BloEx - Journal
Britain International of
EXACT Sciences Journal
Publish: | January - May - September |
E-ISSN: 2686-1208
P-ISSN: 2686-1216
http://biarjournal.com/index.php/bioex

Recovery of Glass Waste in the Manufacture of Cement Mortar

Razafimahefa M. V.[1,5], Rajeriarison A. T. [1,5], Randriantsimbazafy A.[2], Rakotomamonjy P. [1], Razafindramanga A.W. [1,5], Rakotomamonjy L.[1], Koto-te-Nyiwa Ngbolua [3,4], Robijaona Rahelivololoniaina B.[1,5]

[1,5]Engineering and Industrial Process, Agricultural and Food Systems, Polytechnic High School of Antananarivo, Madagascar
[2]Department of Building and Public Works, Antananarivo Polytechnic School, University of Antananarivo, Antananarivo, Madagascar
[3]Department of Biology, Faculty of Science, University of Kinshasa, Kinshasa, Democratic Republic of the Congo
[4]Department of Environmental Sciences, Faculty of Science, University of Gbado -Lite, Gbado-Lite, Democratic Republic of the Congo
[5]Laboratory for the valorization of natural resources
Email: valorena1357@gmail.com

Abstract:

Almond powder of Irvingia smithii has been incorporated, at the doses of 25 and 50 %, in mice standard ration (prepared by Matadi mill), at INRB, composed of wheat flour, wheat bran and pellets for rabbits to evaluate weight gain, live weight gain and feed conversion and to assess motor activity after 50 days of feeding. Results showed an average increase in live weight gain of 31.08% and 8.36% for the groups of mice fed food supplemented with Irvingia smithii almond powder respectively at 25% and 50% higher than the group of control mice fed exclusively with the standard food. On the other hand, the food consumption index (F.C.I) was very low for the group of mice fed with the food supplemented at 50% (F.C.I. 27.73) and low for the group of mice fed 25% supplemented food (F.C.I. 64.83) compared to the control group (F.I.C. 108,14). In addition, the groups of mice fed the supplemented food did not show motor weakness, even fewer respiratory complications or health problems compared to the control during these 50 days of observation. Live weight gain sufficiently demonstrates the nutritional value of the kernel of I. smithii.

Keywords:
Irvingia smithii; almonds powder; mice; weight gain; feed conversion

I. Introduction

Faced with the ever-increasing needs for material resources and the requirements and conditions of environmental preservation in a vision of sustainable development, it has become necessary and relevant to explore and study all possibilities and opportunities for the reuse and recovery of waste and industrial by-products, especially in the field of public works.

Our study consists of the use of glass powder in the mortar, its main objective is to research to contribute to the reuse of the stored glass waste, in the manufacture of cement mortar and to consider

Eliminate the above-mentioned by recycling hence protecting the environment.

Reduce the production of cement and reduce or eliminate the emission of dioxide (CO2) into the atmosphere.

To replace a certain amount of cement in the construction field with glass powder.

That is why we contribute to the "recovery of glass waste in the manufacture of cement mortar".

II. Review of Literature

2.1. Characterization of Raw Materials

We will present in this chapter, the characteristics of materials used for the manufacture of mortar.

The materials used are:

- Drinking water from the laboratory
- River sand from Ikopa
- Portland cement CEM I 42.5 N
- Glass powder

2.2 The Mixing Water

The water used is that of the tap of the city of Antananarivo. It is used on the one hand for the hydration of cement and on the other hand, it allows the fluidification of the paste. As soon as the water comes into contact with the anhydrous cement, it reacts to combine and form the cement hydrates.

The chemical analysis of the water was carried out in the laboratory of chemical tests and it gave the following constitution:

Table 1. Chemical composition of water in mg/l

Ca^{2+}	Na^{+}	Mg^{2-}	K^{+}	Cr^{2+}	SO_4^{-}	NO_3^{-}	HCO_3^{-}	pH	salinity
242	536	125	31	755	755	14,5	124	7.75	2799

2.3 The Sand

a. Origin of the Sand

The basic sand of our research comes from: the edges of the bank of Ikopa

b. Physical characteristics of the sand used

The sand was subjected to several tests at the LNTPB, according to the French standards AFNOR.

c. Absolute density: (Standard NF P 18-555)

It is the mass of the unit volume of the substance, which is the ratio between its mass and its absolute volume.

d. Procedure: (Standard NF P 18-555)

Determine the absolute density of sand using the container of capacity 1000 ml. We take 03 samples of mass 300 g.

Place the sample in a container with a capacity of 1000 ml and pours there 300 ml of water prepared beforehand into a second graduated container, then one mixes carefully the contents to drive out the air which exists there. After this operation, we determine the final volume occupied by the sand-water mixture. Let (V) be this volume.

Knowing that the volume (Ve) of water poured is 300 ml, it would be easy to determine the volume occupied by the sand alone.

Volume of sand:

V1=V- 300 (ml) (Formula 1)

The absolute density of the sand is determined by the formula:

$$\rho = \frac{M}{V_1}$$ (Formula 2)

With : M = 300 g.

Table 2 demonstrates the density of the sand.

Table 2. Absolute density of sand

Test No	M (g)	V_e (cm^3)	V_1 (cm^3)	ϱ (g/cm^3)	ϱ_{moy} (g/cm^3)
1	300	300	115	2.60	2.60
2	300	300	116	2.58	
3	300	300	114	2.63	

Apparent density: (Standard NF P 18-554)

It is the mass of the material per unit of volume including the voids existing between the grains.

Procedure: (Standard NF P 18-554)

- Determine the apparent density of the sand using a standardized funnel of capacity 2 to 2.5 liters.
- Fill the funnel with dry sand.
- Weigh the empty container M1.
- Place the container under the funnel at a distance of 10 to 15 cm and fill it with sand.
- Once the container is filled, level the surface of the sand and weigh it. Let M2 be this weight
- Volume of the container Vr = 900 cm3.

The apparent density of the sand is given by the following formula:

$$\rho_{app} = \frac{(M_2 - M_1)}{V_r}$$ (Formula 3)

Table 3 demonstrates the bulk density of sand.

Table 3. Apparent Density of Sand

Test No.	M_1 (g)	M_2 (g)	ϱ_{app} (g/cm^3)	ϱ_{appmoy} (g/cm^3)
1	114	1320	1.34	1.347
2	114	1338	1.36	
3	114	1321	1.34	

e. Porosity : (Standard NF P 18-554)

It is the volume of voids between the grains of sand. The porosity can be determined by the following formula:

P (%)=100 - (Apparent density / absolute density) × 100 (Formula 4)

$$P\ (\%) = \left[1 - \frac{\rho_{app}}{\rho_{abs}}\right] \times\ 100$$

For sand:
Loose state: PL = 48.19 %.

f. Compactness

The compactness of a material is a proportion of its volume actually occupied by the solid matter that constitutes it, that is, the ratio of the absolute volume of grains to the apparent volume of the material. The compactness is given by the formula:

$$C = \left(\frac{\rho_a}{\rho_{abs}}\right) = 100 - P \quad \text{(Formula 5)}$$

For sand:
Loose state: CL = 51.80 %.

f. The void index

The void index is the ratio of void volume to solid volume.

$$e = \frac{V_v}{V_s} = \left(\frac{P}{100-P}\right) \quad \text{(Formula 6)}$$

With P in percent (%).
For sand:
Loose state: e = 1.08 %

g. Sand Equivalent: (Standard NF P 18-598)

This test makes it possible to highlight the proportion of clayey or ultrafine impurities contained in the sand and the percentage of harmful dust and clayey elements which decrease the quality of concrete and mortar.
Procedure (Standard NF P 18-598)

- Sieve a quantity of sand (mass higher than 500 g).
- Take a weight of 120g
- Fill the test tube with washing solution up to the first mark (10 cm).
- Using the funnel, pour the test sample (120 g) into the test tube and tap strongly several times with the palm of the hand in order to expel all air bubbles and promote the wetting of the sample.
- Allow standing for 10 minutes.
- Close the test tube with the rubber stopper and give it 90 cycles of 20 cm horizontal course in 30 seconds by hand using a mechanical shaker
- Then remove the stopper, rinse it with the washing solution over the test tube, and rinse the walls of the test tube.
- Lower the washing tube into the test tube, roll it between thumb and forefinger, slowly rotating the tube and test tube and at the same time giving the tube a slight prick. The purpose of this operation is to wash the sand and to make the fine and clayey elements rise.

Carry out this operation until the solution reaches the second mark. Then let it rest for 20 minutes.

A /Visual Sand Equivalent (ESV):

After 20 minutes of sand deposition, read the height h1 from the top level of the flocculant to the bottom of the test tube with a ruler.

Also measure with the ruler the height h2 between the upper level of the sedimentary part and the bottom of the test tube.

$$ESV\ [\%] = \frac{h_2}{h_1} \times 100 \qquad \text{(Formula 7)}$$

Where: h2< h1 with: h1: clean sand + fine elements.

B / Visual Sand Equivalent (ESP):

Introduce the piston into the test tube and let it descend gently until it rests on the sediment. At this moment block the sleeve of the piston and take it out of the test tube.

Insert the ruler in the notch of the piston until the zero point comes to rest against the inner face of the piston head. Let h'2 be the height read and corresponding to the height of the sedimented part.

$$ESP\ [\%] = \frac{h'_2}{h_1} \times 100 \qquad \text{(Formula 8)}$$

Where h2′ : The height of the sand (h2' < h1)

Table 4 demonstrates the equivalent of the river sand used.

Table 4. Sand Equivalent

Test No	h_1 (cm)	h_2 (cm)	ESV (%)	h_2' (cm)	ESP (%))
01	8.9	9.8	90.81	8.6	87.75
02	8.9	9.7	91.75	8.7	89.69
03	8.9	9.8	90.81	8.7	88.77

(ESV)moy= 91.12 %
(ESP)moy= 88.73 %
ESP > 80 %
Then, ESV > 85%.

Table 5. Comparison of Values

E.S.V	E.S.P	Nature and quality of sand
ES < 65	ES < 60	Clayey sand: Risk of shrinkage or swelling to be rejected for quality concretes. Slightly clayey sand of admissible property for current quality concretes when there is no particular fear of shrinkage
65<ES<75	65<ES<70	Slightly clayey sand of admissible property for current quality concretes when there is no particular fear of shrinkage
75<ES<85	70<ES≤80	Clean sand with a low percentage of clay flour is perfectly suitable for high-quality concretes.

ES≥85	ES>80	Very clean sand: The total absence of clay fines may lead to a plasticity defect in the concrete which will have to be compensated by increasing the water content.

Ikopa sand is very clean river sand. The total absence of clayey fines may lead to a plasticity defect in the mortar or concrete which will have to be compensated by an increase in the water content.

h. Water Content: (Standard NF P 18-555)

Sand has the capacity to retain a very large quantity of water (it can reach 20 to 25% of its weight), if its humidity is between the limit of 0 to 3%, it is called dry. (NF P 18-555)

- Procedure : (Standard NF P 18-555)
- Weigh a sample of wet sand, which is Mh its wet mass (500 g).
- Leave the sample in an oven at a temperature in the range of 105°C to 110°C for 24 hours.
- Weigh the sample again, which means, Ms is dry mass.

The water content of the sand is:

$$W\,[\%] = \left[\frac{M_h - M_s}{M_h}\right] \times 100 \qquad \text{(Formula 9)}$$

Where:
Mh: mass of wet sand in (g).
Ms: mass of dry sand in (g).

Table 6 shows the water content of the sand.

Table 6. Water content of sand

Test No	M_h (g)	M_s (g)	W (%)	W_{moy} (%)
1	500	494.5	1.1	1.3
2	500	493.5	1.3	
3	500	492.5	1.5	

i. Degree of water absorption: (Standard NF P 18-555)

It is the power of a material to absorb and retain water, it is defined in percentage according to the following formula.

$$A\,[\%] = \left[\frac{M_2 - M_1}{M_1}\right] \times 100 \qquad \textbf{(Formula 10)}$$

Where :
M1: The mass of the dry material in (g).
M2 : The mass of the superficially dry water-saturated material in (g).

Table 7 shows the degree of absorption of sand.

Table 7. Degree of Absorption of Sand

Test No	M_1 (g)	M_2 (g)	A (%)	A_{moy} (%)
1	300	307.95	2.65	2.82
2	300	308.61	2.87	
3	300	308.82	2.94	

According to the procedure defined in the standards NF P18- 554 and NF P18- 555, the upper limit of the water absorption coefficient of the aggregate is set at 5%, which means, Ab < 5%. So, in our case, this property is verified.

The standard NF P 18 541 fixes a maximum value of 5%, for the classic concretes, which is perhaps insufficiently severe, the value moreover brought back to 2,5 % for the concretes of characteristic resistance higher than 36 MPa. (Standard NF P 18 541)

j. Particle Size Analysis (Standard NF P 18-560)

The granulometric analysis allows us to measure the dimensional distribution in weight of the elements of a material, it includes two operations:

a. Sieving
b. Sedimentation

The granularity is expressed by a granulometric curve which gives the distribution of the average dimension of the grains, expressed in the form of a percentage of the total weight of the material, it is drawn in the semi-logarithmic diagram with:

On the x-axis, the logarithm of the size of the sieve openings in increasing values.

In ordinate, the percentage, in weight of the total material of the fraction of sand whose grains have an average diameter lower than that of the corresponding abscissa (passing) we note that the granulometric curve is a fundamental element of the classification of the material. The results of this study make it possible to predict certain properties of the material such as permeability, compaction ability, and use as a filter.

Procedure:

- Take a mass of dry sand material (about 1500 g)
- Weigh the sample taken
- Peser l'échantillon pris

Weigh each empty sieve to the nearest 1 g, that is to say, mi half the mass of the sieve.

Build a column of clean and dry sieves whose mesh opening is respectively from top to bottom: 6.300 – 5.000 - 4.000 – 3.150 – 2.000 – 1.000 – 0.500 - 0.315 – 0.200 – 0.125 and possibly 0.08mm. The column is topped by a bottom to collect the elements passing the last sieve and a cover to avoid the dispersion of dust. The sieves and the bottom are weighed first.

Pour the material (dry sand) onto the column and fix it carefully on the mechanical stirring machine, stir for 5 minutes. Stop the shaker and carefully separate the different sieves.

Weigh each sieve separately to the nearest 1 g. Let Mi be the mass of the sieve (I) + the sand. The difference between Mi and mi (larger mesh sieves) is the partial rejection R1 of sieve 1.

Repeat the operation for the next lower sieve.

Add the refusal obtained on the sixth sieve to R1, that is to say, R2 the mass of the cumulated refusal of sieve 2 (R2 = R1+ Partial refusal on sieve).

Continue the operation with the rest of the sieves to obtain the masses of the various cumulated refusals R3, R4, ….

The cumulated sieve is given by the following relation: T= 100 – Rc

Where :

- T: Sieves in %
- Rc: Cumulative rejects in %

Table 8 shows the particle size analysis of the sand.

Table 8. Particle Size Analysis of the Sand

Sieve	Partial Rejection	Cumulative Rejection		Sieve
(mm)	(g)	(g)	(%)	(%)
6.300	0.0	0.0	0.0	100
5.000	14.0	14.0	1.0	99
4.000	10,5	24.5	1.8	98
3.150	19.0	43.5	3.2	97
2.000	78.5	12.0	9.1	91
1.000	295.0	417.0	31.0	69
0.500	561.0	97.0	72.7	27
0.315	99.0	1077.0	80.0	20
0.200	147.0	1224.0	91.0	9
0.125	88.0	1312.0	97.4	3
0.080	10.0	1322.0	99.0	1
Fond	24.0	134.0	100.0	0

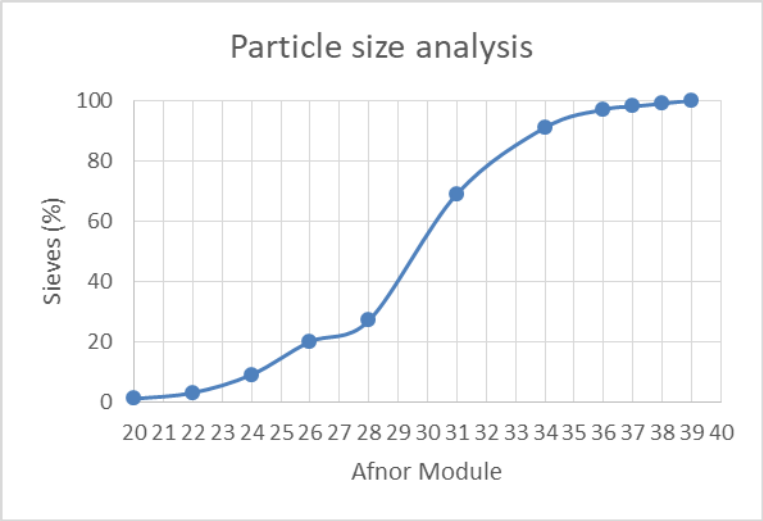

Figure 1. *The granulometric curve of the sand (0/5)*

k. Modulus of fineness (Standard NF P 18- 540)

It is a very important factor, which allows us to judge the coarseness of the sand; it is expressed by the ratio of the sum of the cumulative refusals of the sieves of mesh:

[0.16 – 0.315 – 0.63 – 1.25 – 2.5 and 5 mm] over 100 and calculated by the following relationship:

$$M_f = \sum \frac{R_c}{100} \qquad \text{(Formula 11)}$$

Where: Rc: Cumulative rejection.

For sand: Mf= 2.67

- Soviet standards specify the Mf of sand as follows:

- Coarse sand Mf> 2.5
- Medium sand 2 < Mf< 2.5
- Fine sand 1.5 < Mf< 2
- Very fine sand 1 < Mf< 1.5

2.4 Chemical Characteristics of River Sand

The chemical composition of the sand is established by the laboratory. It is given in the following table:

Table 1. Chemical analysis of sand

Constituents		
Element	Symbol	Water content (%)
Silica	SiO_2	85.95
Lime	CaO	7.35
Iron oxide	Fe_2O_3	0.88
Alumina	Al_2O_3	1.90
Magnesium oxide	MgO	0.57
Sulfate	SO_3	0.42
Loss on fire	L.O.I	2.81

III. Result and Discussion

3.1 The cement

The base cement used in our research is a Portland cement CEM I.

a.Characteristics of Portland cement CEM I 42,5 N

1. Chemical Characteristics

The chemical analysis of a material is essential in order to know the different chemical constituents to be determined: the major elements (SiO2, Al2O3, Fe2O3, CaO), and the SO3 content.

2. Determination of the silica content

The test consists in determining the content of insoluble residues (RI) and silica (SiO2) in the material.

The procedure is as follows:

- Weigh 1g of sample to analyze;
- Introduce in a 600ml beaker;
- Attack with 35 ml of concentrated HCl and 05 drops of concentrated HNO3 ;
- Crush the grains well with a glass stirrer;
- Boil for 6 to 7 minutes on a sand bath;
- Lower the density of the mixture by 15 to 20 ml of hot distilled water;
- Add 10 ml of 2.5% gelatin solution while stirring;
- Let stand for 5 minutes;
- Filter on filter paper quickly;
- Wash the filter paper and sponge it with hot distilled water.
- We have iron, aluminum, magnesium, and calcium in the filtrate and silica in the residue.

The latter is calcined at 1000°C in an oven for 45 minutes, then weighed. Let M be the mass obtained

From where

% SiO2 = M x 100 (Formula 12)

3. Determination of the Content of Al2O3 and Fe2O3

❖ Determination of iron oxide:

To determine the content of Al2O3 and Fe2O3, you need:

- 100ml of the filtrate with 200ml of distilled water, then shake with a magnetic stirrer
- One pours 6 drops of blue of bromophénol, and some drops of NH4OH 50% until the dark blue turning;
- 20 ml of 0.1 N HCl + 15ml of buffer solution are added, and 15 to 20 drops of salicylic acid are added;
- Then heat to 45-50°C for 1min 30s. Titrate with EDTA until the straw-yellow color change.

Let us note A this solution for the determination of the content of Al2O3

Expression of the formula

$$\%Fe_2O_3 = V * f_{EDTA/Fe2O3} \qquad \text{(Formula 13)}$$

With f: EDTA factor for Fe2O3

V: volume of EDTA poured for the determination of Fe2O3

Determination of the alumina content:

To solution A:

- A few drops of CH3CO2NH4 and 5 ml of CH3CO2H are added;
- Then 3 drops of copper complexonate are added;
- And 10 drops of PAN (purplish pink) are added;
- One puts at boiling point the solution while agitating;
- One titrates with EDTA until the straw has yellow coloring.

Expression of the formula:

$$\%\ Al2O3 = V * fEDTA/Al2O3 \qquad \text{(Formula 14)}$$

V: volume of EDTA poured for the determination of Al2O3

f: EDTA factor for Al2O3

4. Determination of the CaO content

To determine the CaO content:

- 50 ml of filtrate is pipetted by adding 200 ml of distilled water;
- Shake with a magnetic stirrer and add 2 drops of helianthine (pink coloration);
- A few drops of NH4OH are added until yellow coloration is obtained;
- One pours quickly 20ml of triethanolamine (TEA) 33% then 40ml of NaOH 2N, one adds reagent of PATON and REEDER (purple-red);
- One titrates with EDTA until obtaining blue color.

Expression of the formula:

:

$$\%\ CaO = V * fEDTA/CaO \qquad \text{(Formula 15)}$$

V: volume of EDTA poured for the determination of CaO

f: EDTA factor for CaO

5. Determination of MgO content

To determine the MgO content:

- 50 ml of filtrate is pipetted by adding 200 ml of distilled water;
- One shakes with a magnetic stirrer then one adds a drop of helianthine (light pink)then a few drops of NH4OH 50% until yellow coloration
- One quickly pours 30ml of TEA 33% then the volume of EDTA for the determination of CaO
- One adds 10ml of concentrated NH4OH and 6 drops of MgO indicator (pink coloration);
- Titrate with EDTA until the colorless turn, let us note V1 the volume poured.

Expression of the formula:

$\%\ MgO = (V1 - V) * f\ EDTA/MgO$ (Formula 16)

V: volume of EDTA for the determination of MgO
f: EDTA factor for MgO

6. Determination of the Free CaO Content

To determine the free lime content:

- One introduces 1g of sample in an Erlenmeyer, which one fills then with 55ml of ethylene glycol;
- One puts at 70°C for 15mn while stirring constantly (the glycol must be free of water to avoid the hydrolysis of CaO);
- One filters quickly under pressure, then one washes the residue with 15ml of ethyl alcohol;
- And 6 drops of bromocresol green indicator are added to the filtrate;
- The mixture is shaken and titrated with 0.1 N HCl until the yellow color change.

Expression of the formula:

$\%\ Al_2O_3 = V * f_{EDTA/Al2O3}$ (Formula 14)

7. Determination of Loss on Ignition

The loss on ignition of the samples is determined at 975°C+/-25 with a calcination time of 45 min to 1 h.

The procedure is as follows:

Putting the sample in a crucible is m2 the total mass, then put it in the furnace. At the exit of the oven cool it in a desiccator until obtaining a constant mass is m3

The loss on ignition (LOI) has been evaluated by the relation:

$\%\ CaO = V * f_{EDTA/CaO}$ (Formula 15)

Where m1: Mass of the empty crucible

8. Determination of Suspended Solids Content

Not all water can be used for mixing concrete and mortar, drinking water is always usable, but in some cases, the water contains impurities, which require chemical analysis to determine the impurities in it. These impurities are either chemical compounds that may be active in cement, aggregates, or reinforcement, or suspended particles that are undesirable.

Excessive impurities deteriorate the properties of the mortar and concrete: physical and mechanical properties (setting and strength), aesthetic properties (stains, efflorescence), and durability (corrosion of reinforcement).

The test consists in filtering a certain quantity of water and determining the mass of the materials remaining on the filter.
The procedure is as follows:

- Weigh a perfectly dry filter paper, note its mass M1 (g);
- Take a volume V of water and filter with this paper;
- Dry the filter at 110°C;
- Weigh the filter again and note its mass M2 (g).

The mass of material in suspension in 1L of water is :

$$m = \frac{M_1 - M_2}{V} \quad \text{(Formula 19)}$$

If m is less than 2 g/l, the water can be used.

Otherwise (m greater than 2 g/l), the use of this water in the manufacture of mortar is prohibited.

9. Determination of the Content of Dissolved Salts

It consists in evaluating the quantity of matter remaining after total evaporation of a certain quantity of water without matter in suspension.

To determine this content of dissolved salts, one proceeds as follows:

- Take a volume V (l) of water and filter it to remove suspended matter;
- Evaporate this water until it is completely dry;
- Weigh the residue and note its mass M1 (g).
- The mass of dissolved salts contained in 1 liter of water is :

$$m = \frac{M_1 - M_2}{V} \quad \text{(Formula 19)}$$

If m is less than 15 g/l, we can use water.

Otherwise (if m is higher than 15 g/l), the use of this water is forbidden.

In table 10 we have the chemical compositions of the cement and in table 11 the mineralogical compositions

Table 2. Chemical Compositions of Cement NM 031-1/2021 et EN 197-1 (2011)

Elements	**CaO** $_{total}$	**SiO_2**	**Al_2O_3**	**Fe_2O_3**	**SO_3**	**CO_2**	**MgO**	**Not assayed**	**Ins**	**PAF**
%	56.88	22.89	6.33	3.09	2.79	0.93	0.89	1.73	1.36	4.04

Table 3. Minéralogical Composition of Cement

Minerals	**C_3S**	**C_2S**	**C_3A**	**C_4AF**	**CaO_{free}**	**Gypsum**
%	52	18	8	16	1	5

b. Physical Characteristics

1. Specific Surface

The determination of the specific surface of our powders was made by the method of Blaine. This method requires the use of the apparatus of Blaine or "Permeabilimeter of Blaine".

Figure 2. *Blaine Permeability Meter*

It is based on the time it takes a constant volume of air, under a well-defined pressure and temperature, to pass through a layer of material packed under well-defined conditions. This time is proportional to the surface developed by all the grains of solids in the sample.

The specific surface of Blaine is given by the following formula:

$$S = K\frac{\sqrt{e^3}\sqrt{t}}{\gamma(1-e)\sqrt{\eta}} \qquad \text{(Formula 21)}$$

Where:
S : specific surface (cm2/g)
K : constant of the apparatus determined by the calibration
t : time measured in seconds
e : porosity of the material, in the cell; a constant value equal to 0.5
γ : density (g/cm)
η : viscosity of air at test temperature (in Poises)

Table 12. Physical Characteristics of Cement

Characteristic	**Results**	**Units**	**Standards EN197-1 (2011) and NM 031-1/2010**
Blaine spécific surface	3106.00	cm^2/g	
Apparent density	1.01	t/m^3	
Absolute density	3.08	t/m^3	
Hot expansion	-	mm	≤ 10

3.2 Glass Powder

Glass powder is obtained by crushing broken bottles and glass panes, it is a colorless white and/or green glass.

Figure 3. *Glass Powder*

a. Chemical Composition of Glass Powder

The chemical composition of the glass powder is classified in Table 13:

Table 13. Chemical composition of glass powder

Composition (% by mass)	Glass powder
Silica(SiO_2)	72.50
Alumina (Al_2O_3)	0.40
Iron oxide (Fe_2O_3)	0.20
Calcium oxide (CaO)	9.70
Magnesium oxide (MgO)	3.30
Sodium oxide (Na_2O)	13.70
Potassium oxide (K_2O)	0.10
Sulfur trioxide (SO_3)	-
Loss on fire	0.36

b. Physical Characteristics

- Specific surface: 3500 cm2/g for powders with a diameter lower than 100 μm
- Absolute density: 2.44 g/cm3
- Apparent density: 1.08 g/cm3
- Granulometry: < 0.5 mm

3.3. Preparation of the Test Tubes

In this chapter, we relate the procedures carried out for the preparation of the test specimens. The test specimens are made in accordance with standard EN 196.

3.4 Mortar Formulation

In order to see the influence of glass powder as a substitute for cement on the physical-mechanical performance of the mortar, variants of the mortars were established from the control mortar PV0, the mortars studied have the dosages of the constituents which are given in the following table:

Table 4. Formulations of Mortars with Glass Powder

Nomination	Cement	Sand	Glass powder		E/L
	(g)	(g)	%	(g)	
PV_0	450.0	1350	0	0.0	0.65
PV_5	427.5	1350	5	22.5	0.65
PV_{10}	405.0	1350	10	45.0	0.65
PV_{15}	382.5	1350	15	67.5	0.65
PV_{20}	360.0	1350	20	90.0	0.65

3.4 Conduct of the Test

The cement mortars were mixed in a rotary mixer. Nanoparticles are not easy to disperse uniformly due to their high surface energy. Accordingly, mixing was performed as follows:

- The glass particles were stirred with mixing water at high speed for 1 min.
- Cement was added to the mixer and mixed at medium speed for another 1 min.
- The superplasticizer was added and stirred at high speed for 30 s.
- Sand was added gradually and mixed for 2 min 30 s at high speed.

3.5 Preparation of test specimens (EN 196).

The specimens are prismatic in shape with a square cross-section (4 x 4 x 16) cm3. They must be molded directly after the mortar has been made. With the three-cell metal mold and its riser firmly attached to the impact table, the first of two layers of mortar is introduced. The layer is spread evenly using the large spatula and then tightened with 60 shocks. The second layer is then introduced, leveled with the small spatula, and clamped again with 60 shocks. The mold is removed from the impact table, and after removing the rise, the excess mortar is removed by leveling. The surface of the specimens is then smoothed.

Figure 4*. Mortar in a test tube (4 × 4 × 16) cm3*

3.5 Preservation of the Specimens

After demolding, the specimens are left to dry for 24 hours. They are immersed in water in a climate chamber for 2, 7, and 28 days. This operation is carried out to avoid water evaporation during the cement setting phase and to ensure proper curing flow.

3.6 Control Tests

The procedures for testing the cement paste and mortar (consistency test, setting test, and mechanical tests on mortars) are in accordance with specific standards.

The mixtures were made in an automatic mixer in the materials laboratory of LNTPB.

3.7 Fresh State Tests

a. Setting Time (EN 197-1 (2011) and NM 031-1/2010)

1. Method of Preparation of the Cement Paste

Water is poured into the mixer tank first. The cement is added to the water in a time between 5 and 10s. The mixer is started immediately at a slow speed of 90s, then stopped for 15s to gather the paste with a small trowel and then started again for another 90s at a slow speed.

The dough is quickly introduced into the truncated cone mold placed on a glass plate, without excessive settling or vibration. Excess dough is removed by a back-and-forth motion with a trowel held perpendicular to the surface of the mold. The assembly is then placed on the Vicat apparatus plate for the consistency and setting test.

2. Consistency and Setting Test Procedure for Cement Paste

Four minutes after the start of mixing, the probe is brought to the top surface of the paste and released without momentum. The probe then sinks into the paste. When the probe stops, or at the latest 30 seconds after being released, the distance d between the end of the probe and the bottom of the mold is measured. This distance d characterizes the consistency and determines the setting of the dough.

If d = 6 mm ± 1 mm, the consistency is the normalized consistency. If d does not reach this value, the test should be repeated with a different value of the water/cement ratio until the value corresponding to the normalized consistency is reached.

To determine the setting, the probe is replaced by a 1.13 mm diameter needle. Under the effect of the load, when the needle stops at a distance d from the bottom of the mold such as d = 4 mm ± 1 mm, we say that the beginning of the setting is reached. This moment, measured from the beginning of the mixing, is called the "time of the beginning of setting". The end of setting time is the time at which the needle is only 0.5 mm deep. Each consistency result is the average of three identical measurements.

3. Subsidence (NF EN 12350-2)

The slump test according to NF EN 12350-2 is used to determine the consistency of conventional mortar mixes with an E/L ratio = 0.65. The slump is measured at 10 min and at 30 min after water-binder coQntact. The equipment used consists of a slump cone which is a conical metal mold 300 mm high, 200 mm in diameter at the base and 100 mm in diameter at the top, and a steel rod 16 mm in diameter and between 450 mm and 600 mm long with a hemispherical end. The moistened cone is placed vertically on a solid, flat, non-absorbent surface. It is filled in three layers of approximately the same volume and pounded at 25 strokes each. After ramming and leveling the last layer, the cone is slowly lifted and the mortar collapses. The empty cone is placed near the mortar. The slump is the difference between the height of the cone and the height of the slumped sample, from the center of the top surface of the mortar, measured to the nearest 10 mm, photo 4.

Figure 5. *Slump test on mortar*

3.8 Tests in the hardened state

a. Porosity

The pores play an important role in estimating the quality of the mortar.

To evaluate the porosity, we will pursue the following steps:

- Drying the test specimens in an oven at 100 to 115°C for 24 hours until a constant mass is obtained.
- Immerse the specimens in water for 24 hours.
- Dry the test tubes in the open air, so that the test tubes can be weighed in the air.

b. Distribution and Positioning of Test Specimens

Before proceeding to the crushing action, the following recommendations should be considered:

Wipe any excess moisture from the specimen surface before positioning it in the testing machine.

All test machine platens should be wiped clean and any particles or foreign matter removed from the specimen surfaces that will be in contact with them.

Place the specimen on the test machine.

c. Bending test (Standard EN 197-1 (2011) and NM 031-1/2010)

To perform this test, three specimens (4 x 4 x 16) cm3 were prepared for each age (2, 7, and 28 days) in order to take an average value. Place the prism in the bending device with a lateral molding face on the support rollers and its longitudinal axis perpendicular to them. Apply the load vertically through the loading roller on the opposite side face of the prism and increase it by 50 N/s ± 10 N/s, until it breaks.

d. Compressive strength test (Standard EN 12390-3)

The specimens used are cubic specimens (4 x 4 x 16) cm3. The specimen is centered and fixed between the plates of a hydraulic press loaded with a constant speed. The compression test is conducted until the specimen breaks (photo 5). Center each half-prism laterally with respect to the machine platens, as shown in the following photo:

Figure 6*. Compression Crushing on a Cement Press Machine*

3.9 Properties of Cement Mortar

In this chapter, we present the results of tests carried out on mortars made according to the different combinations of glass powder replacement of cement dosage. The physical-mechanical properties of mortars with different glass powder dosages are analyzed. The calculation of density, porosity, and flexural strength (EN 197-1 (2011) and NM 031-1/2010) as well as compressive strength (EN 12390-3) on cubic specimens (4 x 4 x 16) cm3 is used to study the mechanical behavior of these mortars.

a. Properties in the Fresh State

1 Setting Time and Normal Consistency

From the experiments carried out, the results of the setting time and consistency of each mixture are given in the tables below:

Table 5.Normal Consistency in Relation to Glass Powder Dosage, W/C = 0.30

Constituents	PV_0	PV_5	PV_{10}	PV_{15}	PV_{20}
Cement (g)	500	475	450	425	400
Glass powder (g)	0	25	50	75	100
Water (g)	144	136	134	132	130

Table 15 shows that to have a normal consistency of the dough, the weight of water decreases proportionally with the dosage of glass powder, of which the control dough has the largest value. This suggests that the glass powder does not absorb water.

Table 16. Setting time versus glass powder dosage

Time (min)	PV_0	PV_5	PV_{10}	PV_{15}	PV_{20}
Start of setting	140	189	198	135	135
End of setting	250	309	348	195	225
Setting time	110	120	150	60	90

A noticeable difference in the time to set completion appears for the mix loaded with 5% and 10% PV. At 10%, the presence of PV delays the time to set by 98min compared to the time to set the reference mix. It is reduced rapidly for PV concentrations of 15% and

above. This means that the amount of water in these two mixes (5 and 10%) ensures the good consistency of the paste but does not ensure a good condition for the hydration of the cement. We, therefore, observe a retarding effect of the PV for low concentrations.

2. Slump

This is the most commonly used test because it is very simple to implement. The results obtained are presented in the following table:

Table 17. Slump values, E/L ratio

Mortars	PV_0	PV_5	PV_{10}	PV_{15}	PV_{20}
E/L	0,55	0,55	0,55	0,55	0,55
Slump	8,5	5,5	4,65	3,85	3,5

The viscosity of mortars containing PV decreases in proportion to the percentage of PV. The viscosity of the reference mortar PV0 is the maximum value of the measurement. A large difference in viscosity is found between the reference mortar and the mortars containing PV. This means that the control mortar is the most viscous.

c. Properties in the Hardened State

a. Density

The results at 28 days are shown in the following table:

Table 18. Density at 28 days of the mortars

Mortar	PV_0	PV_5	PV_{10}	PV_{15}	PV_{20}
Mass (g)	579	587	582	581	574
Density (g/cm^3)	2.262	2.930	2.273	2.270	2.242

According to Table 18, except for the mortar containing 20% glass powder, the density is high in the other components compared to that of the control mortar. Therefore, the addition of glass powder increases the density considerably; and the composition containing 5% glass powder gives the best result.

b. Porosity

The porosity of a cement paste at 28 days can be modified according to the dosage of glass powder, which is illustrated in the following table:

Table 19. Porosity at 28 days of mortars

Mortar	PV_0	PV_5	PV_{10}	PV_{15}	PV_{20}
Porosity (%)	0.69	0.43	0.60	0.51	0.78

According to Table 19, the porosity of mortars containing 5%, 10%, and 15% glass powder is low compared to the control mortar. On the other hand, the highest percentage of porosity is noticed for a glass percentage of 20%.

c. Flexural Test

The specimens were tested in flexural tension; the results are shown in the following table:

Table 20. Flexural strength of mortars

		Mortars				
	Day	PV_0	PV_5	PV_{10}	PV_{15}	PV_{20}
Strength (MPa)	2	3.9	2.8	2.1	2.0	1.8
	7	4.3	4.4	4.0	3.5	2.8
	28	5.4	5.5	5.0	4.8	4.5

From Table 20, it can be said that the flexural strength increases with age for all specimens.

For 2 days, the flexural strength of the mortar with building sand for the different components is low compared to the control. The rates of decrease are respectively estimated at 1.1%, 1.8%, and 1.9% for the compositions PV5, PV10, and PV15, but for PV20 the rate of decrease is 2.1 compared to the control mortar.

For 7 days, the flexural strength of the mortar with construction sand for the different components is low compared to the control. The decrease rates in the different proportions are respectively estimated at 0.3%, 0.8%, and 1.5% for the compositions PV10, PV15, and PV20 except for PV5 which is high at 0.1%.

For 28 days, the flexural strength of the mortar with construction sand, we note that all compositions PV10, PV15, and PV20 are lower compared to the control PV0 while that of PV5 remains higher. The specimens were crushed by compression after drying in the open air. The results obtained are shown in the following table:

Table 21. Compressive Strength of Mortars

		Mortars				
	Day	PV_0	PV_5	PV_{10}	PV_{15}	PV_{20}
Strength (MPa)	2	21.1	20.1	15.2	14.7	10.8
	7	28.0	25.4	23.9	22.8	20.6
	28	43.5	43.6	42.9	40.5	39.0

Table 21 shows that the compressive strength increases with age for all specimens.

For the 2-day case, the compressive strength of the mortar with construction sand is low in the PV compositions compared to the control mortar.

For the 7-day case, the compressive strength of the mortar with building sand remains below that of the control including 2.6%, 4.1%, 5.2%, and 7.4% for PV5, PV10, PV15, and PV20 respectively.

For the 28-day case, the compressive strength of the mortar with construction sand is higher than that of the control mortar at 0.1% for PV5, yet the other compositions are reduced by 0.6%, 4.0%, and 4.5% respectively for PV10, PV15, and PV20.

IV. Conclusion

Industrial waste is increasing due to technological development and population growth. Therefore, we thought of exploitation in another method to reduce them, we chose the glass waste in the form of powder and partly to replace some of the cement.

The addition of glass powder significantly improves the properties of the mortar. The strength of the mortar with the glass powder gradually increases until it equals or even exceeds that of its equivalent control, i.e. from 10.8 to 43.6 MPa. The low compressive strength at the young age of concrete with glass powder is, as for the other supplementary cementing materials, due to the slow pozzolanic reaction.

According to the results obtained, it can be seen that the increase of glass powders causes a decrease of up to 10% of the hydration and density because glass powders do not absorb water and lighten the mortar.

In any case, it is very likely that the different applications of glass powder as a cement additive are interesting and relevant from an environmental, social, health, and potentially economic point of view. However, it is difficult to imagine that any application of PVM could be more interesting, from an environmental point of view, than its integration in mortar. In the latter, the glass avoids a large number of GHGs emitted during the calcination of the cement raw materials.

The results obtained contribute to a better knowledge of the behavior of glass powder in a cement system. They bring answers to the possibilities of using recycled resources like glass in mixtures with hydraulic binders like Portland cement. The diversity in the results shows that this subject is still far from being exhausted. We hope that the contributions of this research can join the contributions of many researchers in this field. We also hope that this work can be an introduction to other research.

References

Standard NF P 18-555: Aggregates-Measurements of density, absorption coefficient and water content of sands

Standard NF P 18-554: Aggregates-Measurements of density, porosity, absorption coefficient and water content of gravel

Standard NF P 18-598: Aggregates-Equivalent of sand

Standard NF P 18.451: Abrams Cone slump test

Standard NF P 18-560: Aggregates-Size analysis by sieving

Standard NF P 18- 540: Modulus of fineness

Standard EN 196-6: 2018 Test method for cement. Determination of fineness.

Standard EN 196: Test methods for cement

Standard EN 197-1 (2011): Composition, specifications and conformity criteria of common cement.

Standard NM 031-1/2010: Cement for common use

Standard EN 12390-3: Test for hardened concrete. Compressive strength of specimens

Standard NF EN 12350-2: Test for fresh concrete - slump test