

Performances of Clay Soils Stabilised Using Recycled Glass Powder and Cement for Sustainable Construction

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Abstract

Clay soils are abundant and readily available in the Congo; their main limitation for housing construction lies in their high sensitivity to water and to cycles of wet and dry conditions. Stabilising these soils using recyclable waste is now an ideal alternative for producing environmentally friendly materials for the construction of sustainable housing. The methodology of this experimental study involves, on the one hand, incorporating recycled glass waste powder into clay soils sourced from the Samba Alphonse (SA) and Mouyondzi (MY) deposits. Secondly, it involves combining this recycled glass powder with 2% cement in order to improve the properties of these soils and assess their potential for use. Two types of soil had to be identified and 14 samples (SA soil) and 15 samples (MY soil) characterised, mixed with different percentages of glass powder (10, 15, 20, 30, 40, 50%). The results show a significant improvement: a reduction in the plasticity index from 17.5% to 8% (SA) and from 14.4% to 10.8% (MY), an increase in dry density from 1.98 t/m³ to 2.03 t/m³ (SA) and from 1.94 t/m³ to 2.01 t/m³ (MY). These physical and mechanical properties are enhanced by chemical reactions between the amorphous silica present in the glass or cement and the clay minerals, which can help to improve the material's durability. Both stabilised soils are suitable for the production of compressed earth bricks (CEB) and adobe bricks, which are needed for the construction of sustainable housing in developing countries.

Keywords

Eco-Materials, Recycled Glass, CEB, Soils Building, Earth Construction

1. Introduction

The construction of sustainable housing has become a global concern in the face of environmental and economic challenges, as well as demographic pressure. In the Congo, the use of rammed earth and recycled glass waste may offer a suitable alternative in this regard, thereby helping to reduce dependence on imported materials. The benefits of using clay in construction are often summarised in terms of its environmental, cultural and socio-economic advantages, as well as its hygroscopic properties, as indicated by recent studies [1]-[3]. Raw earth can be used in a number of traditional sustainable building methods that are accessible to all socio-economic groups without the need for specialist training (adobe, rammed earth, cob and compressed earth bricks). It is an essential material for the development of the circular economy and the promotion of housing in developing countries. Despite the advantages mentioned above, earthen structures face problems relating to damp and structural integrity in all environments, which limits their lifespan [2]. For decades, cement has been widely used as the main binder to improve the mechanical properties of raw earth and contribute to the durability of structures [4]. The use of hydraulic binders, despite their effectiveness in stabilising fine-grained soils, remains a significant source of greenhouse gas emissions [5]. In this context, given the environmental emergency linked to current climate change, it has become essential to reduce the cement content and to seek out binders with a low carbon footprint. Replacing cement with powdered recycled glass has significantly improved the performance of standard concrete thanks to the combined pozzolanic action of the cement and the glass [5] [6]. The Republic of the Congo has significant deposits of clay soil that have not yet been exploited. Furthermore, the abundance of glass debris in several unregulated landfill sites in major Congolese cities (such as those at Pont du Djoue, the Kinsoundi dam and Bongo-Noira in Brazzaville) poses an alarming problem for urban sanitation. Using this waste to stabilise soil for brick-making or construction enables certain types of locally available soil to be reused. The aim is to contribute to the sustainability of earthen structures and to create jobs that cannot be relocated. This study assesses the effect of adding glass powder at different rates (10, 20, 30, 40 and 50%) and cement (2%) on the physical and mechanical properties of two fine-grained soils from the Mouyondzi and Samba Alphonse deposits, with a view to determining their suitability for use in sustainable construction in the Congo. The production of compressed earth bricks (CEB) from soil stabilised with waste is a recent technique, the physical and mechanical properties of which depend on the quality of the materials, plasticity, compaction energy and particle size distribution [7]. The aim is to determine the optimum mixing ratio, taking into account, on the one hand, the geological variability of the raw soil from one deposit to another; and, on the other hand, the reactivity of the recycled glass powder, which depends on its chemical composition and dosage [8]. The aim is to produce eco-friendly, high-performance building materials from enriched raw earth, which contribute to sustainability and have a low environmental impact throughout their life cycle.

2. Materials and Experimental Setup

2.1. Materials

Samples of raw earth were collected from open-cast deposits at Mouyondzi (**Figure 1(a)**), at the following coordinates: average altitude of 322 m above mean sea level, latitude 036 79 71° and longitude 955 98 46°; Samba Alphonse, south of Brazzaville on the Nganga Lingolo-Linzolo axis, at the following coordinates (**Figure 1(b)**): latitude 4°21'54.95", longitude 15°08'33.45", with an elevation of 310 m NMM and an altitude of 7.01 km. Soil samples from the Mouyondzi deposit are designated MY, and those from Samba Alphonse are designated SA. Four soil samples were taken from each deposit for analysis in Laboratory.



Figure 1. Soil sampling, A) MY and B) SA.

Used glass waste was collected from various unauthorised rubbish dumps in Brazzaville. After being sorted and washed, the pieces of glass were crushed in the Los Angeles test machine and then sieved using a 2 mm sieve to obtain the powder required for preparing the mixtures (**Figure 2(A)-(C)**).



Figure 2. Processing of waste glass: A) crushing, B) screening, C) resulting powder.

The binder used is a CEMII 32.5 limestone Portland cement, manufactured by DANGOTE in the Republic of the Congo, with a standard compressive strength of 32.5 MPa.

2.2. Experimental Setup

Following collection, the soil and waste glass samples were prepared by sorting, selecting, washing and sieving through a 2 mm sieve in accordance with

current standards.

The proportions of the mixture of soils and glass powder (10%, 20%, 30%, 40%, 50%) or cement (2%) were determined on the basis of previous studies, expressed as the dry weight of the material [3] [9]. The experimental measurement of each sample was carried out in accordance with the procedure laid down by the relevant test standards:

Particle size analysis by sieving and sedimentometry, in accordance with current standards [10] [11], was used to determine the grain size distribution of the soils studied using a particle size curve. This curve enables an assessment of the changes in the material's grain size following treatment.

The plasticity of soils and mixtures was assessed using the Atterberg limits test, which determines the liquidity limit (LL) and the plasticity limit (PL), in accordance with standard NF P 94-051 [12]. The plasticity index (PI), which is obtained by the difference between the two limits, is a key parameter in the geotechnical classification of soils and their behaviour during compaction Equation (1):

$$PI = LL - PL \quad (1)$$

The methylene blue value (MBV) or soils blue value (SBV) is a physical-chemical property expressed in grams, which measures the amount of methylene blue adsorbed by 100 g of dry soil, *i.e.* on the outer and inner surfaces of clay particles. According to standard NF P 94-068 [13], this index is determined from the methylene blue staining on a 0/2 mm fraction of soil. This test is used to characterize the clay content (or cleanliness) of a soil.

Soil activity (A_c) is a geotechnical parameter that measures the influence of the clay fraction on the soil's overall plasticity; it characterises the mineral nature of the clay particles. Indeed, when the clay content is sufficiently high, grains larger than two micrometres are coated in clay and hardly touch one another. Skempton's 1953 formula is as follows [14]:

$$A_c = \frac{PI}{CF(\%) < 0.002\text{mm}} \quad (2)$$

With CF : Percentage content of the clay fraction of the soil retained on a 2 mm sieve; PI : plasticity index.

The soil blue value (SBV) characterises the activity of the clays presents in soils and indicates the surface activity of the clays, organic matter and iron hydroxides contained within the fine clay particles [15]. Soil specific surface area (SSA) and cation exchange capacity (CEC) are two fundamental properties that characterise the behaviour of fine-textured soils, defined by the following respective formulae:

$$SSA(m^2/g) = 20.93 * SBV \quad (3)$$

$$CEC(meq/100) = \frac{1000 \times SBV}{374} \quad (4)$$

The MBV, SSA and CEC parameters provide a reliable basis for the indirect identification of soil mineralogy in the absence of X-ray diffraction (XRD) analy-

sis. These indicators are widely used in the literature to characterise the nature and activity of clays, enabling the distinction between the main mineralogical families (smectites, illites, kaolinites) based on their respective signatures [15] [16].

Soil compaction conditions are determined by the modified Proctor test, which establishes the optimum compaction moisture content (OMC) and the maximum dry density (MDD) in accordance with standard NF P94-093 [17].

The mechanical strength of stabilised soils is measured by the compression strength test, using standard prismatic test specimens measuring $16 \times 4 \times 4 \text{ cm}^3$. These test specimens were moulded at the optimum moisture contents obtained from the Proctor test (see **Table 1**) for all soil-glass powder mixtures (10%, 15%, 20%, 30%, 40%) and soil-glass powder-cement mixtures (2%). The clay was first dried in an oven at 105°C for at least 24 hours, then rehydrated 24 hours before moulding to prevent the formation of lumps of clay. The prepared test specimens were then left to cure in a room at an average ambient temperature of 25°C for 14, 21 and 28 days prior to testing the compressive (**Figure 3**). For each curing period, six test specimens were prepared and tested on the IGM Universal testing machine, in accordance with standards NF P98-230-2 and NF EN 196-1 [18] [19].



Figure 3. Prismatic test specimen of stabilised soil.

The compressive strength is calculated using the following formula:

$$C_s = \frac{F}{S} \quad (5)$$

where F is the applied force (kN) and S is the cross-sectional area of the test specimen (cm^2).

3. Results and Discussion

3.1. Characterisation of Raw and Stabilised Soils

3.1.1. Effect of GP on the Particle Size Distribution of the Soils MY and SA

Figure 4(a)-(b) shows the different particle size distribution curves for the raw soils (SA, MY) and after the incorporation of glass powder at various percentages. **Figure 4(c)** shows the particle size distribution curve for the glass powder. In its raw state, the SA soil is a clayey sand predominantly sand; it consists of sand

(59.4%), silt (14.2%) and clay (26.4%). The MY soil is predominantly silty; it consists of sand (34 %), silt (49%) and clay (16.7 %). The percentage of particles passing through the 80 μm sieve—namely SA (40.6%) and MY (65.7%)—exceeds the maximum permitted limit of 35%, which means that both these soils are fine sands in according ASSTHO classification [20]. Glass powder is characterised by a broad particle size distribution ($C_u = 5.95 > 2$) and a well-graded distribution ($C_c = 1.36$, falling within the range of 1 to 3). In other words, the particle size distribution is broad and well-graded. Its sand equivalent is 92%, indicating a very clean material; its density (2.45T/m^3) suggests that it is a specific mixture of glass types.

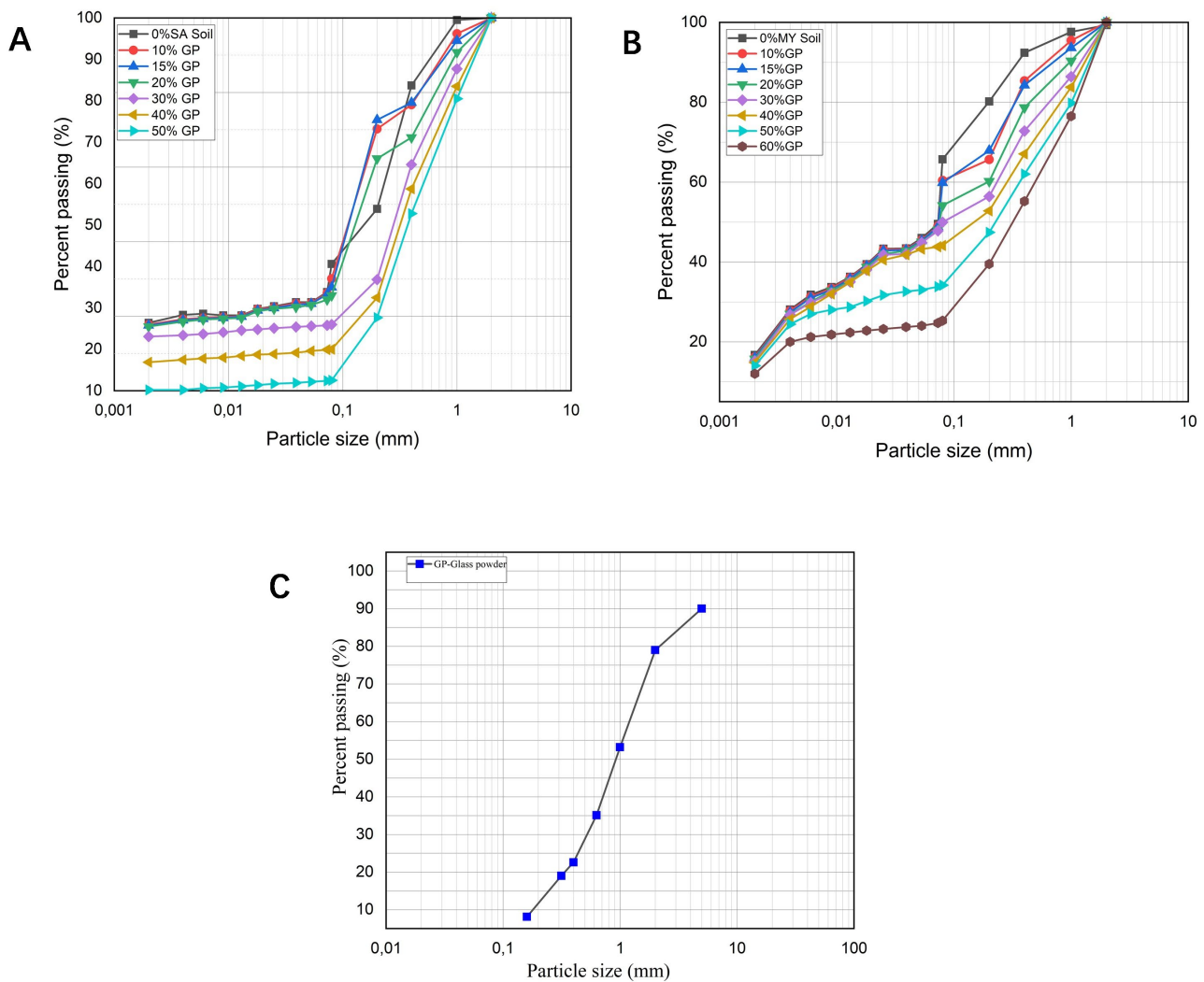


Figure 4. Particle size distribution curves: (a) improved SA soil, (b) Mouyondzi soil, (c) glass powder.

As shown in **Figure 4(a)**, the incorporation of 10% to 50 % glass powder into the SA soil resulted in a reduction in the material's fine particle content. At proportions of 10%, 15% and 20%, more than 30 % of the particles passed through the 80 μm sieve; this percentage of fines is 35% or more when 10% or 15% of glass powder is added. With additions of 30% and 40 % glass powder, less than 30% of

the material passes through the 80 μm sieve; and with a 50 % addition of glass powder, the percentage of fines is slightly over 12%. Furthermore, **Figure 4(b)** shows a gradual decrease in the fines content following the incorporation of 10% to 60 % glass powder into the MY soil. More than 30 % of the particles pass through the 80 μm sieve when the proportion of glass powder is between 10% and 50%. When the glass powder content is between 10% and 40 %, the material has a fines content of more than 35%; when the glass powder content is between 50% and 60 %, the fines content is less than 35%.

3.1.2. Plasticity and Blue Values of MY and SA Soils

The improvement in the granular skeleton resulting from the addition of glass powder led to a gradual decrease in the plasticity index (PI) of the soils tested. The plasticity index (PI) fell from 17.5% (untreated soil SA) to 8 % following the addition of 50% glass powder, thereby confirming the hypothesis that glass powder reacts chemically effectively in granular mixtures [21]. The PI of the MY soil decreased from 14.4 % to 10.8% with the gradual addition of glass powder. **Table 1** presents the Atterberg limits, Proctor values, methylene blue values (VBS) and blue activity index (AC) of the clay fraction in the SA and MY soils, the specific surface area (SSA) and cation exchange capacity (CEC) of the soils, as well as their geotechnical classification (AASHTO) [20] [22].

Table 1. Geotechnical characteristics and classification of SA and MY soils.

Sample	Granular fractions (%)			P (%) 80 μm	LL	PL	PI	VBS	MDD	OMC	Classification ASSTHO/HRB	AC	SSA	CEC
	Argile	Limon	Sable											
SA	26.4	14.2	59.4	40.6	39.4	21.9	17.5	0.66	1.98	11.5	A-6(6)	0.66	13.8	1.76
MY	16.7	49.0	34.0	65.7	30.5	16.1	14.4	1.08	1.94	10.3	A-6(8)	0.86	22.6	2.89

Note: A-6: clay soil; with HRB group indices of 6 and 8.

The soil's blue value quantifies the absorption capacity of the clays present in the soil. According to standard NF P 11-300 [23], the two soils with blue values (VBS) between 0.66 and 1.08 are close to the threshold for loamy soils with low plasticity. In terms of the plasticity index (PI) and the liquid limit (LL), the Casa-grande diagram classifies these two soils as low-plasticity clay (Ap). Furthermore, the activity of the two soils makes it possible to clearly distinguish their respective natures. The activity of soil SA (0.66) which is less than 0.75, shows that the clay fraction is inactive, and this natural soil does not absorb water. The soil activity of MY (1.08), which is greater than 0.75 but less than 1.25, indicates that the clay fraction is active (Ac) [14]. This soil is capable of absorbing a great deal of water, which makes earth blocks less stable in construction.

Meanwhile, the VBS, SSA and CEC indices define the mineralogy of soils. Indeed, for the SA soil, the VBS (0.66), SSA (13.8) and CEC (1.76) values show that the SA soil is composed mainly of kaolinite, characterised by low activity and good

volumetric stability. The MY soil, with a VBS (1.08), SSA (22.6) and CEC (2.89), is composed of illite and exhibits increased sensitivity to changes in moisture and chemical conditions. These results corroborate the work of Elamathi *et al.* [24] and Ike *et al.* [25], who emphasise the importance of mineralogy and specific surface area in the mechanical and hydraulic behaviour of fine-grained soils. SA soil, which contains kaolinite, has good plasticity for moulding green bricks and contributes to stable cohesion after drying. MY soil is more sensitive to water than SA soil due to its mineralogy (illite). To improve the durability of structures against the wet-dry cycles characteristic of a tropical climate, it is proposed that these two soils be stabilised using recycled glass powder and cement (2%). **Figure 5** and **Figure 6** illustrate the effect of recycled glass powder on the improvement in plasticity and the changes in the maximum dry densities of the two soils.

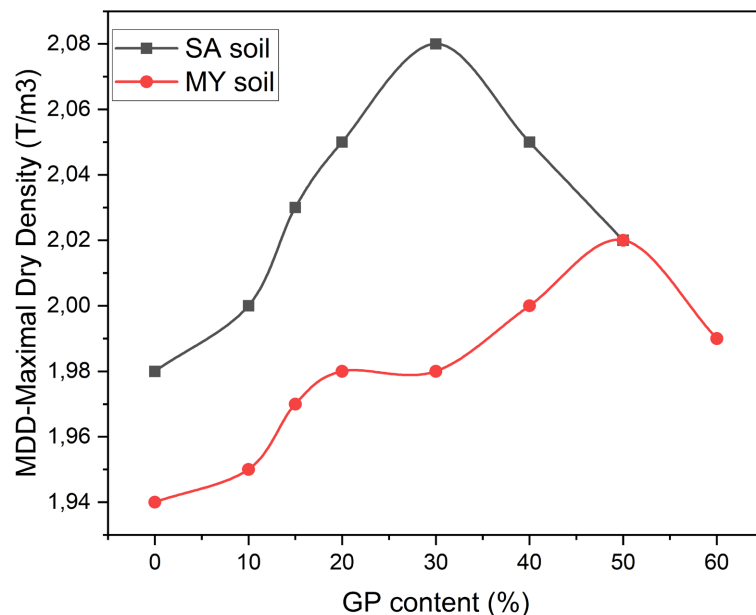


Figure 5. Changes in the maximum dry density of soils treated with recycled glass powder (10, 15, 20, 30, 40, 50, 60%).

Figure 5 shows that adding glass powder to the SA soil significantly improves its compactability. The curve for maximum dry densities clearly follows a parabolic shape, enabling the identification of the optimum point for the mixture containing 30% glass powder, which yields a maximum dry density of 2.08 t/m³. In the case of MY soil, the addition of glass powder results in erratic behaviour between 0% and 30% glass powder; good compactability is observed between 30% and 60%, with the curve taking on a bell-shaped profile at 50% glass powder, corresponding to a maximum dry density of 2.01 T/m³. However, the addition of 2% cement significantly alters the compaction behaviour of both soils, as shown in **Figure 6**, although it does improve their mechanical durability. This phenomenon can be explained by the strengthening of the granular bonds within the mixture due to the cementation of the binder.

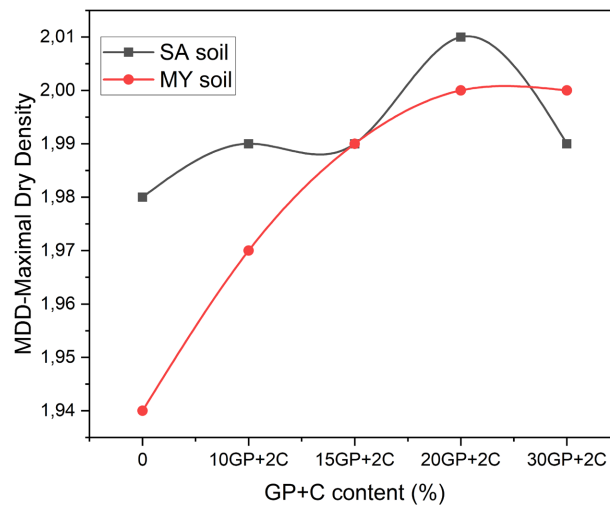


Figure 6. Changes in the maximum dry density of SA and MY soils treated with recycled glass powder (10, 15, 20, 30%) and cement (2%).

3.2. Compressive Strength of CEB Compressed Earth Bricks Following Stabilisation with Glass Powder and Cement (2%)

Compressive strength is an important indicator of structural safety; it characterises the mechanical behaviour of construction materials. **Figure 7** shows the compressive strengths of test specimens made from the two soils, SA and MY, mixed with different percentages of glass powder.

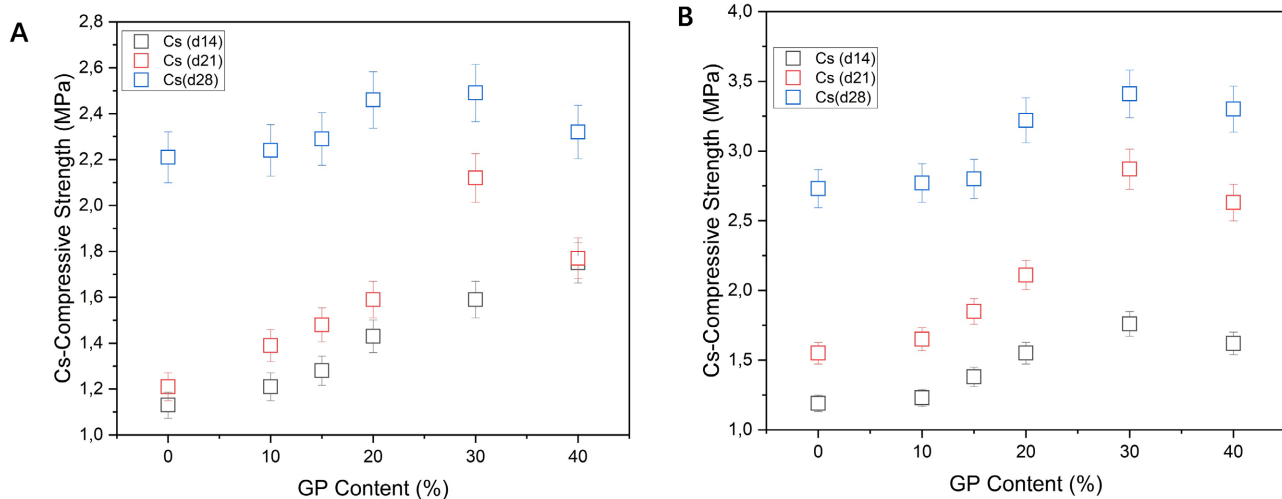


Figure 7. Effect of glass powder (10, 15, 20, 30, 40%) on the compressive strength of: A) SA soil, B) MY soil.

In this experiment, with the exception of the mixture containing 40% glass powder where the mechanical strength decreased at 28 days for both soils studied an increase in strength values was observed for mixtures containing between 10% and 30% glass powder. Optimal strengths were achieved at 28 days for all formulations containing 20% and 30% glass powder, respectively. The mixture containing 30% glass powder yielded the highest strength values: 2.49 MPa at 28 days for the SA soil

and 3.41 MPa for the MY soil. The compressive strength obtained from MY soil mixtures 30% glass powder content (3.41 MPa) is close to the minimum strength of 3.50 MPa specified in the ASTM C129 standard [26], which is sufficient to ensure the safety of the structure. Furthermore, these results also demonstrate the significant influence of fine particles on the mechanical properties of the treated soils.

The setting point determined for the mixture of glass powder and cement with the SA and MY soils is 30% GP (Figure 7). Figure 8 illustrates the development of compressive strength at 14, 21 and 28 days for compressed earth bricks stabilised by the addition of glass powder (10, 15, 20, 30, 40%) and cement (2%).

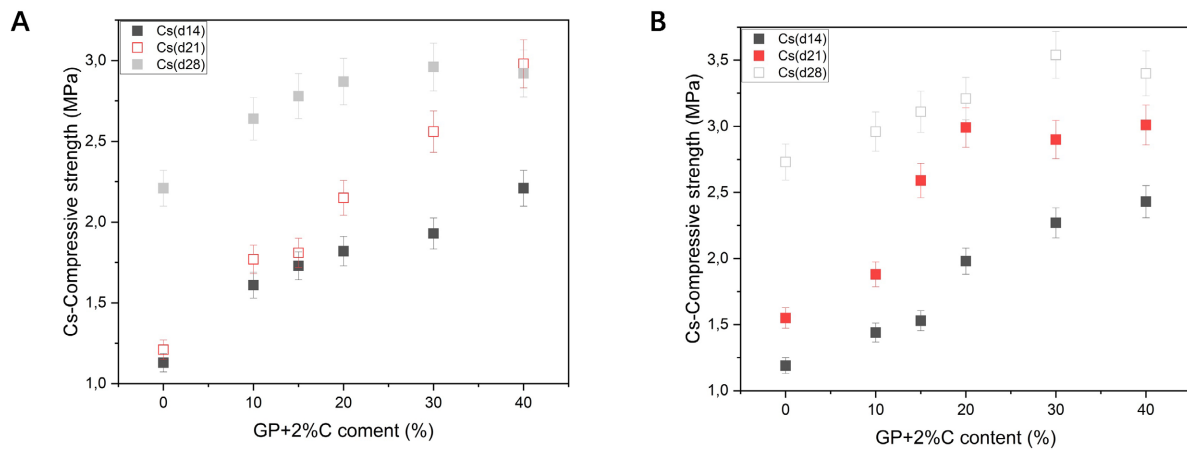


Figure 8. Effect of glass powder (10,15, 20, 30, 40%) and cement (2%) on the compressive strength of compressed earth bricks at 14, 21 and 28 days, A) SA soil and B) MY soil.

The compressive strength of SA and MY soils treated with glass powder and 2 per cent cement typically develops between 7 and 28 days (Figure 8). It shows a marked increase compared with stabilisation using glass powder alone.

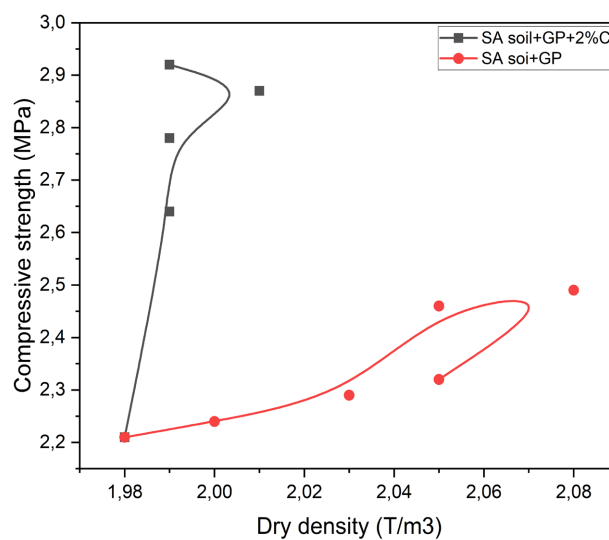


Figure 9. Correlation curve showing compressive strength as a function of dry density for the two soils treated with glass powder and 2% cement of SA soil.

The compressive strength obtained with 30% glass powder and 2% cement at 28 days is 2.96 MPa for soil SA and 3.54 MPa for soil MY, which confirms the compaction results shown in **Figure 3** and **Figure 4**. This shows that glass powder modifies the intergranular bonds in the soil by acting as a hydraulic binder, in the same way as cement. **Figure 9** and **Figure 10** models the mechanical behaviour of these two soils treated with glass powder and 2% cement. The 28-day compressive strength of these two soils varies irregularly along a non-linear parabolic curve, defining its relationship with dry density.

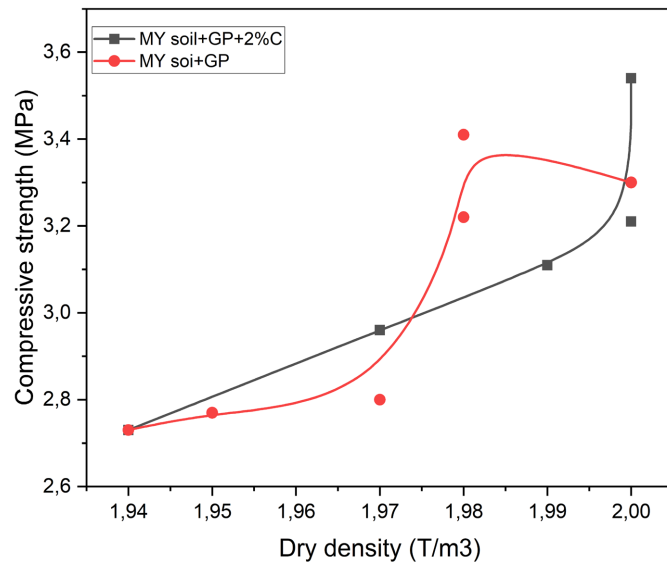


Figure 10. Correlation curve showing compressive strength as a function of dry density for the two soils treated with glass powder and 2% cement of MY soil.

Whether the soil stabilisation involves the use of glass powder alone or a mixture of this powder with 2% cement, the equations obtained follow a second-degree polynomial, the formula for which is as follows:

$$C_s \text{ (MPa)} = A + B(DD) + C(DD)^2 \quad (6)$$

Where: C_s [MPa] is the compressive strength; DD [T/m^3] is the dry density; R^2 is the coefficient of determination, and RSS is the sum of the residual squares.

The values of the determined constants are given in **Table 2**.

Table 2. Determination of the constants A, B, C, RSS et R2 of soils SA and MY with adding GP or cement.

Characteristic	Parameters	Soil formulation and stabilisers			
		SA + GP	SA + GP + 2%C	MY + GP	MY + GP + 2%C
C_s (MPa)	A	-7005.9 ± 2	62 ± 99.7	-132.7 ± 908	527.9 ± 841
	B	7004.4 ± 2	-61.7 ± 98.3	126.2 ± 923	-543.3 ± 853
	C	-1749.9 ± 6	15.9 ± 24.2	-29 ± 234	140.5 ± 216
	RSS	0.01	0.00	0.04	0.03
	R^2	$R^2 = 0.87$	0.83	0.7	0.8

According to **Figure 11**, the addition of glass powder results in a moderate increase in the compressive strength of soil SA, following a relatively gentle trend as the dry density increases, ranging from 1.98 to 2.08 T/m³. The addition of 2% cement amplifies the effect of dry density on compressive strength, with a more pronounced decrease corresponding to a density of 2.08 T/m³. This is due to the improved cohesion and microstructure of the material. **Figure 9** and **Figure 10** shows the increase in the compressive strength of MY soil as a function of its dry density for the two formulations studied (soil + GP; soil + GP + 2% C). Although treatment with glass powder alone already improves performance compared with natural soil, the addition of 2% cement enhances the cohesion and compaction of the soil-GP mixture, resulting in increased mechanical strength. This phenomenon can be explained by changes in the strength of the physical-chemical bonds between the clay platelets and by an increase in capillary resistance due to the gradual reduction in water content, as demonstrated by previous studies [2] [27]. The coefficients of determination ($R^3 = 0.8$) and the sum of squares of residuals (RSS = 0.0) obtained accurately characterise the modelling of the compressive strength curve for the various formulations studied. The identified applications of the eco-materials based on the two soils (SA, MY), discussed in accordance with the relevant experimental diagrams in the following paragraph, highlight the effectiveness of the stabilisation method tested.

3.3. Discussion: Characterisation of the Influence of Glass Powder and Cement on the Production of Eco-Materials

The methods of use for the two soils are defined according to the criteria of wettability, plasticity and compressibility [28] [29]. **Figure 11** assesses the granularity of the MY and SA soils according to the reference range defined in CRATerre [30], where the diameter of the largest particles in the soils must not exceed 20 mm.

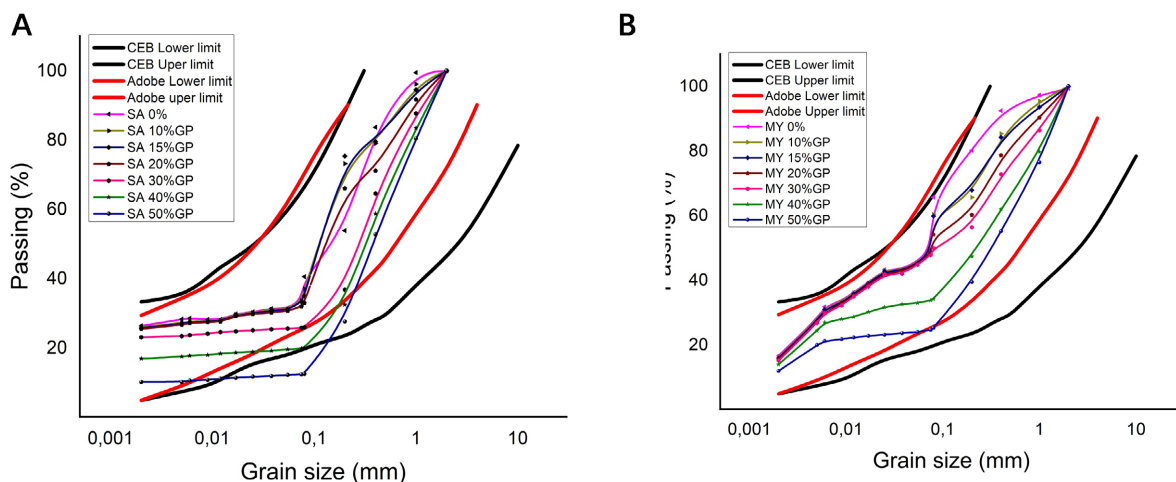


Figure 11. Grain size distribution of MY and SA stabilised soils compared with the CRATerre reference scale (Houben *et al.* 1996) [30].

From 0 to 20% GP, the SA soil is suitable for the production of adobe bricks,

and from 0 to 40% GP, the soil is suitable for the production of CEBs (**Figure 11(A)**); at 50% GP, this soil is no longer suitable for either of these types of eco-materials. However, for MY soil, regardless of the addition rate of GP from 0 to 50%, the soil is suitable for the production of adobe bricks and CEBs (**Figure 11(B)**).

Casagrande's plasticity diagram (**Figure 12(a)**) shows that SA soil initially exhibits excellent moulding properties for pottery, even after the addition of 10% - 15% glass powder. Its moulding properties, which are essential for the production of greenware blocks, begin to change from 20% glass powder onwards, with the mixtures tending increasingly towards a low-cohesion consistency. For the MY soil, adding varying percentages of glass powder gradually alters the consistency of the material, resulting in a low-cohesion consistency, which is recommended for the production of traditional earth bricks (**Figure 12(b)**).

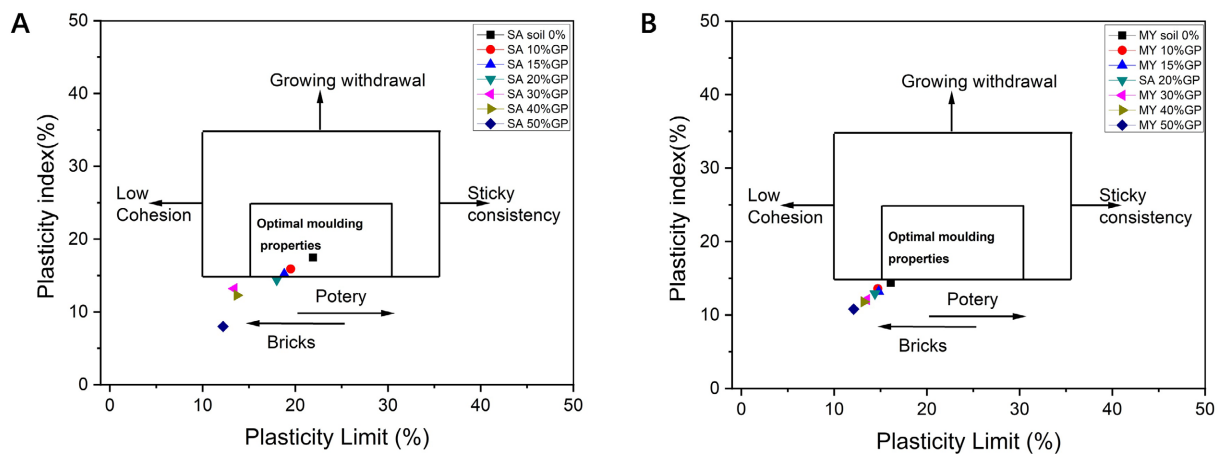


Figure 12. Effect of glass powder on the wettability of A) SA soil and B) MY soil.

Figure 13 illustrates the applications of the two treated soils in terms of their plasticity, combining the plasticity index and the liquid limit.

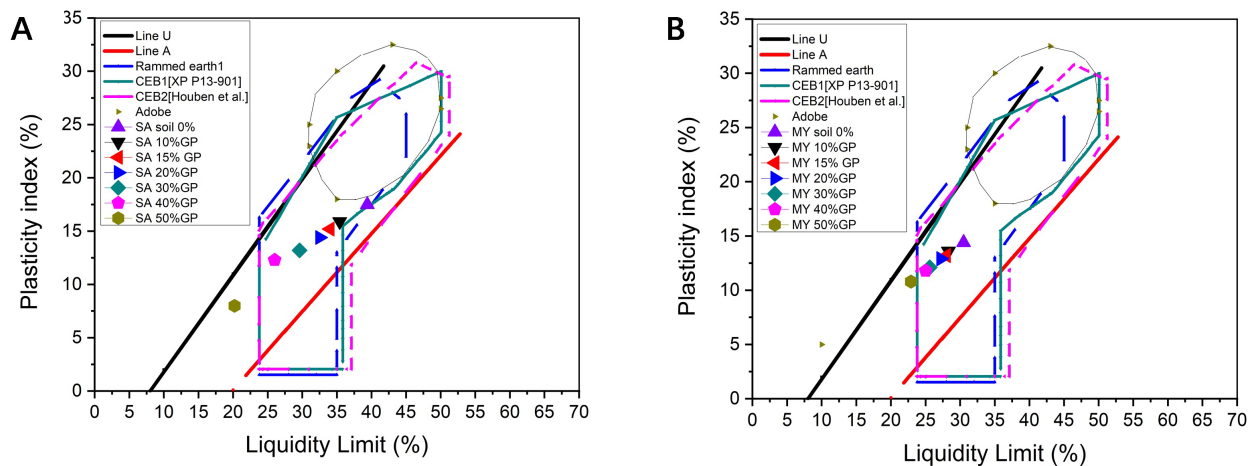


Figure 13. Modes of use for the two soils treated with glass powder, based on plasticity: A) SA, B) MY.

Both soils, SA and MY, treated with glass powder (10% - 40%), fall within the plasticity ranges required for compacted earth and compressed earth blocks (CEB), in accordance with current technical standards [31] [32]. When the glass powder content exceeds 50%, these clays are no longer suitable for the manufacture of earth bricks.

The use of the compaction cone recommended for earthen structures shows that SA soil treatment with the addition of 40% to 50% glass powder falls within the compaction cone range for CEB; a range of 0 to 30% is not permitted. Whereas the addition of 2% cement and 10 to 30% GP fits well within the CEB diagram (Figure 14(a)). As regards MY soil, mixtures containing 10% - 20% glass powder are suitable for rammed earth, whilst those containing 30% - 50% are suitable for CEB, whether or not 2% cement is added (Figure 14(b)).

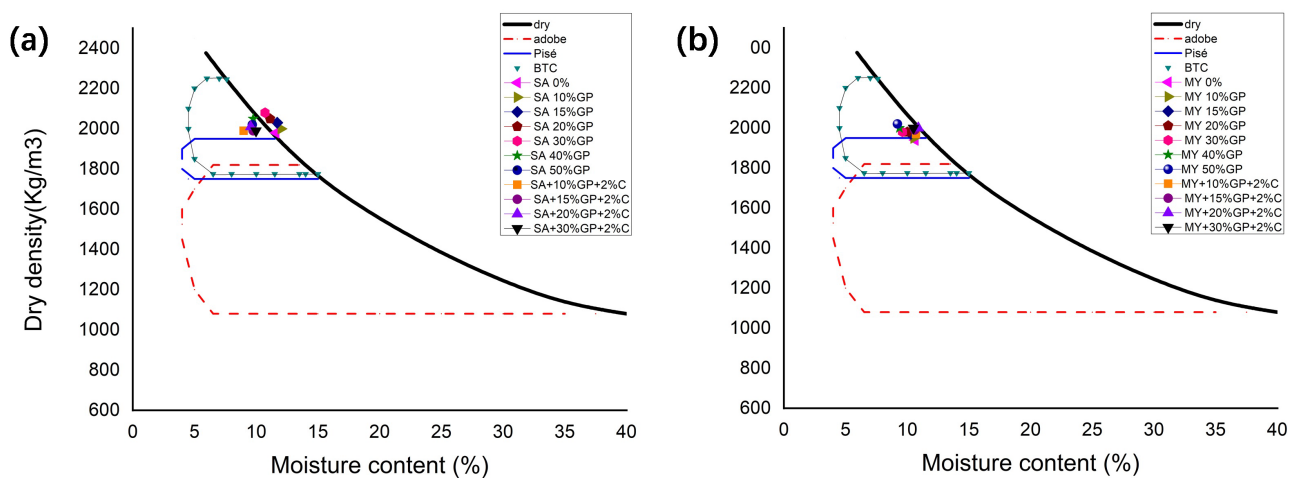


Figure 14. Applications of raw earth treated with glass powder and cement, based on compressibility: (a) SA and GP (10, 15, 20, 30, 40, 50%); SA-GP (10% - 30 %) and C (2 per cent); (b) MY and GP (10, 15, 20, 30, 40, 50%); MY-GP (10% - 30%) and C (2%).

4. Conclusion

This study assessed the potential for utilising waste glass in the stabilisation of clay soils for the construction of sustainable housing. It demonstrated the influence of the chemical reaction of glass powder on the properties of clay soils of Samba Alphonse (SA) and Mouyondzi deposits (MY). A significant increase in the dry density of the modified Proctor optimum was observed, particularly with higher proportions of recycled glass powder. This explains the good compaction of the clay soil–crushed glass powder mixtures, due to the void-filling effect of the grains. The reduction in the plasticity index, the decrease in the percentage of fines and the increase in the compressive strength of the mixtures as the glass powder content increases enable the soils studied to meet the fundamental requirements of sustainable construction (compressed earth block or rammed earth masonry). Adding 2% cement further improves the durability of the material stabilised using the Proctor process. Beyond the disposal of industrial waste (such as waste glass) in urban areas, the reuse of raw earth and waste glass in green building addresses

a major challenge in the development of the circular economy, a cornerstone of the ecological transition. Against a backdrop of strong growth in the local workforce, this method of producing eco-materials helps to conserve natural resources and bolster the construction sector's resilience in the face of current economic and climate challenges. This study will then continue with an analysis of different concentrations of glass powder in other types of soil in the Congo and an assessment of the energy balance of the compressed earth brick (CEB) manufacturing process. It will also examine the thermal and chemical properties and the microstructure of the resulting material (pH measurements, XRF spectroscopy, X-ray diffraction, scanning electron microscopy, etc.), as well as the durability of the CEB building system.

Author Contributions

Conceptualization, S. Ndinga Okina and L. Ahouet; methodology, S. Ndinga Okina and L. Ahouet; software, S. Okassa Mouele and A.S. Ndongo, S. Ndinga Okina.; validation, S. Ndinga Okina and L. Ahouet, and A.S. Ndongo; formal analysis, S. Ndinga Okina; investigation, S. Okassa Mouele; resources, A. Nkombo; data curation S. Okassa Mouele. and A. Nkombo; writing—original draft preparation, S. Ndinga Okina and L. Ahouet; writing—review and editing, S. Ndinga Okina and L. Ahouet and A.S. Ndongo; visualization, S. Ndinga Okina; supervision, L. Ahouet. All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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