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BIO BASED CONCRETE WITH CRUSHED RAPE STRAW, A GOOD ALTERNATIVE TO DEVELOP AN AFFORDABLE BIO BASED CONCRETE FOR CONSTRUCTION AND RENOVATION

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Abstract
The renewable character is one of the major assets of the plant. The various studies consider an increasing development of biobased materials in the construction in the coming years, but it seems that the plant resources type hemp and flax are relatively limited in quantity and surface cultivated. The rarity which can lead to an inappropriate financial speculation, the development of an organic resources sector large-scale thus pass by the use of compatible layers in terms of available resources. While hemp and linen represent respectively approximately 12 000 the Ha/year and 80 000 the Ha/year, the rape is in France cultivated on about 1 600 000 Ha in 2014. These works were thus carried to characterize the rape straws for applications similar to those already used for hemp and for the flax. This study will be centered on the use of the particles with a diameter of 0-35 mm, resulting from the crushing of the rape straw collected into Picardy. The results obtained in this phase of characterization of the raw material, showed that the crushed rape straw have interesting properties, so much on the dry density (ρ = 65 kg m^{-3}), that from the point of view thermal performances (λ = 0.046 $W.m^{-1}.K^{-1}$). The use of the untreated rape straw aggregates with a lime binder of the type Tradical PF70 allowed to show the possibility of a total substitution of the hemp by this type of vegetable particles. Indeed, they have a lower density and better thermal properties. As for their mechanical performances, they are comparable to those some concrete of hemp. The Life Cycle Assessment (LCA) indicators have also been calculated to prevent any environmental problems, and a Volatile Organic Compound (VOC) analysis gave a "A+" mark according to the French regulation of construction products.

Keywords:
Renewable, biobased, hemp, flax, rape, straw, thermal, Tradical PF70, concrete.

1 INTRODUCTION

At the time when the citizens have more and more consciousness of their environment and his necessary safeguarding, it is imperative that the habitat takes into account these dimensions. Far from constituting an effect of mode, the challenges are considerable. Realize and promote a different, thrifty and environment friendly housing, here is a major concern which the actors of the building integrate more and more into their practice. Through the economic development of the last century, the need to find accommodation largely evolved. The residential construction passed of the use of natural materials, selected by their durability, for plastics, resins and other synthetic materials.

Jointly, is born by the middle of the 19th century a real environmental concern, opening the door to the concept of sustainable development. The built environment crosses from now on towards the offer of an environment ecologically and socially healthy. A myriad of concepts and theories is now connected with the sustainable buildings, and a particular attention is carried in building materials. Agriculture is producing biomass: by its cultures, crop residues as well as these livestock manure. It can be valued for valuations materials (bio-lubricants, biomaterials) but also energy (heat, electricity, biofuels).

The use of aggregates stemming from the biomass in the construction opens a new range of possibilities in the reuse of materials in the building industry. After about twenty years of use (building sites of implementation, experimental construction sites), it seems that materials developed with vegetable particles offer a real technical and economic alternative in a lot of building sites. The fact of using vegetable particles to reduce density for mineral matrix is not obviously a new idea in itself. Furthermore, since certain pioneers imagined to integrate the hemp into

the manufacturing of building materials, a range of really innovative products, called "hemp concrete", was able to be developed in about twenty year.

Indeed, the particular structure and the composition of these vegetable particles, which had been considered up to there always as one co-products fibers of separation process the hemp, turned out to be particularly interesting assets to create an ecomaterial with good thermal and hydric performances. The synthesis of the knowledge on hemp concretes and mortars [Hustache 2008] resumes the main properties of these materials. Experience feedback and various scientific works allowed the writing of the professional rules by the association [Construire En Chanvre 2012].

In a parallel to these works, several [Govin 2004], [Cérézo 2005], [Peyratout 2007], [Sedan 2007], [Magniont 2010] and [TAI THU 2010] was initiated jointly in numerous laboratories, to study the potentialities of the other aggregates stemming from the vegetable biomass (flax, miscanthus, bamboo, etc.), for a use as a material of filling, the manufacturing of load-bearing and not load-bearing blocks, etc. Such researches allowed to show that several of these lignocellulosic co-product can be incorporated into hydraulic matrix or not, for the formulation of a good many of materials for the building.

Their mobilization in the construction and in other domains of the green chemistry or the energy (biofuel, biopolymers, etc.), is going to engender certainly tensions and inappropriate financial speculations, in particular for the hemp and the flax. These two resources are very limited geographically and cannot answer an increasing request.

The rape straw are not valorized today and his seeds are used by the food industry and by the green chemistry. The rape also represents a culture of future, by the new perspectives which open through biofuels, bio lubricants and solvents, without forgetting theirs agronomic interests in the diversification of the rotations. Rape is cultivated in France to produce seed and rape oils for food ingredients, but also for chemical products as glycerol. Rape cultivation in France is about 1,5 Million acres, and straw are not valorised. They are redelivered to earth for organic amendment and because of their High potash content. The current estimations give a production of vegetative biomass about 1.3 Ton by ton of produced seeds, that is for a efficiency on 30 q/ha a straw production between 3.5 and 4 t/ha. However, the operations of harvest pull losses esteemed at best at 50%. At the end, one will count rather on a production of 2 t/ha of straw.

There are no works dedicated to the valuation of the straw of rape in materials, or in other domains such as composites. However, two articles were published by Ewa Kopania and al in 2012 [Ewa Kopania 2012] on the use of the cellulose of the rape straw to make reinforcements for composites, as well as the works of Dorota Dukarska and al in 2006 [Dorota Dukarska 2006], on the use of the particles of rape in substitution of wood aggregates in particle boards.

The first works concerning the evaluation of this coproduct were introduced a few years ago by CoDEM Picardy [Laidoudi 2014]. They ended in the realization of a research project with Coopenergie®, where three types of applications were explored: bulk shaves for insulation, concrete of filling (the same formulation as the hemp concrete for an application of type wall and load-bearing blocks.

This study resumes some results obtained for the second way of valorization, which consists in introducing aggregates stemming from the grinding of the colza in a sociable disposition of type Tradical PF70, to formulate rape concretes similar to those some hemp. This paper also describes the first renovation project in an old typical farm of Picardy. Rape concrete was implemented on a timber frame structure by replacing an old “torchi” early degraded by inadequate renovation in the 80s. This case is unfortunately usual in North, Picardy and Normandy and hemp is not cultivated in these regions, so rape straw can be a very good alternative.

2 MATERIALS

2.1 Rape straw

Today there's no n rape straw collection die, it is often left in the field after recovery of the seeds. This resource today has great potential in terms of volume. The rape straw was crushed by a combine harvester, which has to have spread out an enough granulometry, where the size of the particles varies from 0 to 35 mm. Figures 1 and 2 show the appearance of rape straw aggregates crushed and the microstructure of a rape straw particle. It is found that the rape straw has a high porosity.

Fig. 1: Crushed rape straw

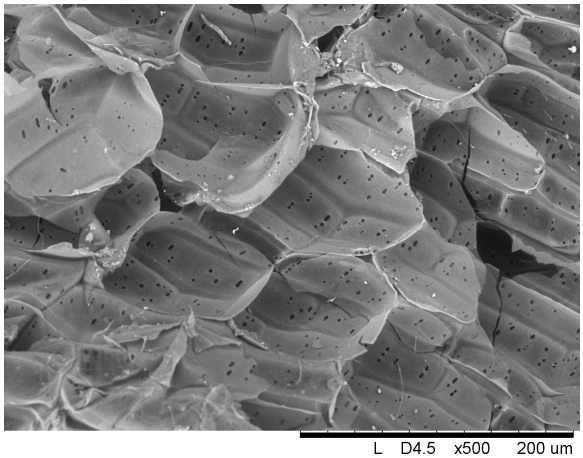

Fig. 2: Structure of the rape particle in electronic microscopy

2.2 Tradical® PF70

TRADICAL PF70 is manufactured binder of limestone-based products, with main components, hydrated lime (75 %), hydraulic lime (15 %) and with the pozzolan (10 %), intended, after mixture with aggregates (sand) and water, to realize mortars of pose for natural stone, rubble stones of every type (except very soft stone), hollow or full bricks, briquettes as well as rough-casting, rough-hewed and sub-filler traditional, in accordance with the DTU 20.1 chap. 2.2, 4.2 and 4.3, and DTU 26.1. The lime Tradical PF 70 was specially formulated for the hemp concrete filled.

3 METHODS

3.1 Thermal conductivity

The technique employed is one of Heat flow meters measurement methods of the thermal conductivity of materials. The apparatus used is a Lambdameter with two flow meters and with a single sample. The heat flow density is measured with two flow meters placed against the test piece (the hot plate is located above the sample and the cold plate below). This Lambdameter is conform to standards ISO 8301, En 12667, etc.

3.2 Aggregates water absorption in liquid phase

The method used to measure the absorption of liquid-phase water by total immersion, is an internal method. It acts indeed, to immerse a quantity of vegetal aggregates (20 - 30g) in a glass jar equipped with a piston which allows to maintain all the aggregates in total immersion to avoid the floating of vegetable fibers on surface. A chronometer is used to check the time of measurement. In the stop of the test a draining by means of the piston of all the free water contained in the jar is carried out by avoiding the loss of aggregates during the operation. At least three tests are realized at a time of 60 minutes. The vegetable particles were dried until constant mass before the realization of the measurement

3.3 Mechanical strength and modulus of elasticity

The compressive strength of the cylindrical biobased concrete specimens were obtained after 90 days of maturation, by uniaxial compression using a press equipped with a 100 KN sensor. Each test specimen (160 mm diameter and 320 mm height) previously surfaced is placed in the machine. The driving test was performed according to the recommendations of the professional rules (Association construire en chanvre). The displacement of the steering traverse at a speed of 5 mm / min on a hydraulic press for compression tests according to EN 12390-4 equipped with a force sensor 100 kN. Although the test pieces have been put in place by a manual compaction, mechanical testing are quite reproducible. At least five specimens were tested for this formulation. The modulus of elasticity in MPa is calculated for each sample according to the displacement. It is calculated at 40% of maximum load

3.4 Capillarity

The capillarity test consist to measure the absorption of water under the effect of capillary forces. We conducted this study to evaluate the durability of rape straw concrete in case of prolonged contact with water (case of flooding for example). These transfer phenomena depend on the geometry of the voids which form the porosity of the specimen. Its flow rate is controlled by the distribution of the pore size and their possible connection. The water absorption test by capillarity were conducted at room temperature on samples previously conditioned by baking at 80 ° C. The side faces were covered with a waterproof plastic film layer that forces the water to pass a uniaxial path and prevents evaporation by these faces. The method used to determine the capillary absorption-way is to put the specimens in contact with an open water 5 mm in height kept constant. The mass of water absorbed is determined by successive samples weighed. The only precaution to take is, after each weighing and using an absorbent with a dry cloth or paper to remove the water film retained in the underside of the sample. During the absorption test, the quantity of overall water having penetrated into the sample is measured and not the maximum height reached by the liquid. Testing has also measured the capillary coefficient of rape concrete. It corresponds to the mass of water absorbed per unit area as a function of the square root of time. It is determined perpendicular to the direction of casting specimens submerged in 5 mm of water at 20 ± 5 ° C.

It is calculated according to the following formula:

$$Cw = \frac{100*m}{S*\sqrt{t}} \quad (1)$$

With:

Cw: water absorption coefficient by capillarity ($g/(m^{-2}.s^{-1/2})$)

m: mass of water absorbed (g)

S: middle section of the lower face of the samples (m^2)

t: time of measurement (s).

To test this capillary phenomenon, three specimens were immersed in water to measure the amount of water absorbed by capillarity.

3.5 Total immersion

Total immersion tests were carried out on rape straw concretes. Which aims to assess the impact of the presence of water in case of flooding and to estimate the amount of water that will be absorbed. A special attention through continuous visual observation of the degradation of the test specimens was performed throughout the test period. Four specimens were immersed in regulated water at 23±5 °C for 28 days. At the end, the test specimens were weighed and subsequently dried to not for any damage.

4 CHARACTERIZATION OF THE RAW MATERIALS AND RAPE STRAW CONCRETE

4.1 Characterization of rape straw

Bulk density

The results indicate that the density of the wet rape straw (65 kg m^{-3}) is relatively low compared to other vegetable particles, such as the boon, flax shives, miscanthus, etc. The drying of rape aggregates confirmed the lightness of these straws. Indeed, when dried, rape straw density below 60 kg m^{-3}, which shows the potential of this type of resources and relief given to materials formulated with these aggregates. The average results and standard deviations of the two types of rapeseed aggregates (wet and dry straw) are shown in Table 1.

Tab. 1: Bulk densities (kg.m^{-3}) of rape straw aggregates

Bulk density (kg.m^{-3})		
	Average	**Standard deviation**
Wet rape straw aggregates	65	2.8
Dry rape straw aggregates	58	0.9

Thermal conductivity of rape straw aggregates

One of the characteristics expected by the valorization of rape straw in the construction materials is linked to its thermal properties. In fact, as we have discussed previously, the aggregates of rapeseed have a considerable advantage in terms of lightness and character of thermal insulation. However, the thermal conductivity of rape straw is identical to that of other agricultural resources, such as, wheat straw crushed at 15 mm, flax shives, etc. that of the hemp being higher (0.048 Wm^{-1}.K^{-1}). In table 2, the median values obtained are indicated.

Tab. 2: Thermal conductivity of rape straw aggregates

Thermal conductivity W.m^{-1}.K^{-1}		
	Average	**uncertainty**
Wet rape straw aggregates	0.0461	2.8E-03

Rape Aggergates water absorption in liquid phase (absorption by total immersion)

The quantities of water introduced during malaxation are function obviously behavior with respect to the water of each component of material. Indeed, the added water should be sufficient to ensure good handling on the one hand, and to allow the normal hydration of the hydraulic matrix. In order to understand and quantify the water sensitivity of rape aggregates used in this study, we conducted a water absorption measurement companion by full immersion for 60 minutes. Choosing this time was performed based on previous studies of vegetable particles. Hemicelluloses, cellulose and pectin have many hydroxyl groups assigning the plant fibers that hydrophilicity promotes the water absorption. Table 3 compares the composition of rape straw relative to that of the hemp. It shows that there is a significant difference in the chemical composition of these biobased aggregates.

Tab. 3: chemical composition of the hemp and rape straw

	Hemp	**Rape straw**
	(VIGNON M.)	**(DZIURKA 2005)**
Hemicellulose	16	31.37
Lignin	4	21.3
Cellulose	55	37.55
Protein	2	-
Ashes	4	6.02

In spite of this difference, the water tests by total immersion were not revealed a significant difference in the rate of water absorbed between hemp and rape straw. Indeed, the absorption of rape straw is very close to that of the hemp (300%), although they do not have the bulk density. These rates are well below the flax shives (324%) and wheat straw (400%) [Laidoudi 2012]. The high porosity and internal structure of the rape straw stalk are responsible for high capacity of absorption and water retention. This property is common to all the lignocellulosic fibers, however these rates vary from an aggregate to another. The results obtained on the rape straw used in this study are grouped in table 4. The absorption rate obtained for the different aggregates confirm the hydrophilic nature of this type of plant fibers.

Tab. 4: Comparison of water absorption between rape straw and hemp

Water absorption rate (%)		
	Average	**Standard deviation**
Rape strawe aggregates	315%	4%
Hemp	290%	9%

4.2 Characterization of rape straw concrete

Formulation of materials

In this work, the rape straws aggregates were employed with a lime binder Tradical PF70 for the formulation of materials. The goal pursued by this study is the exploration of a way of valorization for the rape straw aggregates to manufacture poured concretes similar to those of hemp. Rape straw concrete formulation for an application “wall” was validated in collaboration with the CRDA platform (Lycée Arago Reims) and BCB society (Groupe Lhoist). It has allowed us to estimate the quantity of water required for having a homogeneous mixture of a part, and to facilitate the implementation of the other part. Indeed, the latter has been assessed by the casting of a wall at scale 1 with a wood frame as usually done with the hemp concretes.

The materials formulas with rape straw have made the subject of a characterization study of which has and permits on the one hand, to compare them with the concretes of hemp and on the other hand of the situate in relation to the requirements of professional rules “construire en chanvre”. We have developed materials with the same formulation used for hemp concrete for wall application type. Table 5 shows a sample calculation of the various ratios used in rape straw and hemp concretes depending on the intended application (Wall). The mechanical and thermal tests were conducted according to the packaging protocols and test criteria in the same rules. The choice of this formulation had to aim the comparative study with the hemp in a perspective of complete substitution of the hemp by rape straw aggregates. The objective was to achieve the same performance in conditions of use identical. The rape straw being lighter (<70 kg.m^{-3}) that the hemp (110 kg.m^{-3}).

Tab. 5: Mass composition of hemp and rape straw concrete

Mass composition of concrete (kg)			
	Aggregates	**Tradical PF70**	**Water**
Hemp concrete	110	220	60-70
Rape straw concrete	70	220	55-65

Thermal conductivity of rape concrete

The thermal properties are directly related on the components, the morphology of the medium (matrix solid and network porous inter and intragranular) and to the interactions between the various types of transfers existing in material. One of the characteristics expected by the valorization of rape straw of in the construction materials is linked to its thermal properties. In fact, as we have discussed previously, the aggregates of rapeseed have a considerable advantage in terms of lightness and character of thermal insulation. The measured thermal conductivities are obviously directly related to the compacting energy. In this regard, we found when measuring bulk densities that they are relatively high (572 kg m^{-3}) for this type of material and comparably hemp concrete. For this density thermal conductivity obtained on three test samples is in the range of 0.147 W $m^{-1}.K^{-1}$. The results obtained in the wet or dry (Table 6) indicate that the thermal performance are very interesting, although they can be easily optimized, by decreasing the percentage of binder (lime) and less compact the test specimens during casting. Because, as we have previously emphasized the increase in the energy of compaction severely degrades the character of insulating of rape particles.

The drying of the samples improves the thermal conductivity slightly. We have obtained the same range that the hemp concretes with the same density.

Tab. 6: Mass composition of hemp and rape straw concrete

Thermal conductivity ($W.m^{-1}.K^{-1}$)			bulk density ($kg.m^{-3}$)
	Average	**Uncertainty**	
Wet rape straw concrete	0.147	9.03E-03	572
Dry rape straw concrete	0.125	7.67E-03	539

Moreover, the bulk densities tested of samples seem relatively high in comparison with hemp concretes. This will be able to be explained by an important energy used during the manufacture of test tubes. Another phenomenon will be able to be linked to technique that of the relating easiness of compressibility of the aggregates rape straws. However, these phenomena will be less having an impact during the implementation on construction site, where the concrete will be less compressed, what is indeed going to allow to have lower thermal conductivity.

Mechanical properties of rape concrete (compressive strength and modolus of elasticity)

Mechanical properties are directly linked to constituents, to morphology of middle and to correlations between the different stages existing in the material. The mechanical properties of insulating biobased concretes quantify through two common parameters: the compressive strength and modulus of elasticity. The measures of compressive strength were performed on 5 test tubes and for a period of ripening of 90 days. Indeed, we respected all requirements of the professional rules “construire en chanvre”, that is in term of protocols of tests or to measures of compressive strength. Simultaneous measures of modolus of elasticity have been carried out on each test specimen and the average values obtained are indicated with the compressive strength in the table 7.

Tab. 7: Mechanical properties of rape straw concrete at 90 days

	Average	**Standard deviation**
compressive strength (MPa)	1.44	0.2
Modolus of elasticity (MPa)	47.10	9.0

The densities of the specimens after 90 days of cure, appear relatively high for this type of material. We can make the same observations as the thermal conductivity, or the use of the same energy of compaction that the concretes of hemp, seems to have a more significant impact at the level of the rape straw concretes. The average density as well as the standard deviation obtained on 5 test specimens are shown in table 8.

Tab. 8: Bulk density of rape straw concrete at 90 days

	Average	**Standard deviation**
bulk density ($kg.m^{-3}$)	632	8

It appears clearly that all test tubes gave compressive strength superiors to requirements of the professional rules. Indeed, to us got a medium resistance 7 times upper to the reference value (0.2 MPa). So, we can consider that rape concretes can be easily used as concrete of filling in the best conditions. The modulus of elasticity is also much higher than the requirements of the professional rules. At 90 days we measured a module 3 times higher than the target value (15 MPa). The compressive strength remains acceptable for the field of use is intended. The requirements requested are essentially in the order of the auto flotation. Today we have a return of experience on the use in France of the hemp concretes with performance equivalent to that of the rape concretes and no accident or serious incident has been reported. The professional rules govern today this type of material.

Hydraulic properties (capillarity, total immersion)

Tests of water absorption by capillary action have been carried out on 3 samples of size 100 X 100 X 300 mm. The results have enabled us to measure the water absorption coefficient by capillary action, as well as the obtaining of the curve relative to the binding kinetics of water by capillary action. The water absorption

coefficient by capillarity calculated from the relationship (1) is given in table 9.

Tab. 9: water absorption coefficient by capillarity *of rape straw concrete*

	Average	Standard deviation
water absorption coefficient by capillarity Cw (g/(m^{-2},s$^{-1/2}$)	89.6	13.,5

The variation of mass of test tubes according to time is represented on the figure 3.

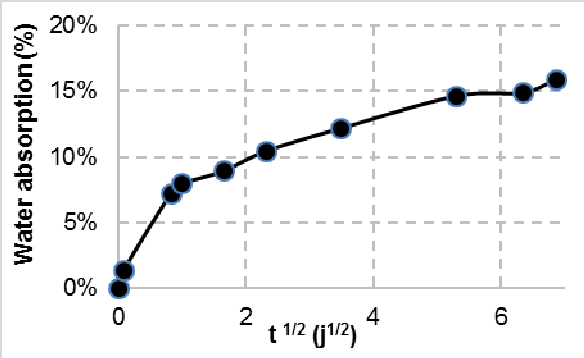

Fig. 3: Evolution of the absorption of water according to time

The results obtained showed that these rape concretes introduce a relating weak absorption of water by capillarity, even after 47 days, we did not record high rates. the maximum value of catch of mass is in the order of 15 %.This property could be explained by the presence of a not negligible part of macro-porosity, which does not make easier transport of water by capillarity. This parameter also shows another advantage of the integration of the rape straws in concretes of filling. And what lets envisage a better durability of this type of materials.

The total immersion tests were also performed on these materials. The objective of which is on the one hand, to assess in case of inundation the quantities of water absorbed and on the other hand to appreciate visually the degradation of the material in contact with the water and possibly after drying. The average value obtained is of the order of 84% and the standard deviation associated with these measures obtained is very low (0.2 %). We noticed no deterioration or loss of samples during 28 trial days or even after drying in the ambient air. This behavior shows the maintaining of the mechanical performances of rape concretes in case of complete submersion of the product. He confirms so results got with capillarity tests. Nevertheless, these tests confirm that once the rape straw aggregates are mixed with lime, their sensitivity to water decreased significantly, which certainly improve their durability in the event of accidental contact with water. The status of the specimens after 28 days of testing and after drying outside is shown on figure 4.

Fig. 4: Specimens after tests and drying

5 LIFE CYCLE ASSESSMENT (LCA)

In this project, we decided to evaluate in a LCA bio-based concrete with straw rape.

We used the software SimaPro V8 with the ecoinvent database v3. According the standard NF EN 15978+A1 concerning PED, we have decided to use the specific calculation method linked to this standard. We present a provisional LCA. We have to point out some datas, especially about transport distances and the end of life's modelization. The functional unit for this analysis is "Make and implement 1 m^3 of straw rape concrete with a wood frame to obtain a thermal conductivity of 0.125 W.m-^{1}.K^{-1} and a lifetime reference of 50 years". In the table 10 are shown the results of this modeling.

Tab. 10: Environmental impacts of bio-based concrete with straw rape

Environmental impact	Unit	Straw rape concrete
Global Warming	kg CO2 eq	3.86E+01
Ozone Depletion	kg CFC-11 eq	9.87E-07
Acidification for soil and water	kg SO2 eq.	8.73E-02
Photochemical ozone creation	kg ethylene	1.14E-02
Depletion of abiotic resources -elements	kg antimony	1.49E-04
Total renewable primary energy	MJ, net CV	0.00E+00
Total non renewable primary energy	MJ, net CV	2.50E+02
Net use of fresh water	m3	3.77E+00
Hazardous waste disposed	kg	6.20E+00
Air pollution	m3	2.61E+03

An eco-design approach has been leaded in the formulation of the concrete which allowed to identify it main contributor : the lime. That's why, a decrease of the quantity of lime allows to strongly reduce the environmental impacts of concrete whereas we keep a good thermal conductivity. Some comparisons are currently doing to compare this concrete to the other bio-based concretes (flax, hemp, wood, etc.) and traditional concrete.

6 EXAMPLE OF RENOVATION OF A HOUSE IN PICARDY WITH A RAPE CONCRETE

A first construction site of renovation of a house was accomplished with a rape straw concrete developed in CODEM. It was led by an artisan approved by the association “Construire en chanvre” and a carpenter specialized in renovation of old buildings. The renovations were carried out on a typical Picardy house, built with wooden panels and the wattle and daub. To which was applied a cement coated on the outside and plasterboard inside, following a renovation in the seventies. The goal of the renovation is obviously the complete replacement of the wattle and daub by a rape concrete. Figures 5 and 6 show the composition of the wall and the start of renovation work (removal of the wattle and daub and replacement of deteriorated wood sides). The figure 7 shows wall ended after the implementation of the pouring of rape concrete in formwork and after 3 weeks of drying.

Fig. 5: Removal operation of the coating of cement and the wattle and daub

Fig. 6: Wall ready to receive the rape concretee

Fig. 7: Finished wall

This photo (figure 7) was taken after 3 weeks of drying. After this period, we have found a very good holding and very low dimensional changes relating to drying of the rape concrete. This rapidity of drying will present a great advantage of the use of this type of biobased concrete compared to the hemp concrete, which often requires the drying times longer.

This example of a renovation project is an additional element in relation to the possible use of rape concrete in renovation or new construction without making any changes, neither at implementation techniques, skills or constraints associated with these specific aggregates.

7 GENERAL CONCLUSIONS AND PERSPECTIVES

This study has shown that the aggregates from grinding the rape straw, by their nature "co-produced", their competitive advantage on price, their geographical availability and their performances, will provide answers to various questions today, especially in the field of agro-materials. Indeed, we have been able to see through the results obtained, all the potential recovery of this type of aggregates in the form of load in the concretes of filling. Their lightness, their porosity, their ease of processing, etc, are major assets for their integration in several areas of applications.

The thermal and mechanical performances of filling rape concretes are comparable to those of hemp concrete. In some cases, the results we have obtained are significantly better than those of hemp. For example the mechanical performances are 2 to 3 times higher than those of hemp concretes. An optimization is easily possible to improve the formulation to achieve better performance, in particular in thermal properties. The durability tests were very successful and they did not show any damage or destruction of property of the same material under severe conditions.

From the point of view of environmental approach, rape concrete is weakly impacting on the environment; these impacts are slightly lower than those of hemp concrete because it is lighter for the same thermal performance. The respect for requirements and for recommendations allowed validating the formulation of type "wall" with the rape concrete. The project carried out with this concrete has shown that it can be used in the renovation of old buildings or the new in the best conditions and requires no adaptation of these professional rules; they are completely transposed to rape concrete.

This work is an important step in the exploration of recovery methods for rape straws. However, further studies are needed to clearly define all the properties of these aggregates and the different locks that must be overcome in order to optimize their performance in different areas of applications in the building.

8 ACKNOWLEDGMENTS

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