ENHANCEMENT OF LIME-HEMP CONCRETE PROPERTIES USING DIFFERENT MANUFACTURING TECHNOLOGIES

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Abstract

The EU directive 2010/31/EU – sets goals to reduce CO_2 emission levels by 20% until year 2020. As primary energy for households and construction industry both are among the largest manufacturers of CO_2, a building material that can positively impact both these industries is topical. A lime-hemp concrete (LHC) is a material with negative CO_2 balance, but to achieve the goals set in EU directive a more industrialized product, that can also be used in insulation of existing buildings is needed, so methods of LHC slab and block manufacture are tested in this paper. Eight different types of hemp shives are taken and twelve LHC mixes are prepared to assess the importance of hemp granulometrical distribution. To measure the effect of different preparation techniques mixes in two different mixers – gravity and forced action – were prepared to test the superiority of the latter as it is widely used in LHC production. Also different drying methods – natural, forced with temperature at various stages and with increased moisture – were tested. As well as various hydraulic additives were tried in order to increase the mechanical properties of the LHC. After complete drying, physical and mechanical properties - density, thermal conductivity, compressive and flexural strength - were determined and compared to assess the most suitable materials and manufacture technologies for LHC blocks. Also a reaction to fire test were performed for one of the samples. The results allow to better understand the principles of how the material works and how it`s properties can be enhanced with various manufacture techniques. The results suggest that LHC blocks have the necessary properties and potential to become widely used in improvement of thermal insulation of existing buildings.

Keywords:

Lime-hemp concrete, LHC, hemp blocks, reaction to fire, thermal conductivity

1 INTRODUCTION

The EU directive 2010/31/EU – created to address challenges of global warming and energy dependence – sets goals to reduce CO_2 emission levels by 20% till 2020 [Broin 2014]. As primary energy for households and construction industry both are among the largest manufacturers of CO_2, a building material that can positively impact both these industries is topical and as such is tested in this paper.

A lime-hemp concrete (LHC) is a material with negative CO_2 balance[Ip 2012][Shea 2012], but is widely used only in low-story wood frame buildings[Latif 2014] and made on site[Barclay 2014]. To achieve the goals set in EU directive a more industrialized product, that can also be used in insulation of existing buildings is needed, so methods of LHC slab and block manufacture are tested in this paper.

LHC has other promising properties, such as high moisture buffering capacity [Maalouf 2014] [Evrard 2014], high moisture transfer [Rahim 2015], excellent thermal performance – a high thermal capacity and low thermal conductivity [Walker 2014].

In order to improve LHC properties, so that it can be used in production of blocks and slabs for insulation of existing and new buildings and to test its conformity to such use, five different directions were chosen in this particular test:

1. Testing on how the properties of shives (density, granulometric composition, etc.) can influence final properties of LHC, as other studies have shown a correlation between the two [Stevulova 2012]. Eight different types of hemp shives from various local producers were taken and a total of 12 different mixes were made.
2. Finding out of the most appropriate drying technique, as the material have shown some problems with drying in previous tests, also to determine the average drying times of 100 mm thick samples. Total number of 6 samples were made for testing.

3. Comparison of properties between samples made with forced action mixer and samples made with gravity type drum mixer. 4 samples were made, two for each type of mixer.
4. Improvement of the currently elaborated formulated lime mix by addition of various hydraulic additives, 6 samples were made for the test.
5. Determination of the reaction to fire class for the LHC, to understand its limitations of use, as natural fibre based composites, without modification typically belong to class E, but with mineral binder can achieve B class [Sassoni 2014].

2 MATERIALS

2.1 Shives

To check the effect that different hemp shives have on material properties 8 different types of shives (Fig.1) were chosen from the largest Latvian hemp fibre processors. From each processor several types of shives were chosen - they differed in sizes, the quantity of fibre and the amount of dust, as it is very dependent on the processing process of the fibre, as, for example, in order to obtain a dust and fibre free material, it has to be re-processed several times.

The obtained shives were sifted through a sieves to determine their size composition, the results are presented in the table (Table 1.) as a percentage of the total mass. Dustiness and fibre amount are also determined with sifting.

Shives with designation RM, RL and RS are from largest hemp processor in Latvia z/s "Rudeņi", which produce shives from local Jelgava county growers as well as from Lithuanian growers. RM is with the largest amount of small particles, as it has undergone several repeated processing cycles, RL is the same, but only once processed, as can be seen by larger quantities of shives over 10 mm and also by the significant amount of dust. RL is with more fibre, which can also be seen in Table 1.

The second type of shives were taken from hemp processing line in z/s "Lieplejas" Salacgrīva district. Two types of shives were taken - LM with a smaller fraction and a larger LL, which has undergone less processing cycles.

Third shives were taken from SIA "Zalers", hemp and flax processing company in Krāslavas county. Two types of samples taken directly from production - ZM with a smaller fraction than ZL. An experimental shives sample with the name EE were obtained from hemp

Fig. 1: Eight different types of shives used

fibre research from which a by-product of 100% dust free shives were obtained. These were experimental shives and cannot be obtained in large quantities, but can show the trend of whether such treatment can improve LHC properties.

Hemp density is in bulk form, it was measured using sand bulk density container of 1 litre and poured in and weighed. Hemp granulometry is measured using sieves 40, 20, 10, 0,63 mm in size. As the length of the shives are much larger than the width, this sifting does not show exact size of shives as some fall through, although their length is larger than the hole. But this does show differences between various shives and how these differences might influence properties of LHC.

Hemp thermal conductivity is measured using LaserComp FOX600 heat flow meter, filling plywood box with open top with bulk material. From the Table 1. it can be seen density does not have direct correlation with thermal conductivity, other factors such as distribution of different size shives and total porosity of shives influence this.

Moisture was measured by weighting all samples after at least 30 days in laboratory conditions (20±2 ^{0}C an 40±10 %RH), then they were put in a drying oven in 80 ^{0}C for 24 hours, then weighed again, moisture is given as percentage of the lost mass.

2.2 Binder

The binder that is used primarily in the tests is formulated lime that has been elaborated in previous studies. It is composed of 60% by mass DL60 dolomitic lime, produced by "Saulkalne" Ltd. and 40% metakaolin, obtained by burning kaolin clay at 800^0 C. In mortar compressive test with binder ratio 1:3 it can reach compressive strength as high as 10 MPa. Metakaolin has also shown its advantages as additive with different limes that is used as binder for LHC.

Tab. 1: Properties of shives

Name	Fibre	>20mm	10-20mm	0,63-10 mm	Dust	Density, kg/m3	Thermal cond. W/m*K	Moisture, %
RM	1,7%	0,5%	3,7%	92,0%	2,2%	108,36	58,07	11,75%
RL	1,7%	4,1%	12,2%	71,4%	10,5%	78,43	55,28	6,15%
RS	6,4%	5,2%	9,4%	78,1%	0,9%	64,64	56,89	6,94%
LM	0,2%	0,2%	11,7%	86,3%	1,5%	87,66	53,48	7,47%
LL	1,0%	0,8%	27,0%	68,8%	2,4%	87,14	57,43	10,23%
EE	7,8%	4,5%	22,0%	65,1%	0,7%	65,38	56,69	6,87%
ZM	3,3%	3,2%	8,0%	84,2%	1,2%	72,26	51,87	6,77%
ZL	1,7%	4,6%	19,4%	74,1%	0,1%	94,06	57,38	7,75%

For additional part of the test five different admixtures to the formulated lime binder were added to test the possible improvements in mechanical properties of the LHC. One of such additives is cement which has shown to improve lime based binder properties.

Making the sample no. 20. (Table 2.) 10% of binder was replaced with Aalborg white cement CEM I 52,5 N, for sample no. 21. – 20%. Microsilica was also used as additive as it has also showed promising properties regarding lime binders. 10% of the regular binder were replaced with Elkem Microsilica Grade 971-U Undensified for the sample no. 22. For the samples no. 23. and 24. a 36% sodium silicate solution (Na_2SiO_3) were used 5% and 10% of the binder mass, it was dissolved in the mixing water, as sodium silicate has shown good binding capabilities with bio-based filler materials in previous studies.

3 METHODS

3.1 Mould preparation

Before the tests, preparations are made, first the mould preparation. Moulds are made of 28 mm thick moisture resistant plywood, in four corners holes in diameter of 10 mm are perforated so threaded rods can be inserted (Figure 2.). Moulds are greased with formwork oil so the samples didn't stick to the surfaces while curing.

3.2 Preparation of the ingredients

Before starting all the ingredients were weighed and prepared - hemp shives, binder and water. Amount of shives weighed – 2 kg (where two kinds of shives used, the ratio is 1:1 by mass) and 3.4 kg of binder, the ratio between shives and binder is 1: 1.7 by mass, it has also proved appropriate in previous studies. Binder is plain formulated lime or with additives, either way it is premixed manually before being added to shives. In the case of sodium silicate – it was dissolved in the second portion of the added water. The total amount of water used is 4.86 litres.

Fig. 2: Moulded samples for mechanical and reaction to fire tests

3.3 Mixing

For the mixing of the samples a forced type double shaft laboratory mixer BHS DKX 0.06 were used. First the designed quantity of shives – 2 kg - were inserted into the mixer, then it was turned on at the 60 rpm. During this process, from almost all types of shives, dust were emitted. Then, after premixing the shives for 30 sec., a 2 litres of water were added by spraying it evenly over all shives for further 30 sec. After the addition of water the dust were no longer emitted and surface of all shives was slightly wet.

The mixing was continued for 1 minute, then, not stopping the mixing process, the pre-mixed binder was added. It was evenly dispersed over the shives in 30 second period and as the shives were wet the binder quickly stuck to them. Mixing was continued for another 30 sec., then the remaining amount of water – 2,86 l – was added, the same way as previously – by evenly spraying all over in 30 sec. period, then it was left mixing for 2 minutes. After that, without stopping the mixer, the mixture was dumped through the hatch underneath.

For a part of the test two samples were prepared using gravity drum type concrete mixer (no. 18. and 19.) and different types of shives RM and RL. All of the procedures were done in same order and time period, but there were a need for some breaks in the mixing process to take off the mixture from the walls of the mixer and to crush the lumps.

3.4 Moulding

Then 8 kg of the mixture was weighed and put in the preoiled mould. The filing of the mould was done by 4 cm thick layers, each being tamped slightly. When all of the mixture had been used, the mould was almost full – at around 14 cm height. Then a pressing plate - 4 cm thick - is put on top and by tightening of the threaded rods the material was compressed to a same thickness for all of the samples – 10 cm.

Only difference in the moulding procedure was for the part of the test in which curing conditions and their influence on properties were measured. For this test one of the samples (15) were put in a mould of which all the planes were drilled with 20mm diameter holes with 80 mm between the centres. It was done, so that the sample start to cure in air immediately after moulding.

3.5 Demoulding

After curing for two days, the samples were demoulded, but left horizontally on the back plate to cure for two days in laboratory conditions (20±2 ^{0}C and 40±10 %RH). After these two days the samples were weighed and put to cure in vertical position. Then the samples were left to cure for 30 more days, after which they were put in the drying oven for 5 days at 50 ^{0}C temperature, after this period the samples didn't show any more drying progress.

For the curing conditions part of the test this stage was done differently. Total number of six samples were prepared for this test. After two days of curing from demoulding, one of the samples (13) was put in the drying oven, another was wrapped in plastic foil (17), and the rest were kept to cure in laboratory conditions. Then, after 10 days another sample was put in drying oven (14). And then after 20 more two samples were put in the oven – regular (4) and the one from mould with drilled holes (15). One of the six samples was not put in the oven, it dried only in laboratory conditions

(16). After complete drying all of the samples were tested as regular samples.

3.6 Testing

Thermal conductivity was measured using LaserComp FOX600 heat flow meter, according to LVS EN 12667 guidelines, test settings 0 ^{0}C upper and 20 ^{0}C lower plate. For compressive and flexural strength tests the samples were sawn in smaller pieces – two samples - 100x100xheight for compressive and two 150x350xheight for flexural strength. Samples were tested on Zwick Z100 universal testing machine. The pressure applied was at 10 mm/min, force-deformation diagram (Fig. 3.) was recorded in the process. Compressive strength part of the test was done until 10% relative deformations (according to LVS EN 826), flexural – until rupture (Fig. 4.). For more correct results a 5 N prepressure was applied, the span between points in flexural test – 250 mm.

3.7 Preparation of sample for reaction to fire test

The samples were mixed, demoulded and cured in the same way and conditions as regular samples, only the size of specimens were different. As the test were be done according to LVS EN 13823:2010 "Reaction to fire tests for building products", sample needed to be made accordingly. As the achieved reaction to fire class can be awarded to the material that is equal in thickness or more as the tested one, the thinnest possible sample of 50 mm were prepared.

Total specimen width was 495 ± 5 mm for the small wing, and 1000 ± 5 mm for the large wing, height 1500 ± 5 mm. Both wings were made out of two pieces with a joint in the middle at 750 mm height (Fig. 5.). For extra stability the samples were glued with gypsum to 12 mm gypsum board plates, the joint were also filled with gypsum.

The tests were done in certified laboratory of Forest and Wood Products Research and Development Institute according to LVS EN 13823:2010. Before the tests the specimens were put in a climatic chamber with 23 ^{0}C and 50 %RH until equilibrium point were reached. Then the specimen were put in an L shape frame for the test.

4 RESULTS AND DISCUSSION

4.1 Various shives and their influence on LHC properties

Hemp shives from various Latvian producers and their influence on the final LHC properties can be seen in Table 2. samples 1 to 12. Looking at the density it can be seen that it is quite similar - from 349.30 to 364.16 kg/m^3. As the weight of the material that was put in the mould was the same – 8 kg – the difference in the density can only be explained by the amount of water that was absorbed by the shives in the mixing process – the more water shives absorbed, the less density of material, as the water evaporated.

Although the thermal conductivity of the material is more diverse than the density - from 0.0718 to 0.0778 W/m*K it can be seen that it does not correlate directly with the density as would be typical. The EE shives with the lowest thermal conductivity does not have the lowest density, as well as RM+LM shives with the worst thermal conductivity does not have the highest density. If the material is with similar density, then the greatest impact on the thermal conductivity of the LHC gives the right size composition, because it is important that all large voids are filled with shives, as they have closed pores, which provides enhanced thermal conductivity than open voids between shives. However, the filling cannot be made up of only with small sized shives, as such shives are obtained by repeatedly crushing the shives and damaging their pore structure.

Also, the material compressive and flexural strength is highly dependent on the size composition, as compressive strength range is from 0.140 to 0.337 MPa, flexural from 0.021 to 0.059 MPa. Compressive/bending ratio of around 5:1 is typical for hemp lime materials. From the results it can be seen that the samples where larger shives were used show poorer compressive and flexural strength. The reason could be the granulometric composition, as there are too many large shives that creates voids and uneven composition with weaker inclusions that deforms faster. Overall the sample no. 8. with experimentally cleaned shives showed the most promising results as it had the best thermal conductivity and average, but sufficient strength properties. The samples no. 10. and 12. also showed good results, thus showing that mixing together small and large fraction shives can have positive impact on LHC properties.

Comparing the results of compressive strength to other studies it can be seen that compressive strength of around 0,25 MPa for 350 kg/m^3 density material is typical when using similar binder and proportions [Walker, Pavia 2014][Elfordy 2008], but if a MgO binder is used then a much higher compressive strength can be achieved [Sasonni 2014][Stevulova 2013]. This result is also similar with those obtained from hemp-starch mixture, although the latter has lower density [Le 2014]

Comparing the results of thermal conductivity to other studies it can be seen that achieved thermal conductivity of around 0,077 W/m*K is an improvement comparing to other studies with similar mixtures [Bruijn

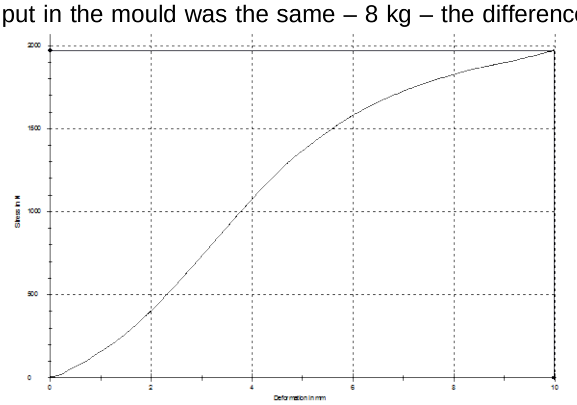

Fig. 3: Typical Force-Deformation diagram of the commpresive test

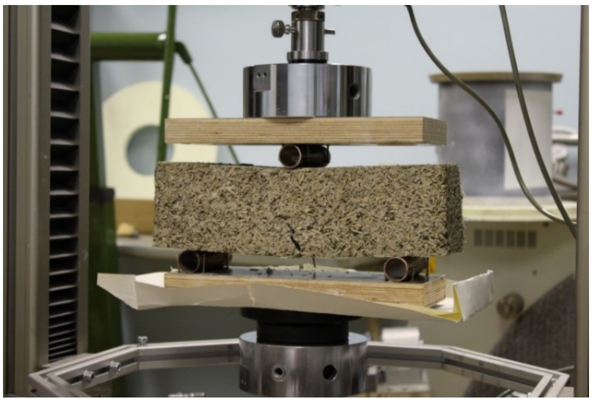

Fig. 4: Flexural testing on Zwick Z100

2013] and similar densities [Bentratello 2013] [Collet 2014]. Similar results have been achieved using cement and starch binders [Balciunas 2013].

4.2 Drying conditions

In the Table 3. an impact of drying conditions on the material density over time can be seen. From the table we can see that using a mould with holes for air exchange does not give the desired result as the density for the sample no. 15. is only slightly lower after demoulding. The density of the sample, while it is the lowest, is only about 7 kg/m^3 less than for sample no. 16.

The sample no 13. was placed in the drying chamber 2 days after demoulding and in 7 days was completely dry, which means that sample reached dry state 11 days after being manufactured. The sample no. 14 was placed in the chamber after 10 days of curing and dried in 5 days. The samples no. 1. and 15. were placed in the chamber after 30 days, but as can be seen from the Table 3., after 30 days of curing in the laboratory conditions, they were almost dry, as the densities before and after the drying in the chamber doesn't differ very much. The sample no. 17. was also placed in the chamber after removal from the film.

The sample no. 17. shows that long-term exposure to moisture does not give a positive effect on the mechanical properties of the material, because the material was so fragile that it could not be sawed in the required dimensions for the mechanical properties test. This phenomenon is similar to observation that LHC materials produced in this experimental series showed weaker mechanical strength on the inside and had stronger outer shell. Explanation could be one of these three reasons:

- Internal material does not get enough air exchange, thus there is no lime carbonization, although samples that used cement and sodium silicate additives also showed this weakness on the inside.
- In a presence of additional moisture hemp shives excretes organic substances that interfere with the binder curing [Diquelou 2015].
- Hemp shives, because of its hygroscopic nature, takes up water from the binder, thus depriving the water required needed for curing of the binder [Arizzi 2015].

However, the sample no 17. was so fragile, suggesting that the humidity from LHC materials is to be removed as soon as possible, and not added extra. This phenomenon should be analysed chemically, that way it could be determined what substances are encountered on the surface and inside of the material.

By analysing the properties of the rest of the samples form Table 2., it can be seen that both the thermal conductivity and mechanical strength of all the samples are very similar. This means that when different manufacture processes are available, the choice of the drying process can be based economically, as it doesn't influence LHC properties.

Tab. 2: Results from mechanical and thermal testing

No.	Type	DI (%)	Add. (%)	Cc	Mix. DKX	Density, kg/m^3	Thermal cond., W/m*K	Compr. strength , MPa	Flex. strength, MPa
1	RM	100%	-	-	-	359,15	0,0777	0,213	0,053
2	RL	100%	-	-	-	355,28	0,0737	0,174	0,053
3	RS	100%	-	-	-	349,30	0,0771	0,211	0,038
4	LM	100%	-	-	-	358,67	0,0776	0,203	0,039
5	LL	100%	-	-	-	361,41	0,0745	0,140	0,021
6	ZM	100%	-	-	-	356,57	0,0760	0,204	0,039
7	ZL	100%	-	-	-	364,16	0,0766	0,156	0,021
8	EE	100%	-	-	-	355,11	0,0718	0,253	0,043
9	RM+EE	100%	-	-	-	362,87	0,0775	0,218	0,054
10	RM+RL	100%	-	-	-	356,08	0,0762	0,240	0,049
11	RM+LM	100%	-	-	-	361,90	0,0778	0,337	0,039
12	LM+LL	100%	-	-	-	358,51	0,0761	0,241	0,049
13	RM	100%	-	2d	-	355,11	0,0795	0,201	0,048
14	RM	100%	-	10d	-	359,88	0,0788	0,209	0,049
16	RM	100%	-	30d h	-	358,67	0,0796	0,202	0,055
17	RM	100%	-	Lb.	-	368,52	0,0798	0,221	0,060
18	RM	100%	-	Pf	-	347,04	0,0791	0,000	0,000
21	RM	100%	-	-	Dr	364,32	0,0764	0,192	0,026
22	RL	100%	-	-	Dr	358,99	0,0727	0,170	0,043
24	RM	90%	10%cem	-	-	356,24	0,0783	0,205	0,034
25	RM	80%	20%cem	-	-	362,22	0,0787	0,211	0,032
26	RM	90%	10%mic.	-	-	361,74	0,0778	0,194	0,022
27	RM	100%	5%NaSi	-	-	369,97	0,0793	0,203	0,050
28	RM	100%	10%NaSi	-	-	371,51	0,0801	0,234	0,054

4.3 Mixer

Looking at the results in Table 2. it can be seen that the mixer choice does not have a large impact on thermal conductivity, since results for samples 21. and 22. are similar to those of samples 1. and 2. Also, the mechanical properties do not differ significantly, but they are slightly better for forced action mixer samples, which can be explained by the lumps and heterogeneous mixture of gravity-type mixer.

More significant differences both mixers have on technological level. The samples made in drum mixer quickly sticks to the walls of the mixer, thus losing some part of the binder for the mixture, it has to be removed manually. Also the mixture in the drum mixer quickly starts to form lumps which has to be crushed by hand.

Taking into account the technological shortcomings that emerged during the mixing and the lower mechanical properties it is recommended that for further experiments only forced action mixer is used.

4.4 Different binders

From the Table 2. it can be seen that the addition of additives to the binder has an effect on thermal conductivity – sodium silicate (no. 27. and 28.) samples has higher thermal conductivity and density. This is due to the fact that sodium silicate substituted water instead of the binder, which means that the sample has more binder in it, which attributed to this increase. In order to objectively compare the effects of sodium silicate on LHC samples, lime binder should be replaced instead of water.

The table also shows that the use of cement (24. and 25.) and mikrosilica (26.) has little effect on the thermal conductivity and compression, but showed lower results in flexure. This is due to the fact that the binder has high compressive strength and also large percentage of hydraulic additive (40%) which makes addition of additional hydraulic additives unnecessary.

Given that all of the applied additives raise the cost of the production process, but does not significantly improve the material properties, the addition of additional hydraulic additives at this stage has been found inexpedient.

4.5 Fire reaction test

The duration of the test is 1600 seconds, at the beginning a normalization of conditions in the chamber with additional burner is done, then after 300 seconds the main burner (Fig. 5.) is turned on. At the beginning of the test it was visually observed that there was a small ignition of the shives at the surface, but it went out fast and burning only from main torch continued. For the rest of the test only the main torch burned with open flame. Towards the end of the test, a small sample parts broke away and fell. After 1600 seconds, the burner was switched off, sample did not continue to burn, it was cooled by spraying water all over it.

Fig. 5: Reaction to fire test

From reaction to fire test report (Table 4.) it can be seen that the tested sample can be classified as class C s1, d0. The classification s1 indicates that almost no smoke were generated in the in the burning process, this is the highest class for smoke evaluation, d0 indicates that there were no flaming droplets, and this is the highest class in this assessment.

Class C obtained for the surface of reaction to fire is satisfactory, but it indicates that there were some burning of the material on the surface. Looking at THR and FIGRA graph (Fig. 6.) it can be seen that the curve is only slightly higher than 120 W/s and then falls rapidly, which means that only in the beginning the surface burned and generated additional amount of heat, but later the burning process did not continue. From the Table 4. it can be seen that FIGRA(0.2) was 123,2 W/s at 357s, this result is very close to the B-class which is lower than 120 W/s, which means that B class could be achieved by only slightly reducing the material reaction to fire.

Tab. 3: Drying conditions and densities of the samples

Nr.	Curing cond.	After drying, kg/m3	Before drying, kg/m3	30 days, kg/m3	10 days, kg/m3	2 days, kg/m3
13	2d	355,11	586,04	-	-	586,04
14	10d	355,87	465,57	-	465,57	587,41
1	30d	364,56	369,64	369,64	485,53	594,05
15	30d h	355,85	360,34	360,34	443,15	560,57
16	Lb.	363,13	-	364,08	462,43	567,37
17	Pf	343,47	556,84	556,84	571,31	587,45

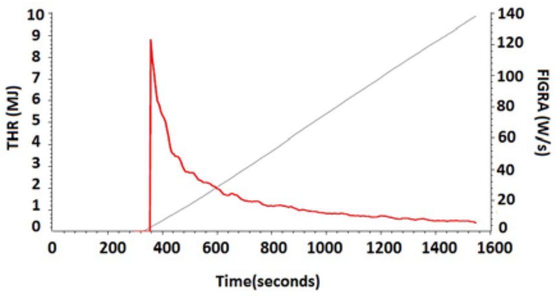

Fig. 6:THR and FIGRA graph

During the test and after, it was observed that the part that experienced the most surface burning was the lighter parts of the material (Fig. 5.) where it was more fragile and not fully cured. These lighter stripes were caused by imperfections in the curing process as the plates of material were stored on top of each other with plywood strips in between, and the material were exposed to moisture for a longer period in these places.

This means that an improvement in technology could already be sufficient to achieve B class. Or it could also be achieved by adding more binder, or by treating the surface of a material with liquid form flame retardants afterwards, or adding them in dry state in the mixing process.

The difference between B and C class is important as it defines the possible uses of the material. As, for example, by Latvian fire safety regulations B class materials can be used as thermal insulation materials on surfaces of buildings up to 28 meters height, C class only for up to 8 meters.

Tab. 4: Reaction to fire test report

Classification results	
FIGRA(0.2)	123.2 W/s at 357 s
FIGRA(0.4)	81.6 W/s at 387 s
THR(600)	4.6 MJ
SMOGRA	threshold not reached
TSP(600)	44.3 m²
Classification observations	
LFS to edge?	No
FDP flaming <= 10s?	No
FDP flaming > 10s?	No
Potential classification	
Class	C
Smoke production	s1
Flaming droplets/particles	d0

5 CONCLUSIONS

1. If particular mixing technique is applied, the thermal conductivity does not vary a lot between eight types of shives - from 0.0718 to 0.0778 W/m*K. It is concluded that the thermal conductivity is dependent on granulometric composition of the shives – too much large or small particles have a negative effect either on strength or thermal conductivity, the same applies to mechanical properties.
2. From the drying conditions test it can be concluded that the drying conditions after the 4th day after manufacture does not have significant influence on material properties. The only condition is to allow the material free air access on all possible sides, not to cover or wrap material. After 30 days of drying in laboratory conditions 10 cm thick block is almost fully dry.
3. Mixing of the material using forced action mixer instead of gravity type drum mixer showed little improvement in mechanical properties and thermal conductivity, but the technological advantages were significant, as drum mixer made the process slower and included more .manual work.
4. The additions of small amounts of hydraulic additives did not show significant increase in mechanical properties, as the binder mixture already contains enough hydraulic additive for all lime to react with. Sodium silicate addition could be promising but in present study it was added as a substitution for water not binder, so the achieved result is not fully comparable.
5. Although in present study a C s1, d0 reaction to fire class was achieved, it was due to material imperfections caused by the manufacturing technology. LHC materials can achieve B s1, d0, which is the highest generally achievable, as almost none of the materials with organic filler has A class reaction to fire. B class would be entirely sufficient for LHC to serve as insulation material for almost all of its possible applications.
6. The results suggest that LHC blocks have the necessary properties and potential to become widely used in improvement of thermal insulation of existing buildings

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