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MECHANICAL PROPERTIES OF HEMP YARN IMPREGNATION IN CEMENTITIOUS MATRIX

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Abstract

Natural fibers are achieving progress in their application; it is diversified into engineering constructions such as building materials. Today, hemp yarn uses as reinforcements in cementitious composites to replace synthetic fibres such as glass fibers. For a sustainable economic development, natural fibers include low price, low density, high specific strength and elastic modulus, unlimited and sustainable availability, and low abrasive wear of processing machinery, as well as their availability as renewable resources. Mechanical properties of plant fibers are much lower when compared to those of the most widely used competing reinforcing glass fibers but their specific properties, especially stiffness are comparable to the glass fibers.

This paper is an investigation on the effect of embedded continuous hemp yarn in the microstructure and mechanical properties of cementitious composites. The quantitative physical of yarn impregnation was done by experimental methods such as measurement of capillary rise using colored water which permits to observe movement of water in the hemp yarn celluloses. The results were discussed on the basis of the wettability of the yarn. In addition, porosity accessible to water has determined according to AFPC-AFREM procedure. And mercury intrusion porosimetry (MIP) classic test authorizes to determine pores size associated to presence the yarn in the matrix and it compared to reference samples that qualitative and quantitative yarn impregnation. In addition, Flow rate measurements leads to measure the flow rate of water along the yarn and identical pore size. Pull-out test was used to determine the mechanical parameters at pre-peak and post peak zone. Extracted length enhances characterization un–impregnated yarn when the embedded length is extracted entirely. All physical parameters determined previous have related to pull-out parameters in order to understand the correlation between physical and mechanical parameters.

Keywords:
Hemp yarn; cementitious matrix; wettability; porosity of the yarn; Pull-out test

1 INTRODUCTION

In recent years, environment has become a most popular area of research using natural fibres as reinforcements in polymer composites to replace synthetic fibres such as glass. For a sustainable economic development, natural fibres include low price, low density [Wretfors 2008], high specific strength and elastic modulus [Wretfors 2008], unlimited and sustainable availability, and low abrasive wear of processing machinery, as well as their availability as renewable resources [Rong 2001; Yuanjian 2007]. Mechanical properties of plant fibers are much lower when compared to those of the most widely used competing reinforcing glass fibers [Sedan 2007] but their specific properties, especially stiffness are comparable to the glass fibers [Taj 2007]. Another reason is a need to develop concrete with less cement but still a good durability. Properties of natural fibers vary considerably depending on the fiber diameter, structure (type of cellulose) and whether the fiber comes from the plant stem, leaf or seed, and structural composition and growth conditions.

Furthermore, chemical composition and cell structure of natural fibers are quite complicated; each fiber is essentially a composite in which rigid cellulose polymeric microfibrils are embedded in a soft lignin and pectin and hemicellulose matrix. The lignin makes the stem rigid and the pectin glues the fibre bundles together moreover hemicellulose is only partly removed by the retting process. The strength and stiffness of the fibers are provided mostly by hydrogen bonds between the different chemical components. Chemical composition, moisture content, and microfibrillar angle of vegetable fibers more explained in [Taj 2007]. On the other hand, a natural fibre is a very porous and variable material. It is therefore difficult to calculate an accurate volume fraction when such fibres are incorporated in a polymeric matrix (variability in fibre density, possible penetration of the resin inside the fibre). In addition, properties of fibre-reinforced composites are strongly dependent on the interfacial interactions between the fibres and the matrix. Sèbe et al. [Sèbe 2000] studied the effect of fiber modification since it is believed that the bonding between fibres and matrix did not affect the load bearing capacity of the fibres (which kept their strength efficiency), but was detrimental to toughness. There are a few studies on the impact behaviour of natural fibre reinforced plastics compared with glass fibre composites. Santulli et al [Santulli 2009] studied the post-impact behaviour of plain woven jute/polyester composites subjected to low velocity impact, and found that the impact performance of these natural fibre composites is poor.

The main aim of the present study is to investigate the possibility for using hemp yarn to reinforce cementitious matrix after yarn pre-treatment.

- Qualitative physical properties of impregnation yarn.
- Analyse the influence of pre-treated yarn on mechanical properties.

2 MATERIALS AND METHODS

2.1 Hemp yarn reinforcement

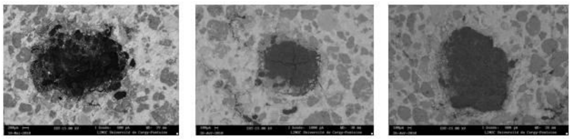
Hemp yarn its origin is Libya (named Ch), its density measured of 1159.26 kg/m^3. Hemp yarn consists of strands dispraised and very brittle easy to broken. Fig 1 showed structure of the yarn. When yarn is in contact with water, these strands agglomerated together and then become more brittle. The diameter of yarn doesn't constant along the yarn and mean diameter is in rang of 179 µm, No. of strands estimated is equal to 65.

Fig. 1: Hemp yarn.

Direct tensile test on hemp yarn was applied on real surface, so σ_{max} = 187 MPa, E= 7,049 MPa and $\varepsilon_{rupture}$ = 3.1 %.

Three methods of pre-treatmentd were used before introduce the yarn in the matrix, firstly, a yarn wetted by the water (W), secondly, yarn is pe-draied (D) and thirdly, yarn pre-impregnated into a slurry of the same composite as cementitious matrix (PI), the composition of cementitious matrix and slurry cement are detailed in [Aljewifi 2010].

Fig 2 shows SEM images of pre-treatment yarn embedded in cementitious matrix. Black colors inside W yarn indicated the high percentage of voids within the fiber due to disorder the strands. D and PI yarns, the strands were agglomerated together and cement past filled the voids in between the filaments.



Ch W Ch D Ch PI

Fig. 2: pre-treatment yarn embedded in matrix.

2.2 Wettabilty of hemp yarn

Hemp yarn is known to grand ability of absorb water so its volume could be doubled and its strands become disordered. To observe liquid ascent in the yarn, simple test based on colored the water by fluorescence, ascending water into the yarn observed by the lamp of teravolts device. Fig 3 appeared capillary ascent of five specimens and fluorescence height into yarn in function of the time. Fluorescence ascent increases linearly until one hour then it remains stable and maximum height is 10.7 cm. It was difficult to observe fluorescence ascent inside core of the yarn as seen by lamp of teravolts. The results were discussed on the basis of the wettability of the yarn.

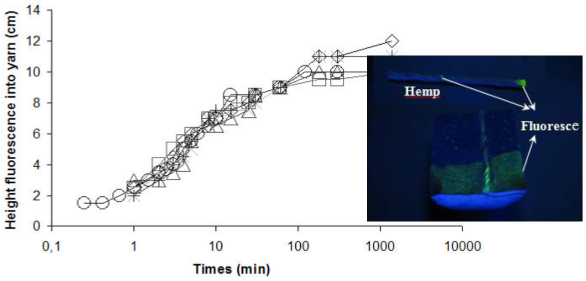


Fig. 3: Maximum height fluorescence into hemp yarn vs. times.

2.3 Porosity accessible to water

Measurement of the porosity was obtained from the difference between dry and saturated weight, the total volume of the sample was determined by hydrostatic weighing, and it was thus possible to calculate the porosity accessible to water according to AFPC-AFREM. The measurements correspond to sample contain hemp yarn and its reference (without hemp yarn), of same batch. In addition, samples with a hole that has the same diameter of the yarn [Aljewifi 2011].

Fig 4 shows that value of porosity were almost close values for each sample and there was no difference between them and those that contain hole. Thus introducing hemp yarn doesn't change significantly water porosity of composite reinforced by hemp yarn.

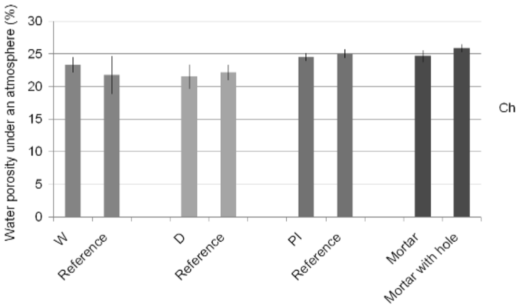


Fig. 4: Measurement of porosity accessible to water: pre-treated hemp yarn.

2.4 Mercury intrusion porosimetry test (MIP)

To determine pore repartition interfilaments of the pre-treated yarn, mercury intrusion porosimetry (MIP) classic test was used, more detailed in [Aljewifi 2011]. Fig 5 shows cumulative pore volume of all pores size rang results of MIP test. To simplify comparison, we choice different pores size rang named $v_{0.3-3}$, v_{3-30}, $v_{0.3-30}$, v_{30-300} and $v_{0.3-300}$. Furthermore, $v_{0.3-3}$ is the cumulative pore volume in the pore size range from 0.3 to 3µm when $v_{0.3-30}$ corresponds to the sum cumulative pore volume in the pore size range from 0.3 to 30 µm.. Higher cumulative pore found in rang $v_{0.3-300}$ but in real this rang correspondent to macro crack of composite thus we ignore this rang. And for v_{3-30} cumulative pore volume was constant of W case thus the different cumulative pore volume between 3 and 30 µm was equal to zero. The same case finds between 30 and 300 µm. Then we will give attention to pore size rang from 0.3 to 30 µm. Influence yarn pre-treatment appears on $v_{0.3-30}$ of all configurations. Thus penetration cement particles inside the yarn induce increasing pore volume at interface level. Pre-wetted yarn values approach to reference with the same order of standard deviation, PI yarn has big pores size; as see in Fig 5.

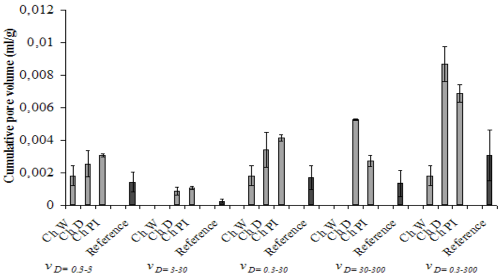


Fig. 5: Cumulative pore volume correspondent to different mean pore diameter (µm).

2.5 Flow test

Flow rate measurements were achieved on the sample of micro concrete of 2 cm in which pre-treated yarn is centered and embedded. This test consists measuring the flow rate of water along the yarn, under imposed pressure gradient of 107.5 kPa/cm. Subsequently flow rate measurements are compared to reference sample (without yarn) which correspondent to the same batch than reinforced matrix.

This test gives a physique quantitative measure on an impregnated yarn and bonding interfacial. Fig 6 shows that introducing the yarn in cementitious matrix enhance the flow rate 3 or 4 times than reference. This indicates that W pre-treated yarn leads to increase the void at the interface of yarn/ matrix (already seen in SEM observation). Flow rate of dry yarn (D) measurement is rather approach to W case. Due to disorganising filaments and poor bonding in D case more pores are connected along embedded yarn than W case. Contrary to D case, yarn impregnation induces diminishing porosity connected along the embedded yarn where water flow passes in tortuous porosity of the mortar thus flow rate decreases that PI configuration.

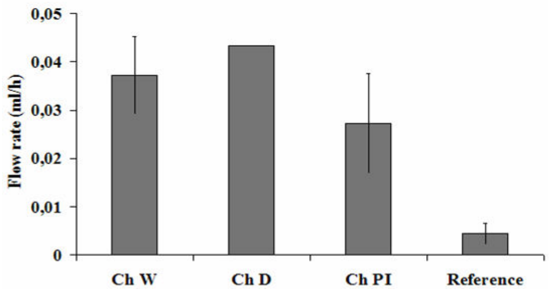


Fig. 6: Compared flow rate measurement along vegetal fiber to reference sample.

3 MECHANICAL TEST

3.1 Pull-out test

To investigate the behaviour of the materials, a pull-out test is performed on the previous pre-impregnated yarn. Micro concrete, in which embedded length locates, vertically was positioned on specific basket clamped beam. Testing principle and specimen's preparation were already explained in [Aljewifi 2010]. The lengths of hemp yarns studied were 1, 3, 5, 10, 15 and 25 cm. For each length, three samples different were investigated at 28 days old specimens.

In comparison between un-impregnated yarn and pre-impregnated yarn; Ch W gave different behavior for three specimens of same patches (two ductile composite and one, it has gave brittle behavior), example Ch W, Le = 10 cm. Ch PI appeared quasi brittle behavior, see fig 7.

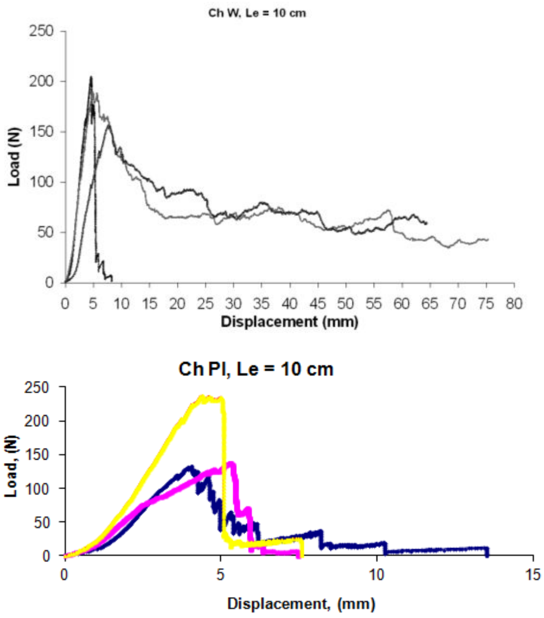
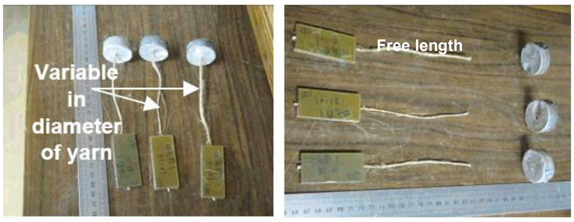


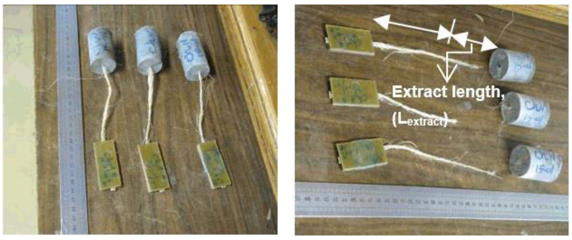
Fig. 7: Load – Displacement curves.

Pullout curves have three stages; firstly elastic stage (linear line between15% to 80% of line), secondly; peak stage and thirdly frictional stage (between yarn and matrix at interface). This last stage is more if yarn is W or D pre-treatment, and this indicated foible impregnated yarn. If the bonding of the matrix and the yarn break, the yarn tends to slipping (as shown in fig 8) and significant residual frictional creates resulted in roughness yarn surface (twisting geometry**)** [Aljewifi 2011]. Residual frictional tend to disparate of W, D and PI cases when embedded length is more than 10 cm. Roughening effect related to celluloses of filament dispersed in the matrix. Hence increasing surface contact between the yarn and the matrix induces mostly yarn deformation. On the other hand, during displacement of the yarn mortar can hinder slipping yarn when it accumulates around twisted filaments thus yarn slash.

Elongation to rupture (noted δ_{max}) increases with embedded length. It is important noted that the displacement results from slipping yarn and aligned free length which is approximately 1.2 mm for 10 cm under loading of 100 N.



Ch D. Le = 1 cm; before (left) and after (right) pull-out test.



Ch W. Le = 5 cm; before (left) and after (right) pull-out test.

Fig. 8: Variation extracted length of the same specimen.

3.2 Determination relative extracted length

Extracted length enhances characterization un–impregnated yarn when the embedded length extract entirely of the matrix moreover extracted length to initial embedded length ratio designed extracted length relative abbreviated by L_{er}. Fig 9 shows that L_{er} tends to decrease with embedded length or no residual frictional measuring again see fig 8**.** On the other hand, L_{er} is very higher than 100% of short embedded length**.** Low accuracy measures on initial values of free length and total length (including free length and extracted length). After pulled yarn high accuracy measurement appears due to variable behaviour of the same specimens, such as twisted yarn, aligned yarn during loading and the retouches found at ended specimens, influence directly on measurement of relative extracted length (e.g. 1.5 cm instead of 1 cm).

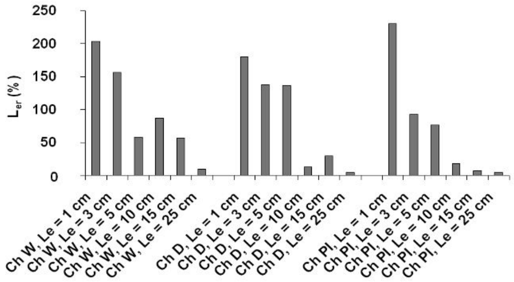


Fig. 9: Extracted length relative vs. embedded length.

3.3 Percentage of extracted filaments

Estimation the portion of extracted filaments that was a part of the embedded length after the pullout test, was estimated. Extracted filaments (P_{fc}) is the weight of filaments on embedded length corresponds to 4 cm to the weight of filaments on free length corresponds to 4 cm ratio if embedded length is ≥ 5 cm. When embedded length is less than 5 cm, P_{fc} correspondent to linear mass of filaments on extracted length to linear mass of filaments on free length ratio. Fig 10 shows that P_{fc} tends to decrease with embedded length with high accuracy measurement resulted in variable the behaviour of the same specimen.

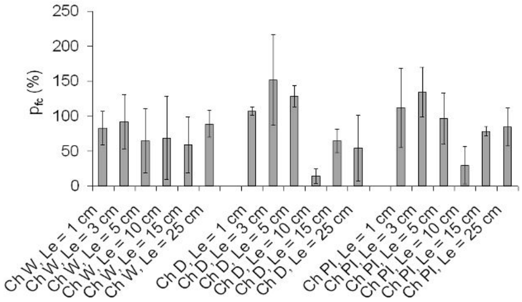


Fig. 10: Percentage of pull-out filaments vs. embedded length.

4 INFLUENCE EMBEDDED LENGTH ON MECHANICAL PARAMETERS

Pullout mechanical parameters at the three stages have been determined. The parameter at first stage (pre-peak zone) corresponding to the mean values which has determined for each configuration (two configurations: embedded length, pre-treatment of yarn).

δ_{max} as explained already is elongation the yarn to rupture. P_{max} is maximum load supported by transition zone (yarn/ matrix interface) to rupture. Furthermore, ascending stiffness represents the interfacial stiffness, noted by k_{bond} is calculated from linear part of the slop of the load-displacement curve in rang of 0.5 to 0.8 P_{max}.

Pull-out work or energetic work to progressive debonded the embedded yarn of the surrounding matrix noted by A. Pre-peak. It is determined up as integral below the load-displacement curve to P_{max} for each configuration. Parameter at second stage (post-peak zone) corresponding to descending stiffness of descending branch of pull-out curve noted k_{debond} was calculated that k_{bond} but on descending load curve. $A_{.post\text{-}peak}$ is correspondent to a parameter energetic which characterise the work energetic necessary to continue opening the specimens at post-peak transition. It was subtracted from total work ($A_{.total}$) where which it determine as the total area under load-displacement curve. If hemp yarn is considered as multi-filament yarn thus it is important of note that high variation coefficient obtained from tensile test according to ISO 3341 [**ISO 3341 2000**] is un-equivalent.

4.1 Influence of embedded length on pre-peak parameters

Maximum strength of pre-treated hemp yarn is an increasing function with short embedded length of W, D and PI configurations. It important to note the diminishing immediate of pull-out strength of all configurations if embedded length is superior to 10 cm. Furthermore, the strength becomes approximately stable whoever increasing of embedded length. The strength of pre-treated yarns is approximately the half of direct tensile strength of anchored yarn (right bars on Fig 11).

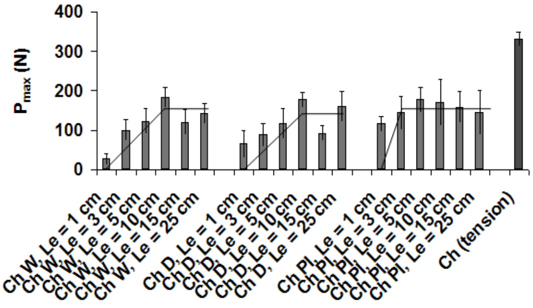


Fig. 11: Influence embedded length on maximum strength.

Hemp yarn configurations appear low bonding stiffness due to the effect that no perfect anchor yarns. W case needs approximately 50% or more to reach the stiffness of PI with short embedded length and 20% if the length more than 5 cm. D case remains low than W case thus the stiffness of PI case is twice of D case. Although, yarn stiffness of W and D pre-treatment is very lower than anchored yarn when PI case can reach 40% of fully anchored yarn. Bonding stiffness appears the same behaviour which has obtained with P_{max}, see Fig12.

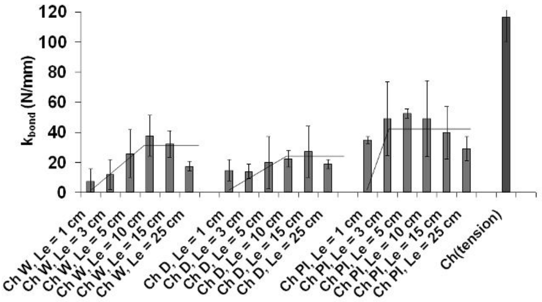


Fig. 12: Influence embedded length on ascending stiffness. k_{bond}.

The energetic work tends to decreasing with embedded length for W case. While increasing embedded length resulted in fracture main part of filaments with very small slipping. PI case shows that this work is quasi similar for all embedded length used and approach to $A_{.pre-peak}$ obtained directly from the yarn. So D pre-treated yarn appears an opposite behaviour than W case, from which it tends to increasing with embedded length as indicated on Fig 13.

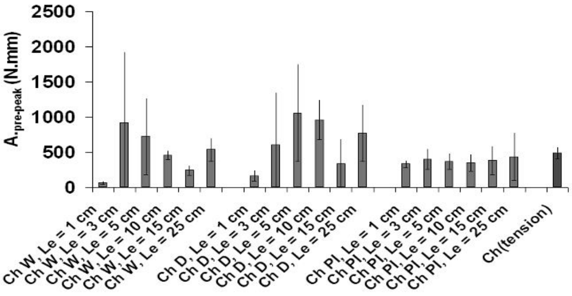


Fig. 13: Influence embedded length on energetic parameter at post pre-peak.

4.2 Influence of embedded length on post-peak parameters

Descending stiffness measurement of behaviour curve is increasing function with embedded length with high accuracy due to variation of pull-out behaviour as explained already. Fig 14 shows that the stiffness measured directly of the yarn remains higher than all pre-treatment methods used. So long length of W and PI cases give significant values of stiffness where with D case k_{debond} remains very lower if even embedded length increasing.

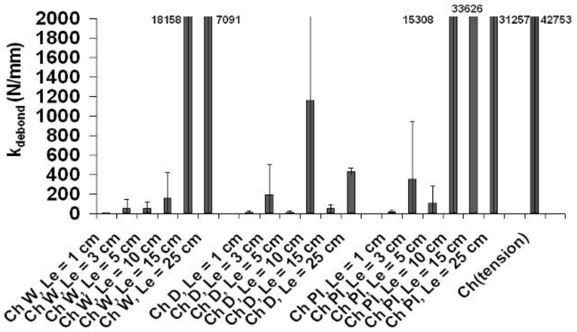


Fig. 14: Influence embedded length on descending stiffness. k_{debond}.

Complementary information obtain of pull-out work post-peak ($A_{.post-peak}$) while short embedded length needs significant energetic work because material gives ductile behaviour and it tends to decreasing with long embedded length that presents quasi brittle behaviour, Fig 15.

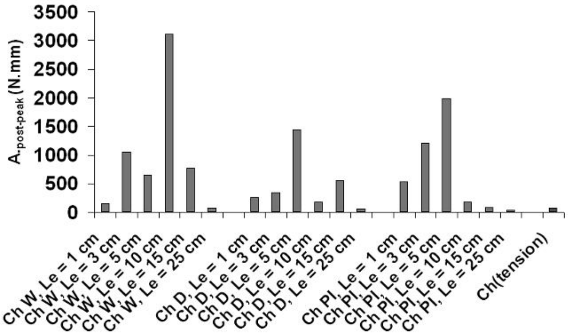


Fig. 15: Influence embedded length on pull-out work at post-peak. $A_{.post-peak}$.

4.3 Influence of embedded length on frictional parameters

The residual frictional parameter noted $k_{frictional}$ described as a straight continuous after post-peak stage. If yarn slipping after P_{max}, is corresponding to fully debonding the yarn of surround matrix. In this paper, no yarn slipping if embedded length > 10 cm, brittle failure happen as indicated in fig 16. Thus, $k_{frictional} = 0$ for almost cases.

This parameter may be modified by damage processes in the yarn or in the matrix when the yarn undergoes slippage in post debonding stage assumed by [Naaman 1991]. They supposed that the fiber not ruptured tends to slide out. $k_{frictional}$ was calculated as following:

$$k_{fricitonal} = \frac{P_2 - P_1}{\delta_2 - \delta_1}$$

(1)

Where:

P_1: 10 % P_{max} at fully debonding the fiber from the matrix (i.e. x= Le);

P_2 : load correspondent à δ_2 ;

δ_1: displacement correspondant à P_1;

δ_2 : ½ δ_1.

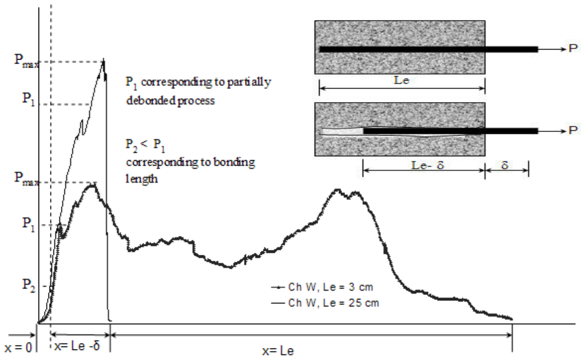


Fig. 16: Load distribution with embedded distance for pre- peak zone.

5 INFLUENCE PRE-TREAED HEMP YARN ON MECHAICAL BEHAVIOUR

5.1 On pre-peak zone

The results of pull-out test shows that using different pre-treatment methods on hemp yarn exhibit the same maximum strength, Fig 17**.** Pullout strength measurements are directly depending on the interfacial adhesion, [Weichold 2009]. Thus, adherence or without adherence the yarn to the matrix, it will support the same applied maximum strength. Strength values of W and D configurations were very similar when PI measures strength of a factor superior than 10-15 N. Consequently, pre-treated yarn doesn't give significant improvement on pull-out strength.

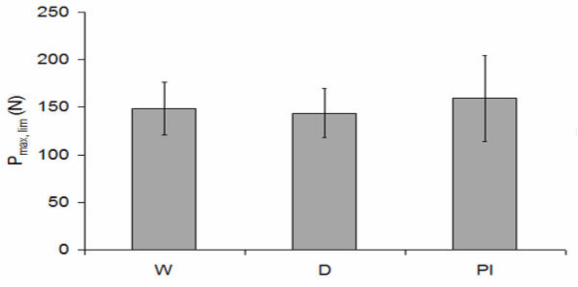


Fig. 17: Influence pre-treated yarn on mean pull-out strength.

Minimum embedded length ((L_{min}) which require to reach anchoring optimal of strands in cementitious matrix to attain maximum pull-out strength was calculated as indicated in Fig 11.

Stabilization the strength is drawn by thin line over each configuration. From Fig 11**,** W case needs L_{min} of 10 cm; D case of 10 cm either 3 cm for PI case. Optimisation anchoring length and its influenced on mechanical parameters that correspond to L_{min} were determined as follows:

$P_{max,\ lim}$: maximum strength values $P_{max,\ lim}$ of P_{max} which has been determined as mean values of P_{max} for an embedded length superior than L_{min}.

$k_{bond,\ lim}$: maximum stiffness values $k_{bond,\ lim}$ of k_{bond} which has been determined as mean values of k_{bond} for an embedded length superior than L_{min}. The same method was used for remaining of mechanical parameters.

Influence pre-treated yarn on bonding stiffness depends on pre-treatment method before cast these lead to vary interfacial stiffness as is seen of PI case from where W and D configurations have been given approximately approached stiffness, see Fig 18. This is linked to increased yarn adhesion to the matrix. Taj et al. [Taj 2007] supposed that composite materials made with the use of unmodified plant fibers frequently exhibit unsatisfactory mechanical properties.

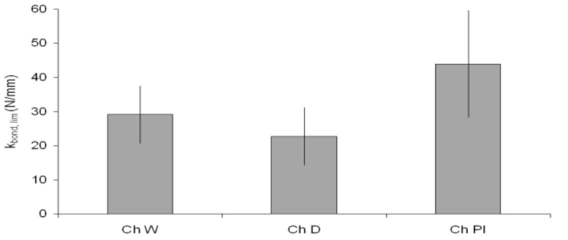


Fig. 18: Influence pre-treated yarn on bonding stiffness.

Fig 19 shows that the dissipated bond energy [Weichold 2009] is influenced by method of pre-treatment of yarn. D case needs more energetic work. Due to irregularity yarn structure, the filaments found disparate in matrix without adhesive contact to the matrix. In effect, presence the water in pre-treated W leads to group the filaments of the yarn if even the yarn is swilled. With PI case, filaments are enclosed to the matrix especially with long embedded length and generally with pullout test happens rupture almost part of filaments but slipping small part of filaments generates lower wasted of energy.

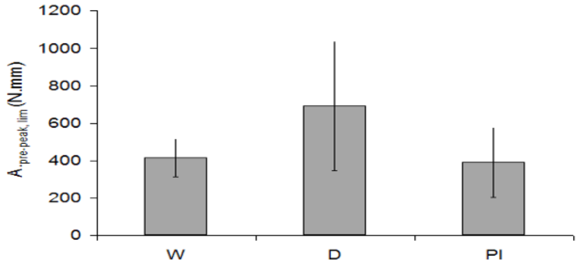


Fig. 19: Influence pre-treated yarn on parameter energetic at zone pre-peak.

5.2 On post-peak zone

Influence the three methods of pre-treatment on debonding stiffness is shown in fig 20.

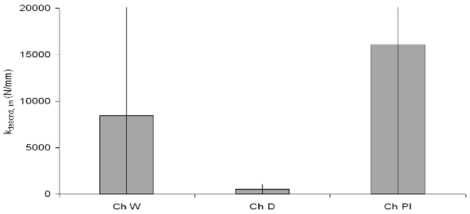


Fig. 20: Influence pre-treated yarn on debonding stiffness.

High accuracy gives the impression on variation of curve pull-out behaviour. Better descending stiffness measurement was obtained from pre-impregnated yarn (PI) when wetted yarn (W) has been gave approximately the half stiffness of PI configuration. D pre-treatment method leads to decrease the mean descending stiffness of hemp yarn (effect of yarn geometry).

Opposed descending stiffness, pre-impregnated yarn (PI) necessitates less pull-out work as shown in fig 21. The energetic work of W pre-treated yarn was significant because high slipping of embedded length equal to 10 cm but with D and PI cases slipping yarn prevent with (Le) superior than 5 cm, consequently W case needs to high energetic work to debonding the yarn of the matrix.

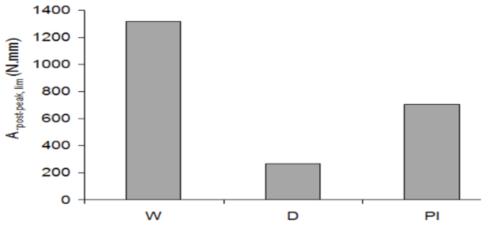


Fig. 21: Influence pre-treated yarn on parameter energetic at zone post-peak.

6 CORRELATION BETWEEN PHYSIACAL PARAMETERS AND MECHANICAL PARAMETERS

6.1 At pre-peak zone

Physical parameters have obtained from MIP test and flow test was correlated to all mechanical parameters presented previously.

The physical state of the impregnated yarn was quantified by water flow test. Correlating this parameter to pull-out strength permit to evaluate influence connected porosity along the yarn on the mechanical behaviour. In other words, related interfacial physical properties which include the void at bonding zone between the yarn and the matrix on pull-out strength. Fig 22 shows that diminishing the flow rate lead to increasing strength pull-out (P_{max}). More porous yarn gives from D pre-treatment case. The strength increase progressively with embedded length except Le = 15 cm for each configuration. For embedded length (3 - 15 cm) very similar behaviour obtaining from which maximum strength decrease of all configurations. In other words, increasing pore volume induces diminishing maximum strength. Despite of Le = 1 cm and Le = 25 cm have more pores of (D) pre-treated yarn than (W) pre-treated yarn their strength are higher.

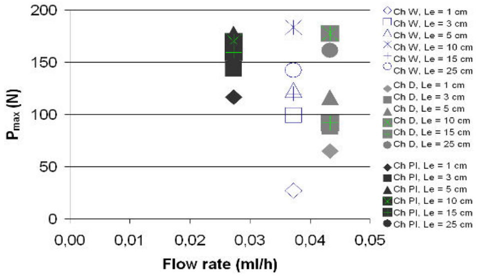


Fig. 22: Correlation between flow rate and maximum strength.

For W pre-treatment, bond stiffness is increasing until 10 cm of embedded length after it tends to decrease with a long embedded length, fig 23. It is important to note the correlation between flow rate and stiffness (k_{bond}) depends heavily on an embedded length than on pre-treatment method used. As indicated early, for different pre-treatments methods and the same embedded length, the stiffness of the yarn is dissimilar. As a result, better bond stiffness induces passing a low quantity of water.

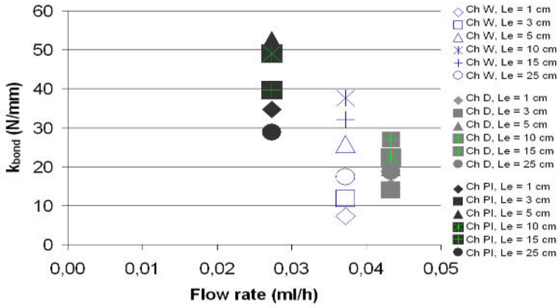


Fig. 23: Correlation between flow rate and k_{bond}.

With PI pre-treatment method, yarn needs to less energetic work approximately. Thus the energetic work isn't heavily influenced by increasing embedded length, Fig 24. However, D pre-treatment method showed higher energetic work values than W (pre-treated) yarn of the same embedded length except Le = 10 cm that measured a behaviour dissimilar.

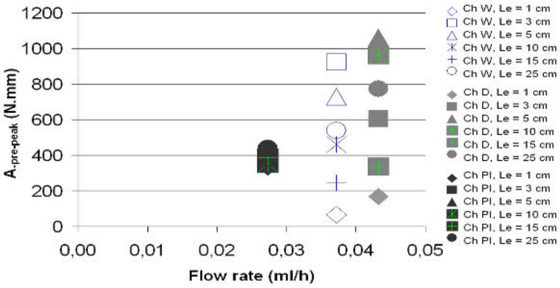


Fig. 24: Correlation between flow rate and parameter energetic ($A_{.pre\text{-}peak}$).

6.2 At post-peak zone

Low porosity leads to increasing the debonding stiffness of the yarn, fig 25. It appears that for all configurations k_{debond} is influence by initial state of the yarn. Slipping the yarn leads to decrease debonding stiffness because more porous found in between the filaments. Furthermore, it can't relate between each length used of pre-treatment method and initial state.

Post-peak behaviour of D pre-treatment isn't heavily influenced by the embedded length in function with flow rate as shown in fig 26. PI pre-treated yarn either appears the same behaviour only with long embedded length. Globally, short embedded length of PI case tends to exploit significant energetic work as Ch W, Le = 10 cm. As a result long embedded length corresponds to PI case break at tip of free length (quasi- brittle behaviour).

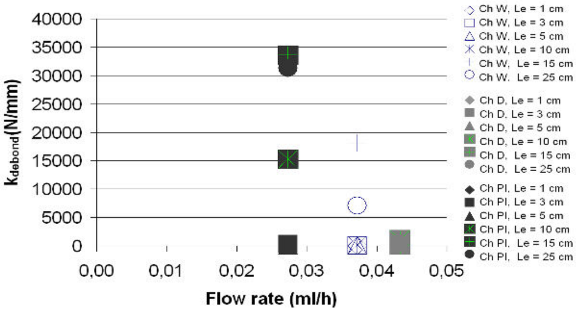


Fig. 25: Correlation between flow rate and k_{debond}.

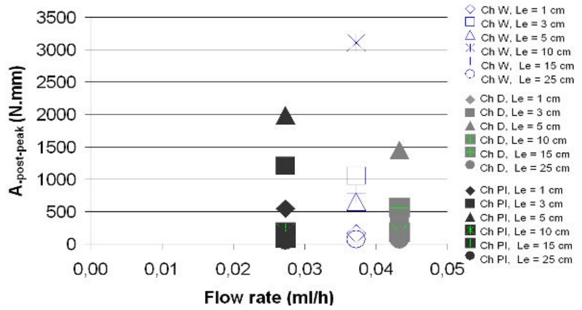


Fig. 26: Correlation between flow rate and parameter energetic ($A._{post-peak}$).

7 SUMMARY AND CONCLUSION

A hemp yarn continuous, has used as reinforcement, as the yarn synthetic (glass yarn continuous) used in [Aljewifi 2010]. Mechanical and physical properties are linked to type of the yarn, from which maximum pullout strength of hemp yarn doesn't reach the mechanical properties of glass yarn. The maximum tensile strength of 331 N and the stiffness of 11655 N/mm/mm, without introduce the cross section area into the calculus. While the natural and manufacture process of hemp yarn have major influence, from which they induce flaws in its structure that have an effect directly on tensile and pull-out strength. In addition, heterogeneous in yarn structure can never lead to obtain identical behaviour of the same pre-treated specimens. Hemp yarn absorbs more of the water, it appeared that when the yarn is in contact with the water, it absorbs the water in short time and its volume doubled (this simple test gave some information on the wettability of the yarn); strands become disordered and with the time it brittles (natural cause) resulting adhesion insufficient between the hemp yarn and the matrix. Consequently, yarn pre-treated is necessary to obtain optimal results. In this research, introduce different methods of pre-treatments hemp yarns does change fundamentally anchoring yarn in cementitious matrix, best behaviour obtained of yarns: W = 10 cm, D = 10 cm and PI = 3cm as indicated in fig 11. It appeared that introduce the yarn into the matrix lead to reduce its tensile strength to more than one half approximately. Furthermore, short embedded length is inefficiency (because extracted total embedded length of the matrix is possible), increasing embedded length is an important parameter which leads to improve pull-out strength, but fig 11 demonstrated that embedded length of 10 cm is more efficiency and length of 15 cm, 25 cm doesn't give modification in pull-out strength (values stabilisation). The different pre-treatments methods appear a little increasing in pull-out strength with PI case compared to W or D yarns. And influence yarn pre-treated on stiffness of the yarn as exhibited in fig 18; PI method enhances yarn stiffness and reduces pore size in the yarn as shown in fig 22. From the experimental investigation carried out, it was observed that when pre-impregnated yarn (PI) is used in concrete, it enhances the porosity in range $v_{0.3-30}$. This trend is observed from presence cement particle inside cells of the yarn as indicated SEM pictures; which would impede the flow of water into the cells and thus the flow rate decreases in this case.

Influence pre-watted method on W yarn increases the stiffness of the yarn and as we said the strands are disarranged in the matrix than the water pass along disorder strands lead to diminish flow rate (particles of cement fill space interstrands. Un-treated yarns (D yarn) don't have main influence on mechanical properties, and fig 22 shows that water would be passing along the yarn directly. Consequently,non-impregnation yarn helps to increase the water flow rate Uneven hemp yarn deformation leads to local interaction yarn/ matrix.

Thus this research appeared that hemp yarn would be efficacy if yarn pre-treated before casting and PI is more efficacies.

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