcoals for the cooking. In fact, we cannot ask at the same time to plant locust trees to collect the gum Arabic and bring down them to recut branches and produce the charcoal!

BIBLIOGRAPHICAL REFERENCES

1. **J.P. BAILON and J.M DORLOT**., "Materials", Third edition. *Polytechnic International Press*. Montreal 2553007701 (2000)
2. **G. BRYS,** "Tiles in vibrated mortar and fibro-mortier", *Manuel of production. Technical report*. BIT, Genève (1990)
3. **YAMBA and al**., "Tiles in vibrated mortar normative document", LOCOMAT. Ministry of the infrastructures of the housing environnement and the town planning Burkina Faso (1997)
4. **H. –E. GRAM and P. GUT**, "Quality control guidelines – fibre or micro concrete tiles", SKAT- BIT**,** element 23. March (1991)
5. **G. C BAGAN**, "Contribution to the improvement of tiles in micro-concrete **-** characterization of materials and structures", *Doctoral thesis of the University of Abomey Calavi. Sciences of materials* (2002)
6. **P. ODUL, "**Roofs in tiles of mortar **-** Production and implementation", teaching aid. Preliminary version. BIT (Genève). 60 p. November (1996)
7. **AUTODESK ROBOT STRUCTURAL ANALYSIS PROFESSIONAL** version: 25.0.0.3774 **-** User manual (2012)
8. **D. GAY** and **J. GAMBELIN**, "Sizing of the structures", *HERMES Science Publications*, Paris (1999)
9. **E** A. **FOUDJET**, "Courts of calculation of the structures by the method of finished elements", POST-GRADUATE DIPLOMA-SPI EPAC of the UAC in Benin (2009-2010)
10. **DAOUI**, "Identification of the frequencies of echo and the module of elasticity by the vibratory method of analysis", SBEIDCO – 1st International Conference on Sustainable Built Environment Infrastructures in Developing Countries ENSET Oran (Algeria). October 12-14 (2009)
11. **J.T BROCH, "**Mechanical vibration and shock measurements"**,** Brüel & Kjaer. 2nd Edition (1984)
12. **G. A. GBAGUIDI, "**Courts of dynamic analysis of the structures", *DEA-SPI EPAC of the UAC Benin. (*2009-2010).