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ANALYSIS OF THE WATER AND THERMAL BEHAVIOR OF COUCH GRASS FIBERS

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ABSTRACT
Wrongly considered a "weed", Couchgrass is a tenacious grass whose rhizome (underground stems) contains many compounds with diuretic, draining and purifying properties. This fiber is traditionally used to improve the characteristics of the soil for earth constructions. This study is intended to physically characterize couchgrass fibers (ELYTRIGIA REPENS). The fibers, collected in AGOE DALIKO in Togo, cut into pieces of dimensions of approximately 3 to 5 cm, underwent identification tests, physical and water characterizations. Couchgrass fibers have an apparent density of 0.49 and an absolute density of 1.6. They become saturated with water after an imbibition time of 2.5 h and lose their water after drying times of 128 h, 80 h and 3 h at exposure temperatures of 29°C, 32°C and 140°C. After 2 h to 3 h, couch grass fibres completely lose their properties. This study has highlighted the sensitivity of couch grass fibres to water and heat, allowing provisions to be made regarding their use as reinforcing fibres for earth constructions.

KEYWORDS: Couch grass, earth construction, water characteristic, fire resistant

1. INTRODUCTION
To shelter from bad weather, man initially took refuge in sites or natural shelters, such as caves, but as the population grew, he was forced to design his own homes. This gave rise to traditional construction methods. It is an ecological, simple and local technique, but vulnerable. More than two billion people on the planet now live in raw earth dwellings. The study of the physical properties of grains of sand and construction techniques show the diversity of earth architecture which, far from being just a tradition, is a promising technique for the future in the context of sustainable development [1]. Indeed, when raw earth is left in the open air, it is particularly sensitive to climatic conditions (rain, wind, etc.). Water and sun are factors likely to cause significant damage to earth structures, compromising their durability [2]. Which reduces the lifespan of earth constructions.

With the advent of the material "Reinforced Concrete", the need to offer personal and modernized comfort arises, pushing man to an innovative and personalized use of modern or conventional materials to the detriment of local materials (raw earth materials). However, faced with energy problems and recurring economic crises, as well as an ecological awareness, the interest in building in earth becomes a preferred choice. It is estimated at 30% the share of earth constructions in the world [3]; mainly in underdeveloped countries, earth construction treaty. On the African continent, the majority of rural and even urban constructions are in "banco" (West Africa), in "thobe" (Egypt and northern regions), in "daga" (South-East Africa) or in "leuh" (Morocco) [2]. Although concrete construction is experiencing a certain boom, earth is still used in Togo, particularly for housing in rural areas. The term "earth" here more or less refers to clayey soil or bar earth which is very common on the surface of the earth and constitutes the local materials par excellence. Also, the mechanical characteristics of unstabilized earth material are quite weak and often random in a context of construction that is very predominantly artisanal. To give the earth a certain number of sought-after qualities, it is often modeled, compressed, associated or not with other materials such as plant fibers in order to improve its physical and mechanical characteristics. These works,

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once built, most often present pathologies such as cracks, cavitations, craters, bursts, crazing, porosities, permeabilities, etc.

Many methods of manufacturing earth bricks have been developed in Africa and particularly in Togo, in relation to the level of development of housing in urban and rural areas. Among these, the processes of compaction and chemical stabilization of the earth by adding a stabilizer, in particular lime, cement and plant fibers, give the brick physical and mechanical properties that determine its behavior with respect to the stresses imposed on it. The texture and structure of the earth, its porosity and its granulometry are essential elements of the behavior of the brick with respect to air humidity and the direct action of rain. Although the problem of the resistance of earth bricks has always interested building engineers, it remains difficult to solve in a general framework. In order to enhance the value of these earth materials locally available in Togo, for use in earth constructions, by improving their failing properties through the use of additive materials from vegetation, this study aims to study the properties of couch grass fibers, by characterizing them by their physical, water and thermal properties.

2. MATERIALS AND METHODS

The following raw material and equipment are used for this study:

- Couch grass fibers collected from a plantation in the maritime region near the city of Lomé (locality of AGOE – DALIKO) (**Figure 1)**
- A SINBO brand digital scale, with a maximum capacity of 5kg and a precision of 1g;
- A SIMEO brand microwave oven, maximum temperature 150°C for drying samples;
- Tares;
- A graduated cylinder with a capacity of 800 ml
- A MIDNIGHT SUN brand thermometer with a maximum temperature of 60°C, for room temperature

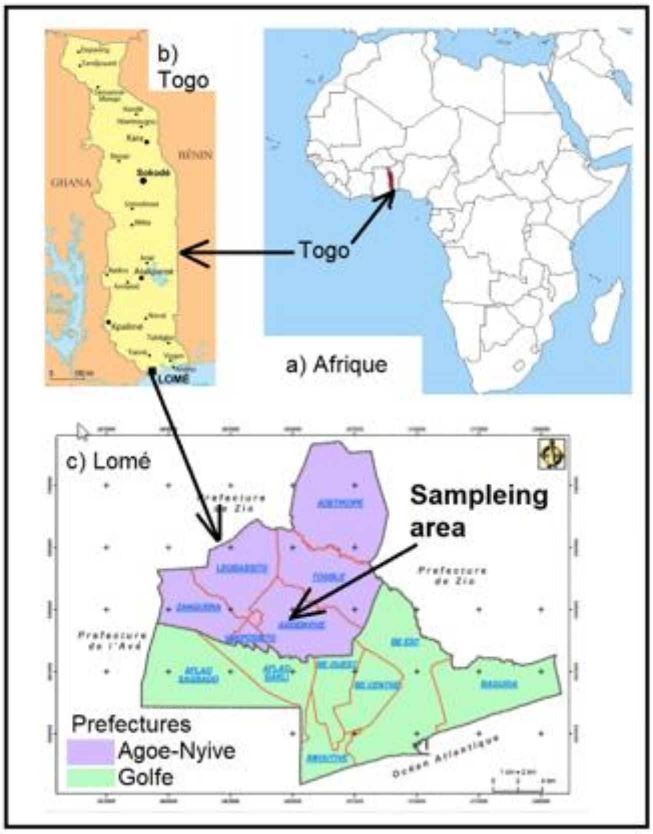

Figure 1: Location of the couch grass fiber sampling area

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The fibres collected on site are cut into pieces of approximately 3 to 5 cm before undergoing physical characterisation tests after their exposure to the shade at 29°C, to the sun at 32°C and to the oven at 140°C.

Evolution of natural water loss over time **[4] [5]**: It is obtained under three states (shade, sun, oven). The mass of the dry material is determined by successive mass measurements (mn_i) up to constant mass by exposing the fiber taken to the shade, sun and oven **[6].** For each state (shade, sun, oven), the natural water content is calculated by equations (1) and (2).

— For the instantaneous natural water loss rates (Tn_i)

$$Tn_i = \frac{mn_{i+1} - mn_i}{mn_0} \qquad (1)$$

— For cumulative natural water loss rates (Cn_i)

$$Cn_i = \frac{mn_i - mn_0}{mn_0} \qquad (2)$$

mn_o denotes the initial mass at the start of the test

- **Water absorption measurement [4] [5]:** Water absorption is obtained by successive mass measurements (ma_i) up to a constant mass after imbibition of the dry fiber. The calculation of the absorption coefficient is given by equations (3) and (4):

— For the instantaneous water absorption rate (Ta_i)

$$Ta_i = \frac{ma_{i+1} - ma_i}{ma_o} \qquad (3)$$

— For the cumulative water absorption rate (Ca_i)

$$Ca_i = \frac{ma_i - ma_o}{ma_o} \qquad (4)$$

ma_o is the mass of dry fibers (mass at the start of the absorption test)

- **Measurement of absorbed water loss**: The determination of water loss after saturation of the fibers is obtained by measuring masses (mp_i) up to a constant mass during drying under the 3 states (Shade, sun, oven). Equations (5) and (6) give the expressions of water losses:

— For instantaneous water loss rates (Tp_i)

$$Tp_i = \frac{mp_{i+1} - mp_i}{mp_0} \qquad (5)$$

— For cumulative water loss rates (Cp_i)

$$Cp_i = \frac{mp_i - mp_o}{mp_0} \qquad (6)$$

- **Measurement of fire resistance**: It consisted in the search for the water content at which the fiber begins to calcine. Thus, to determine it, mass measurements up to the start of calcination of the fiber by passing the wet fiber through the oven are made. The calculations of the fire resistance are given through equations (7) and (8):

— For instant fire resistance

$$Tte_i = \frac{mte_{i+1} - mte_i}{mte_0} \qquad (7)$$

— For cumulative fire resistance

$$Cte = \frac{mte_i - mte_o}{mte_0} \qquad (8)$$

With:
mte_{i+1} : mass of water content at time i+1
mte_i : mass of water content at time i
mte_0 : mass of water content at the initial time

3. RESULTS

Couch grass fibers with an apparent density of 0.49 and an absolute density of 1.6, have the hygrometric and fire resistance properties given in **Figure 2 to Figure 11.**

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These results show two distinct behaviors of the fibers in the presence of water:

— Rapid absorption or loss of water during the first periods
— Very slow absorption or loss of water with parking.

This behavior is also observed on the fibers in the presence of heat.

So :

- The fibers lose their natural water after 80 h, 56 h and 1.5 h for respective storage in the shade (29°C), in the sun (32°C) and in the oven (140°C) (**figure 2(b)** to **figure 4(b)).** These instantaneous water losses are sudden in the first hours: 32 h, 24 h and 1 h respectively at 29°C, 32°C and 140°C (**figure 2(b)** to **figure 4(b), table 1**).

Table 1: Natural water loss coefficients of Couch Grass

Measured parameter	Place of conservation	Mean temperature	Natural water loss: Tn_i , Cn_i (%)	Duration (Hour)
Instantaneous water loss	Shade	29°C	0.38	32
	Sun	32°C	0.46	24
	Oven	140°C	0.52	1
Cumulative water loss	Shade	29°C	2.02	80
	Sun	32°C	1.79	56
	Oven	140°C	1.03	1.5

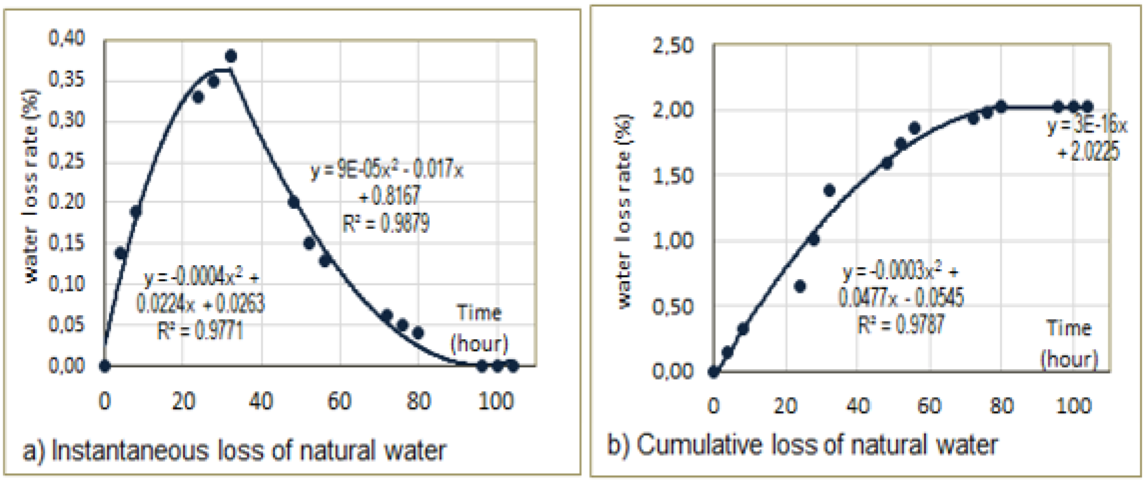

Figure 2. Variation of natural water loss of Couch Grass in the shade (29°C)

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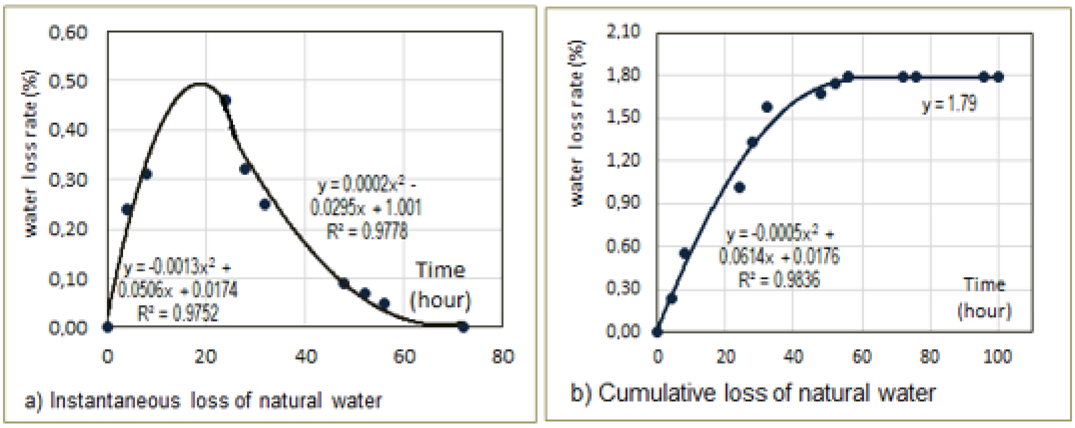

Figure 3. Variation of natural water loss of Couch Grass in the sun (32°C)

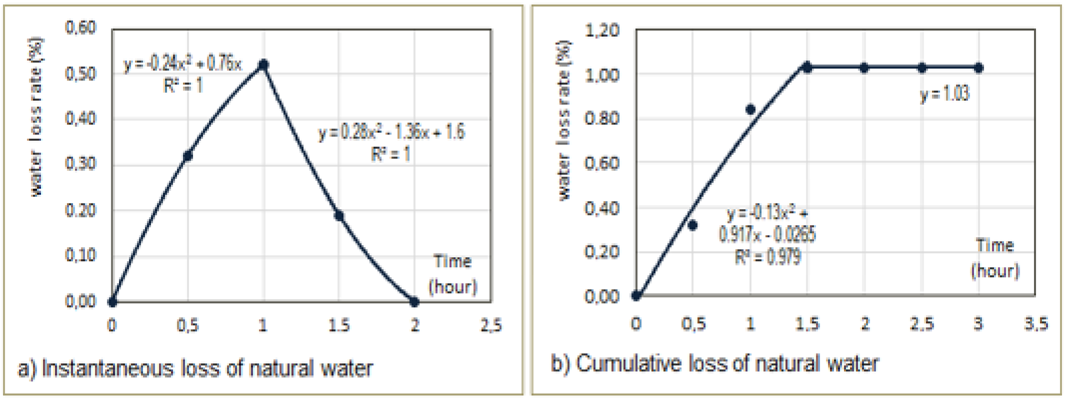

Figure 4. Variation of natural water loss of Couch Grass in the oven (140°C)

- The dried fibers soaked in water become saturated with water in 2.5 h (**Figure 5(b), Table 2**). This water absorption increases in the first thirty minutes (**Figure 5(a), Table 2**).

Table 2: Water absorption coefficient of Couch Grass in the shade (29°)

Measured parameter	Water absorption: Ta_i , Ca_i **(%)**	Duration (Hour)
Instantaneous water absorption	25	0.5
Cumulative water absorption	46.24	2.5

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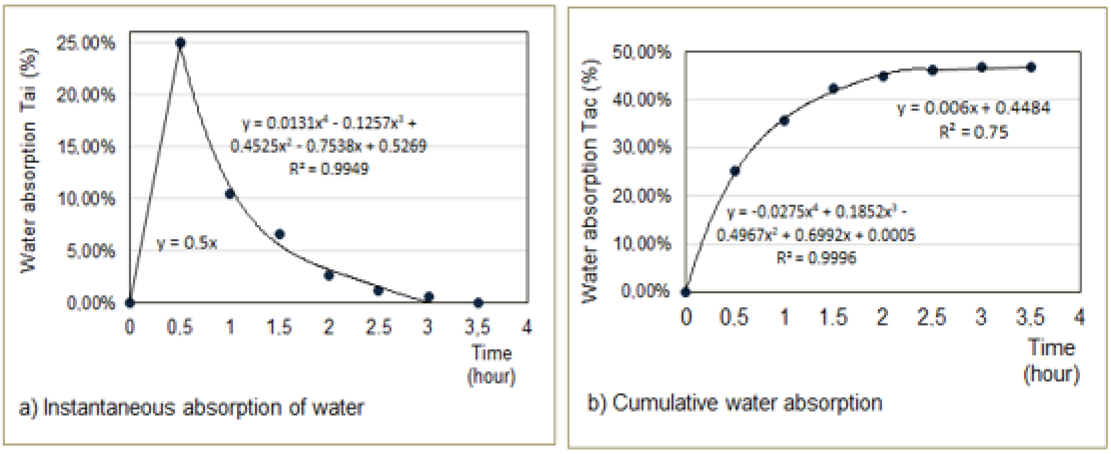

Figure 5. Variation in water absorption of Couch Grass (29°C)

- Total water losses from the fibers after saturation occur in 128 h at 29°C of storage, 52 h at 32°C and in 2 h at 140°C (**figure 6(b)** to **figure 8(b), table 3**). These water losses are sudden in the first 80h, 52h and 2h respectively for temperatures of 29°C, 30°C and 140°C (**figure 6(a)** to **figure 8(a), table 3**).

Table 3: Water loss coefficients absorbed by Couch Grass

Paramètre mesuré	Place of conservation	Mean temperature	Loss of absorbed water : Tp_i , Cp_i (%)	Duration (Hour)
Instantaneous water loss	Shade	29°C	0.70	80
	Sun	32°C	0.62	52
	Oven	140°C	0.60	2
Cumulative water loss	Shade	29°C	6.63	128
	Sun	32°C	4.49	80
	Oven	140°C	2.88	3

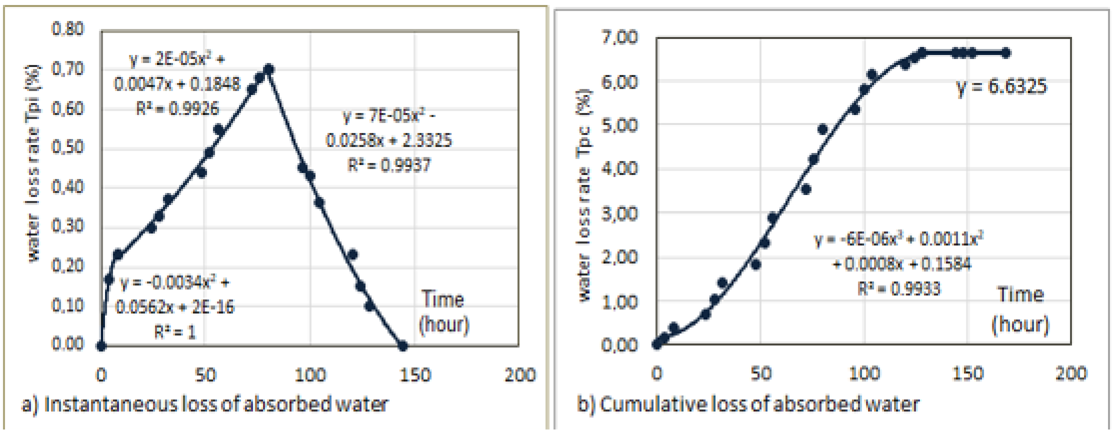

Figure 6. Variation in water loss of Couch Grass in the shade (29°C)

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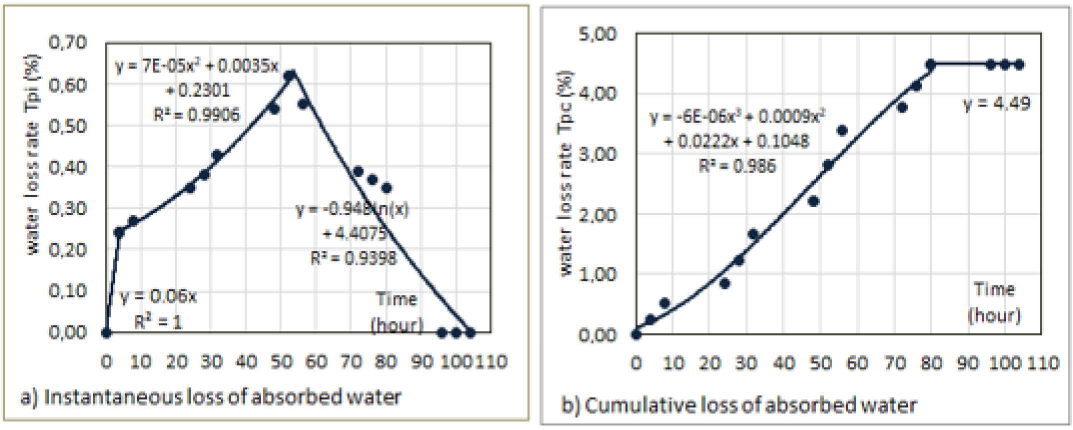

Figure 7. Variation of water loss of Couch Grass in the sun (32°C)

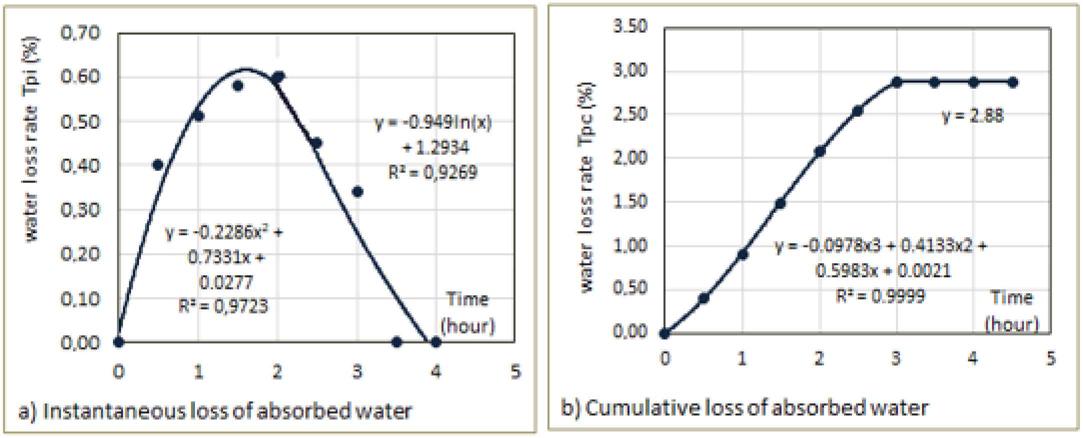

Figure 8. Variation in water loss of Couch Grass in the oven (140°C)

- In the wet state, Couch Grass fibers lose their characteristics under the action of high temperature after 3 hours, whereas these properties are lost after 2 hours in the dry state (**figure 9, figure 10** and **table 4**).

Table 4: Fire resistance coefficients of Couch Grass

Paramètre mesuré	Condition of fibers	Fire resistance (%)	Duration (Hour)
Instantaneous fire resistance	Dry fiber	0.90	1.5
	Wet fiber	0.90	2
Cumulative fire resistance	Dry fiber	2.25	2
	Wet fiber	3.63	3

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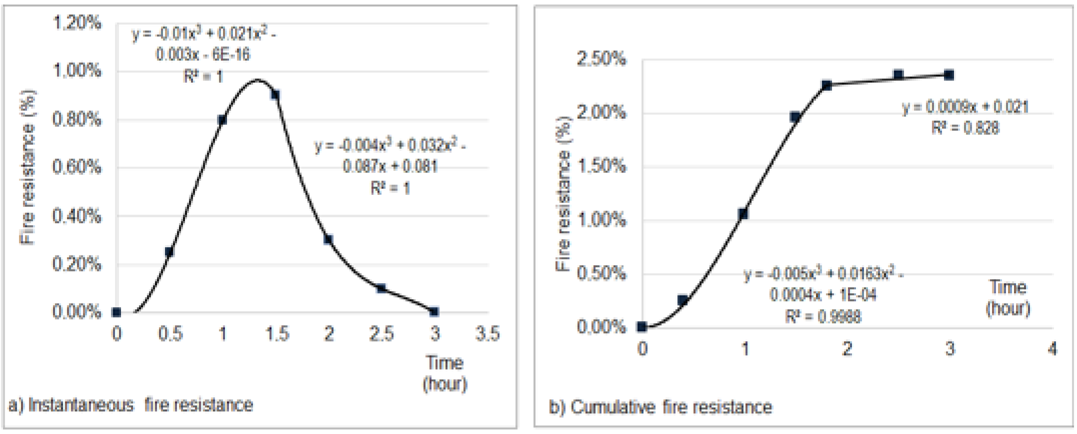

Figure 9. Results of the instantaneous fire resistance of dry Couch Grass fiber

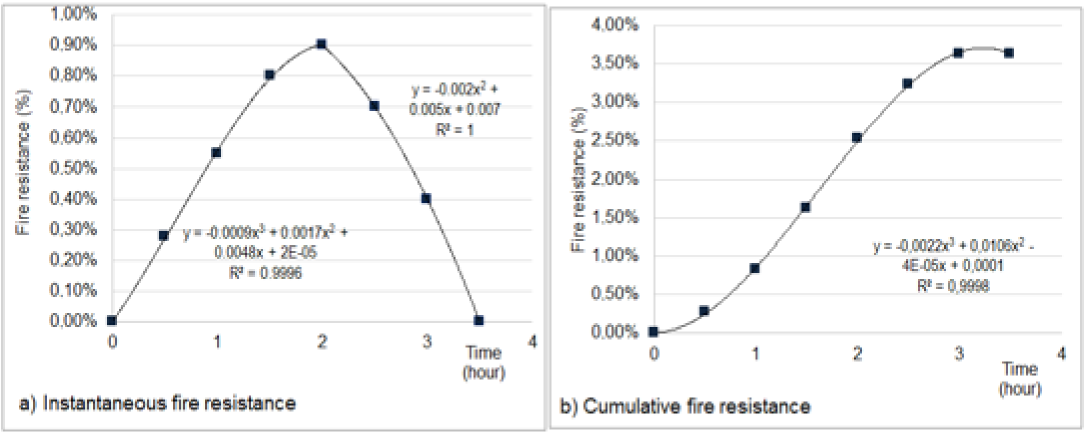

Figure 10. Results of the instantaneous fire resistance of wet Couch Grass fiber

The evolution of water losses of couch grass varies according to its state: natural water (fresh couch grass) and absorbed water (dry couch grass introduced into water). Drying times according to exposure temperatures are given by equations (8) and (9) (Figure 11).

For the time (Tpa) of loss of absorbed water:

$T_{pa} = -68{,}64\,\ln(t) + 340{,}41$ with : $R^2 = 0{,}9034$ (8)

For the time (Tpn) of loss of natural waters:

$T_{pn} = -44{,}82\,\ln(t) + 222{,}21$ with : $R^2 = 0{,}9485$ (9)

T denotes the exposure

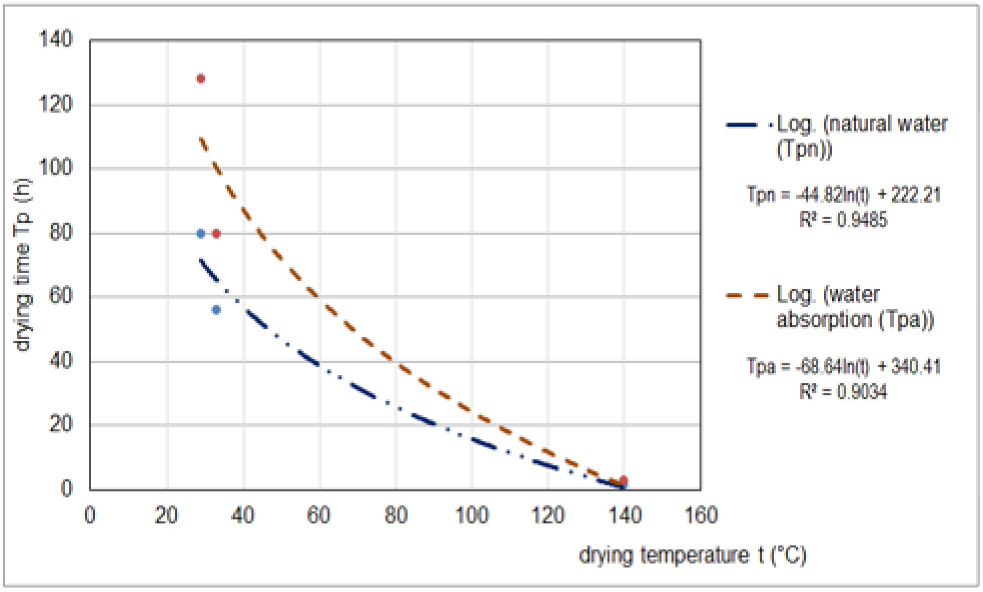

Figure 11: Drying time as a function of temperature

4. DISCUSSIONS

Couch grass stems with a density of 0.46 are classified as light woods (density less than 0.5) **[7] [8].** It exhibits two behaviors in the presence of water and temperature. A very rapid absorption and loss of water following an increasing polynomial function of degrees 2 or 3 in the first hours; followed by a slow absorption and loss of water in a decreasing logarithmic or polynomial form (**Figure 2** to **Figure 8**). Couch grass stems have the same behavior in the presence of heat (**Figure 9** and **Figure 10**). For a temperature ranging from 29°C to 140°C passing through 32°C, the drying time is respectively 80 h, 56 h and 1.5 h for water losses of 2.02%, 1.79% and 1.03% (**Figure 2** to **Figure 4**). In the presence of a high temperature, couch grass releases more water in the first hours. This gives it a sensitive character in the presence of water and a humid environment. This behavior is confirmed by its absorption rate of 25% in the first half-hours with a cumulative rate of 46.24% after a period of 2.5 hours to reach saturation (**Figure 5**). This possibility of absorbing water indicates an enormous degree of porosity of couch grass. Saturated, couch grass fiber takes longer to empty itself of water than the fresh state of the material. It has a loss of absorbed water of 6.63%, 4.49% and 2.88% respectively under temperatures of 29°C (128 h), 32°C (80 h) and 140°C (3 h) (**Figure 6** to **Figure 8**). Saturated couch grass releases water quickly in the first hours. Couch grass loses its characteristics under the action of a temperature of 140°C after 3 hours in a saturated state and 2 hours in a natural state. Its lifespan then depends on the quantity of water absorbed (**Figure 9** and **Figure 10**). Saturated couch grass and fresh couch grass exhibit the same water loss behavior over time (**Figure 11**). Indeed, water loss follows a decreasing logarithmic law as a function of the increase in the temperature of the service conditions. Couch grass used as reinforcing fibers for earth constructions will undergo strong reactions in the presence of humidity and high temperature of the structure.

5. CONCLUSION

This study aims to study the characteristics of couch grass fiber. These fibers cut into pieces of approximately 3 to 5 cm underwent identification and physical characterization tests. Couch grass loses its water from the saturated state after 80 h, 56 h and 1.5 h at temperatures of 140 ° C, 32 ° C and 29 ° C respectively. Couch grass is a very light plant fiber with an apparent density of 0.49 and an absolute density of 1.60. The water absorption coefficient of couch grass is 46.24% with water loss coefficients of 6.63% at 29 ° C, 4.49% at 32 ° C and 2.88% at 140 ° C. Couch grass is very sensitive to contact with water and has a very high degree of porosity. Earth constructions reinforced with couch grass fibres will be vulnerable if they are not protected against humidity.

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