FIRENWOOD

Improved fire design of engineered wood systems in buildings

Small-scale tests with adhesive bonds with CLT, GLT and finger joints

Editors/Authors:
Magdalena Sterley (RISE Research Institutes of Sweden, Sweden)
Robert Olofsson (RISE Fire Research AS, Norway)
Jane Liise Nurk (Tallinn University of Technology, Estonia)
Alar Just (RISE Research Institutes of Sweden)

Contributors:
Morten Daffinrud (RISE Fire Research AS, Norway)
Ingrid Öberg Månsson (RISE Research Institutes of Sweden, Sweden)

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Coordinator: Tian Li at RISE Fire Research AS

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1 Introduction

Wood construction is growing rapidly and provides a substantial contribution to the development of a more sustainable construction sector. Several modern wood-based building systems are developed with a focus on tall wooden houses and industrial production, where glued products are an important part. Fire safety is important, but the adhesive properties in fire conditions are not fully understood. This applies in particular to new adhesive systems but also to existing ones that exhibit poor load carrying capacity in a fire. The problem has been noted by the FSUW (Fire Safe Use of Wood) global network, which formed a sub-group of "Glue-line failure of engineered wood products" with representatives from Australia, NZ, Canada, USA, France, Italy, Switzerland, Sweden, and Germany. The global network has gathered knowledge and experience from known cases of fire testing of glued wood components (especially glulam, finger joints, and CLT) and has defined research needs. The results highlighted by this group relate to the delamination of glued bonds in a fire which can cause increased charring of glued wood products, especially for CLT. The results show that the temperature during standard fire testing increases continuously without cooling phase and with delamination of CLT until a collapse of the structure occurs. Thicker CLT may be required to reduce delamination risks or to protect the wood material. This can lead to increased costs and greater weight of the construction as well as reduced possibility of using visible wood. Therefore, it is of the utmost importance to find methods for evaluating the adhesive bond properties in a fire. The hypothesis is that different adhesive systems have different behaviour in fire, and especially that delamination behaviour can be avoided by choosing a suitable adhesive system. The best method for the evaluation of fire delamination is a full-scale test, but considering the high costs of such full-scale tests, a smaller-scale test needs to be developed. The intention of FIRENWOOD project is that such small-scale methods should give the same results as full-scale tests. A new, smaller-scale method for classifying adhesives concerning fire properties would also simplify the planning of full-scale tests. In Work Package 3 of FIRENWOOD project, some small-scale fire testing methods for adhesive bonds were evaluated at RISE, and this report includes results from small-scale fire tests of adhesive bonds in finger joints, CLT and GLT.

The report is organized in three chapters based on the three different products tested. The common for all three tests was that the same eleven adhesive systems were used in all adhesive bonds.

2 Adhesives

Eleven adhesives are used in FIRENWOOD project in order to compare properties in a fire. Adhesives originate from four different chemical backgrounds and represent the state of the art of adhesives used in timber structures. Adhesives are manufactured by four leading European adhesive manufacturers, and all eleven adhesives have passed requirements in European standards for load-bearing timber structures. Adhesives are marked with numbers 1 to 12 (adhesive number 10 is not included in this Work Package).

3 Testing of finger joints

3.1 Timber and manufacturing of finger joints

Knot-free timber of spruce with dimensions 50x150 mm was used. The average density was 470 kg/m^3 and moisture content was 12%. Six finger joints were manufactured with eleven adhesives. Densities for each specimen are presented in Appendix 1.

Finger joints were cut industrially in the production line of Masonite Beams. The adhesive was applied manually (see Figure 1) with an adhesive amount specified by the adhesive manufacturer. Two-component adhesives were mixed with hardener, and a specified mixing time was maintained.

Figure 1. Manual application of adhesive on finger joint.

3.2 Finger jointed specimens

In total, sixty-six specimens were produced—six specimens with each of eleven adhesives. The raw size of the specimen was 100x50x400 mm (BxHxL) with a finger joint in the middle. The thickness (H) of the specimen was planed from both sides to 45 mm. 50 mm specimen was cut from both ends and labeled with the name of the adhesive and the raw material (e.g. A1 for glue A, series 1) for use in density measurements.

The planed raw specimen 100x45x300 mm (See Figure 2) was cut lengthwise into 8-9 slices measuring 10x45x300 mm. Three slices were tested in tension at ambient conditions. Three specimens with each adhesive were tested under a cone heater with a gypsum board, and five specimens with each adhesive were tested under a cone heater directly without a gypsum board. The rest was saved as a reserve.

All specimens were marked according to the raw material and adhesive used. For example, 1.2.3 represents Adhesive 1, Raw specimen 2, and Test specimen 3. Extra plywood pieces measuring 45x45x10 mm were glued on both sides of both ends of the cone specimens with

PRF (phenol-resorcinol-formaldehyde) adhesive. All specimens were conditioned at 20°C and 65% RH before testing.

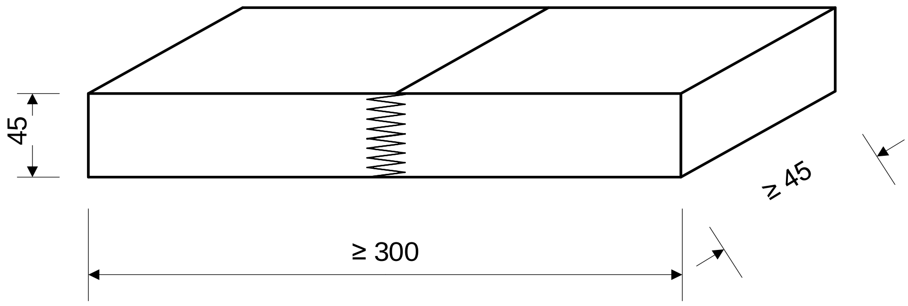
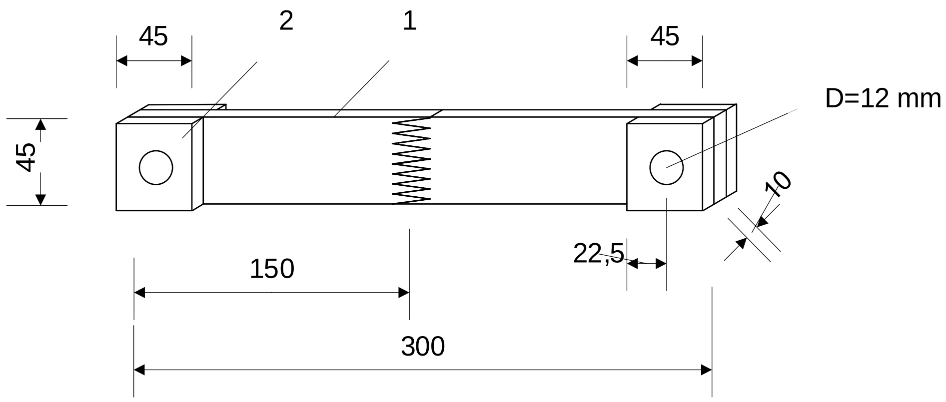


Figure 2. The raw specimen (units in mm).



Key: 1 – Test specimen, 2 - Plywood species

Figure 3. Test specimen (units in mm).

Densities of both parties of finger jointed raw specimens were measured and are documented in Table 1.

Table 1. Densities of timber used for finger jointed specimens

Adhesive	Densities [kg/m^3]												
	Material group												
	1		2		3		4		5		6		Average
1	484	484	462	458	453	453	493	493	489	489	436	436	469
2	489	489	462	458	467	467	498	502	476	476	440	440	472
3	484	484	458	449	453	453	489	489	471	471	471	467	470
4	453	453	480	480	458	458	489	489	498	502	444	444	471
5	467	467	453	453	471	471	502	493	449	449	449	444	464
6	462	462	453	453	480	480	502	502	476	476	440	440	469
7	467	467	470	476	453	458	489	489	489	489	444	444	470
8	485	484	467	467	458	462	493	498	476	471	444	444	471
9	480	480	462	462	453	458	489	489	498	498	440	440	471
11	484	480	467	467	462	462	480	480	480	480	449	449	470
12	470	476	471	471	458	453	502	493	489	484	449	449	472

3.3 Testing of finger joints at ambient temperature

Reference tests of finger joints in tension at ambient temperature were conducted. Specimens were the same size as cone specimens with nominal dimensions of 10x45x300 mm. A photo taken during the test is shown in Figure 4. Test results are shown in Table 2.

The relation was also studied between density and tensile strength. See Figure 5. The relation does not have a good correlation.

Figure 4. Tension test at ambient temperature.

Table 2. Tension strength of finger jointed specimens

Adhesive	Material group	Slice number	Density (kg/m^3)	Failure load (N)	Average failure load (N)
1	1	1	484	17240	16908
1	1	2	484	15862	
1	1	3	484	17622	
1	2	1	460	20951	21187
1	2	2	460	21423	
2	1	1	489	22469	24421
2	1	2	489	26224	
2	1	3	489	24571	
2	2	1	460	18671	18248
2	2	2	460	17825	
3	1	1	484	18600	17677
3	1	2	484	15815	
3	1	3	484	18615	
3	2	1	454	17400	21126
3	2	2	454	24852	
4	4	1	489	26833	28269
4	4	2	489	33330	
4	4	3	489	24643	
4	1	1	453	16288	17098
4	1	2	453	17908	
5	3	1	471	19156	19051
5	3	2	471	17421	
5	3	3	471	20577	
5	1	1	467	19533	20366
5	1	2	467	21199	
6	3	1	480	22416	22284
6	3	2	480	21191	
6	3	3	480	23245	
6	1	1	462	19443	18869
6	1	2	462	18295	
7	2	1	473	15808	20002
7	2	2	473	27923	
7	2	3	473	16275	
7	4	1	489	19520	19589
7	4	2	489	19657	
8	1	1	485	23054	18692
8	1	2	485	18018	
8	1	3	485	15005	
8	2	1	467	12800	14586
8	2	2	467	16372	
9	1	1	480	14277	16767
9	1	2	480	19097	
9	1	3	480	16927	
9	2	1	462	15965	15983
9	2	2	462	16000	
11	1	1	482	19475	20357
11	1	2	482	20069	
11	1	3	482	21526	
11	2	1	467	19587	22810
11	2	2	467	26033	
12	2	1	471	23484	21921
12	2	2	471	22265	
12	2	3	471	20015	
12	4	1	498	21450	19992
12	4	2	498	18533	

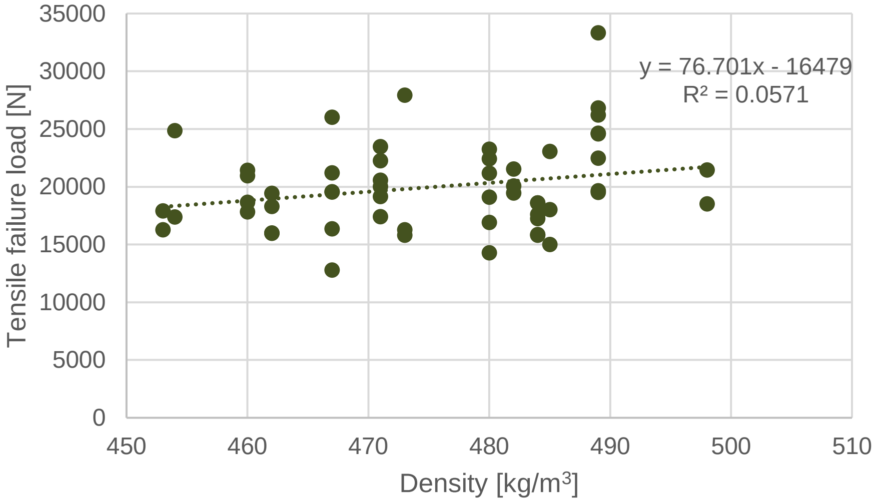


Figure 5. Relation between tensile failure load and density.

3.4 Testing of finger joints under cone heater

The specimen size for the cone test was 10x45x300 mm. Reinforcement for load application with four pieces of plywood with a size of 45x45 mm was glued on both flat surfaces at both ends of each specimen. A hole with a diameter of 12 mm was drilled in both ends of specimens providing a connection to the loading device. Specimens were exposed to a constant heat flux of 50 kW/m^2 by the Cone heater. Cone tests were performed in 3 different test series.

Test series 1

The test specimen is protected at the top by a gypsum board with a thickness of 12,5 mm and insulated on both sides with stone wool (133 kg/m^3, thickness of 50 mm), and loaded in tension by 225 kg. Details can be seen in Figures 6, 7, and 9. Tests were held in Trondheim.

Test series 2

The test specimen is not protected at the top but is still insulated on both sides with stone wool (133 kg/m^3, thickness of 50 mm). Unlike test series 1, the specimen is loaded in tension by 100 kg. Details can be seen in Figures 6, 8, and 9. Tests were held in Tallinn.

Test series 3

Same as test series 2, the test specimen is not protected at the top and is insulated on both sides with stone wool (133 kg/m^3, thickness of 50 mm). This test series changes the tension load to 200 kg. Details can be seen in Figures 6, 8, and 9. Tests were held in Tallinn.

The test load was hanged on a steel wire. Testing time started when the shutter under the cone heater was opened. Time to failure (TTF) was measured. After failure occurred, the specimen was removed from the cone heater and extinguished. The maximum time from failure to extinguishment was 15 seconds. After testing, specimens were measured in order to determine the residual cross-section and charring depth (char layer). Failure mode was observed as well.

It is worth mentioning that in addition to tension stress, the finger jointed specimens which are tested under the cone heater are also influenced by the bending stress. The bending occurs when the cross-section height decreases due to the charring.

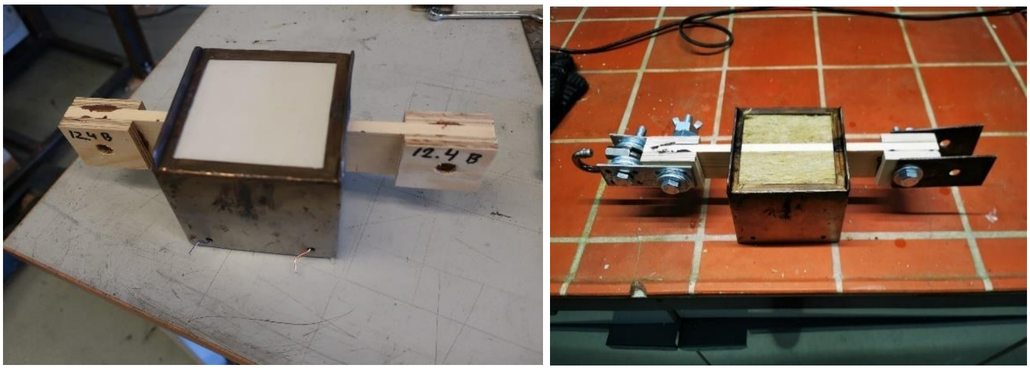


Figure 6. Test specimen with the holder. Left – test series 1, right – test series 2 and 3.

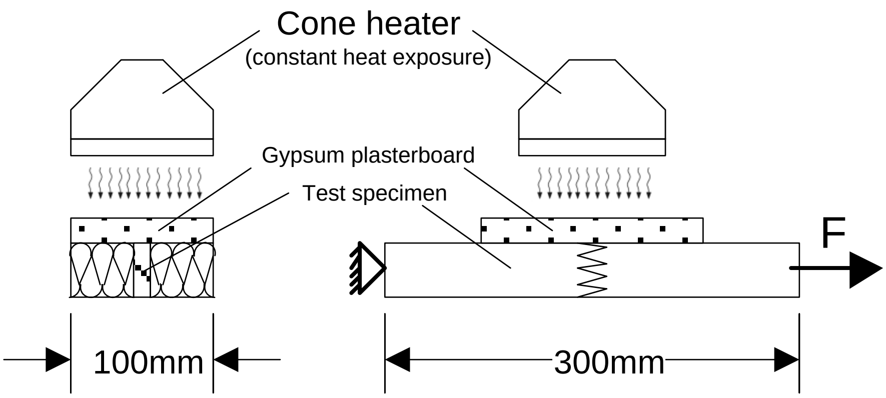
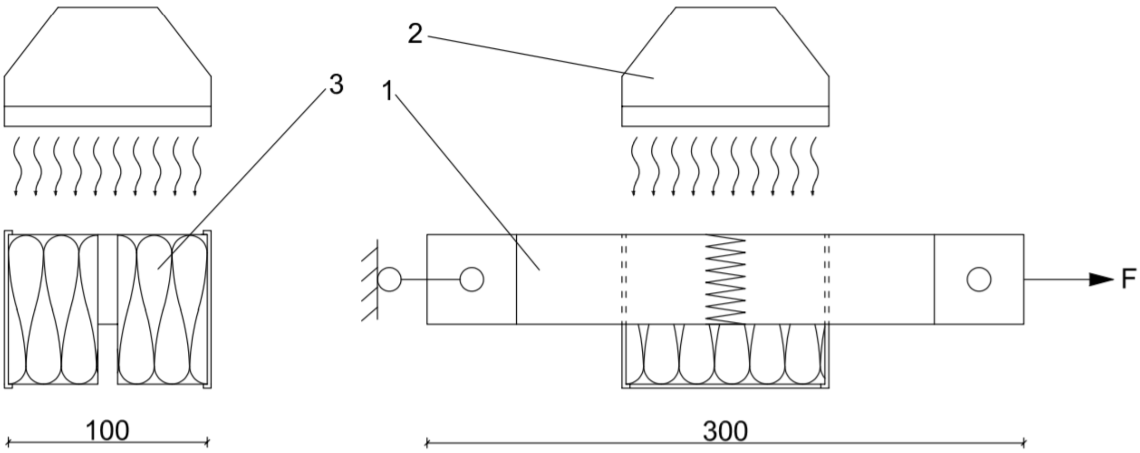


Figure 7. Test setup for test series 1.



Key: 1-test specimen, 2-cone heater, 3 - stone wool, F - tensile load

Figure 8. Test setup for test series 2 and 3. Units in mm.

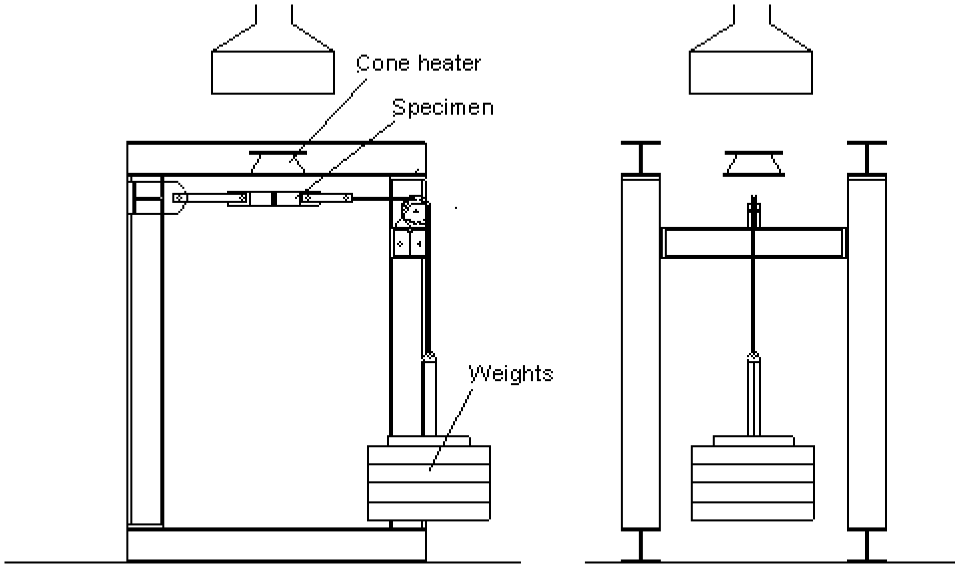


Figure 9. Testing rig for finger jointed test specimens.

Figure 10. Test series 2 specimen after cleaning.

Failure modes were determined after testing.

A representative example of a test specimen after fire testing is shown in Figure 10. The char layer after the test was brushed off, and residual cross-section could be measured, as well as determination of failure mode.

Following failure modes could be defined:

A - the governing failure mode is a failure in adhesive – the adhesive (or the adhesion) is the weakest part of the bond

A/W - mixed failure in adhesive and wood - mostly in adhesive with a small amount of fibers torn out from the bond, the adhesive is the weakest, but partially good adhesion is present, and therefore fibers are torn, or wood is weaker than bond

W/A - mixed failure in wood and adhesive - deeper wood parts torn out and fiber failure, strong adhesive and bond or weaker wood

W - the governing failure mode is failure in wood - strong adhesive and bond but also weaker wood

3.4.1 Fire testing under cone heater with gypsum

Here the results of tested finger jointed specimens with gypsum are given. In Figure 11, all the time to failure results are plotted against residual cross-section height at the moment of rupture. The relations show a good correlation. The tests show good repeatability.

The time to failure and failure modes of all the tests with gypsum plasterboard (Type A, 12,5 mm) on the fire side are shown in Figure 12. The results are grouped according to the adhesive groups. The start time of charring is assumed to occur at approximately 1250 seconds.

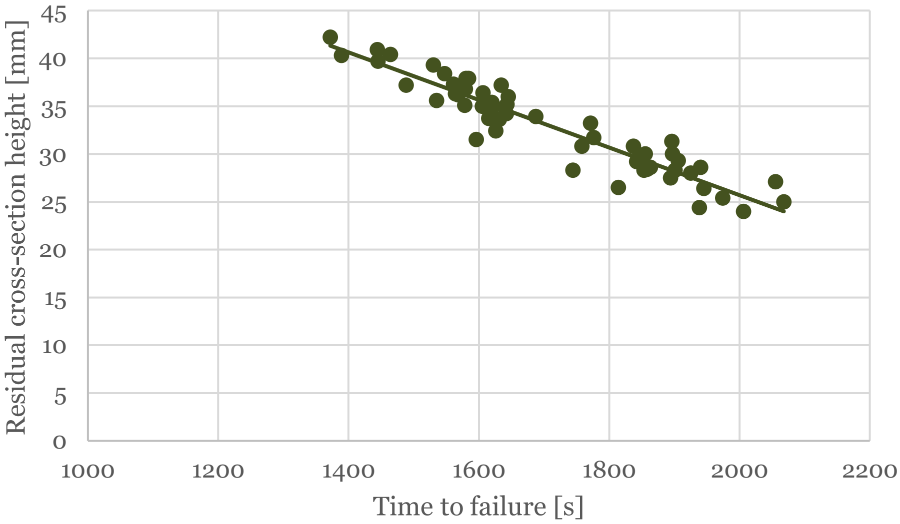


Figure 11. Time dependence of the height of the remaining cross-section.

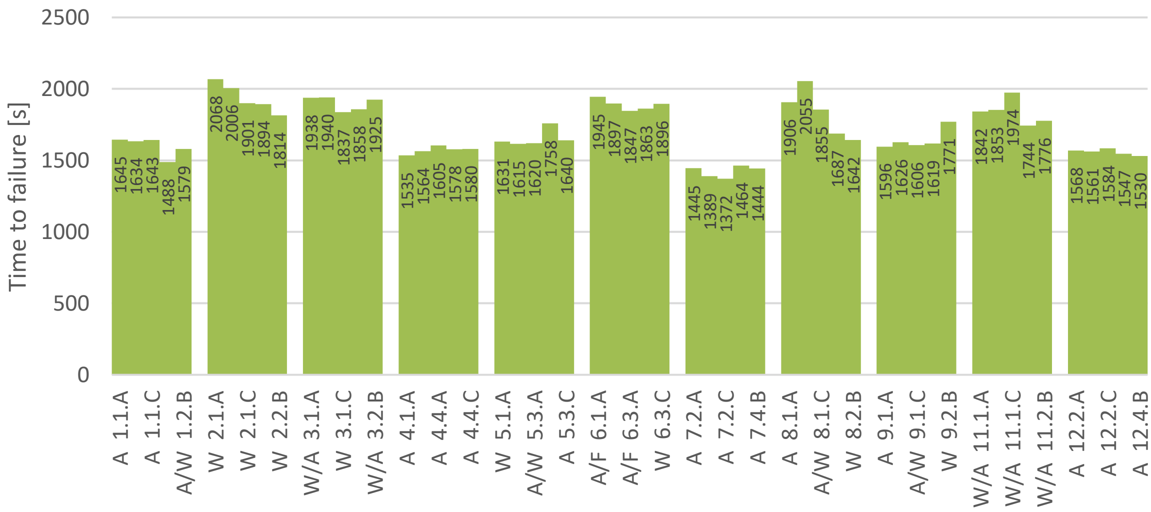


Figure 12. Time to failure and failure modes of test specimens loaded with 225 kg. Specimens are covered by gypsum plasterboards 12,5 mm

Table 3. Summary results of loaded finger joint cone heater tests with gypsum

Adhesive	Average TTF	Residual strength		TTF	Residual strength
no	min	MPa	Failure mode	Standard deviation	Standard deviation
1	26.63	6.05	A/W	1.12	0.12
2	32.28	8.55	W	1.67	0.62
3	31.66	7.93	W/A	0.81	0.69
4	26.21	6.16	A/W	0.42	0.19
5	27.55	6.56	A/W	0.99	0.37
6	31.49	7.59	W/A	0.63	0.49
7	23.71	5.43	A	0.66	0.17
8	30.48	7.23	A/W	2.79	0.75
9	27.39	6.59	A/W	1.2	0.37
11	30.63	7.81	W/A	1.48	0.67
12	25.93	5.78	A	0.38	0.19

3.4.2 Fire testing under cone heater without gypsum

Here the results of tested finger jointed specimens without gypsum boards are given. In Figure 13, all the time to failure results are plotted against residual cross-section height at the moment of rupture. The relations show a good correlation. The tests show good repeatability.

The time to failure and failure modes of all the tests are shown in Figure 14 and Figure 15. The results are grouped according to the adhesive groups.

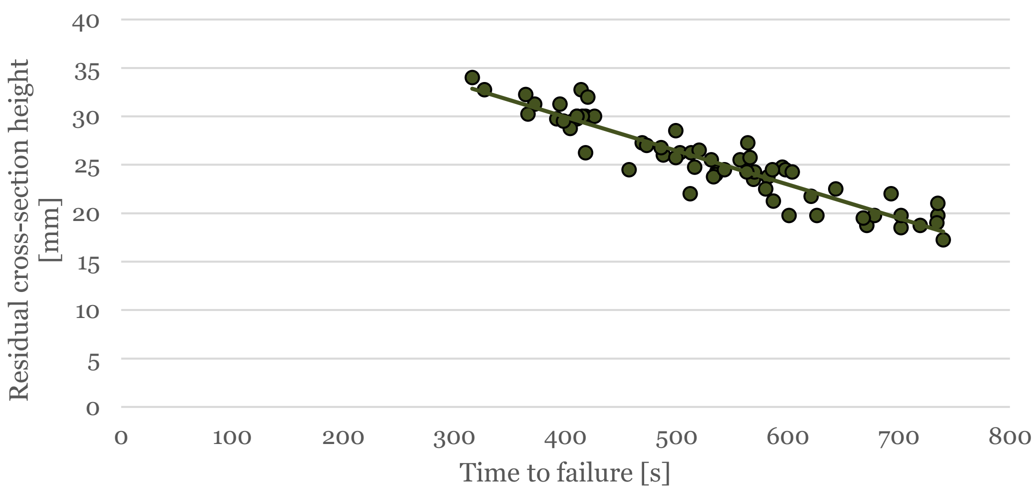


Figure 13. Time dependence of the height of the remaining cross-section.

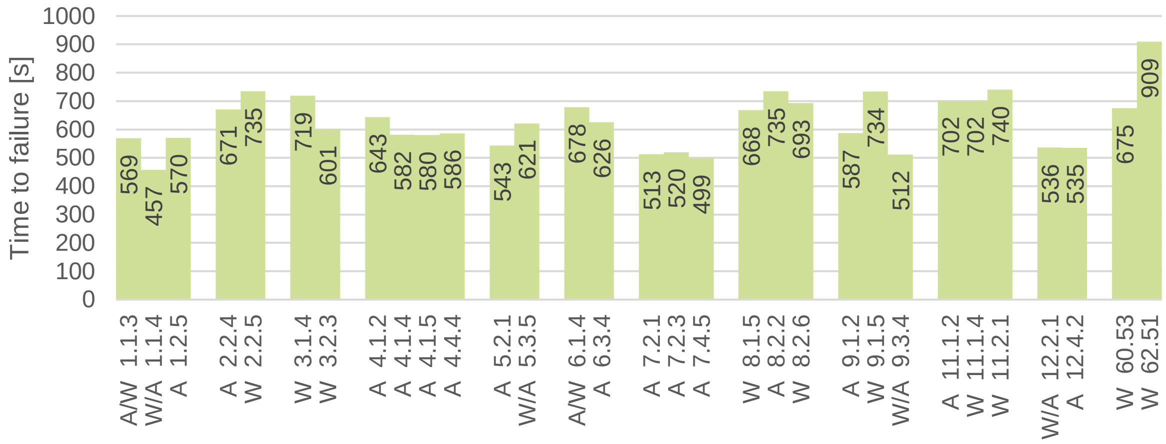


Figure 14. Time to failure and failure modes of test specimens loaded with 100 kg.

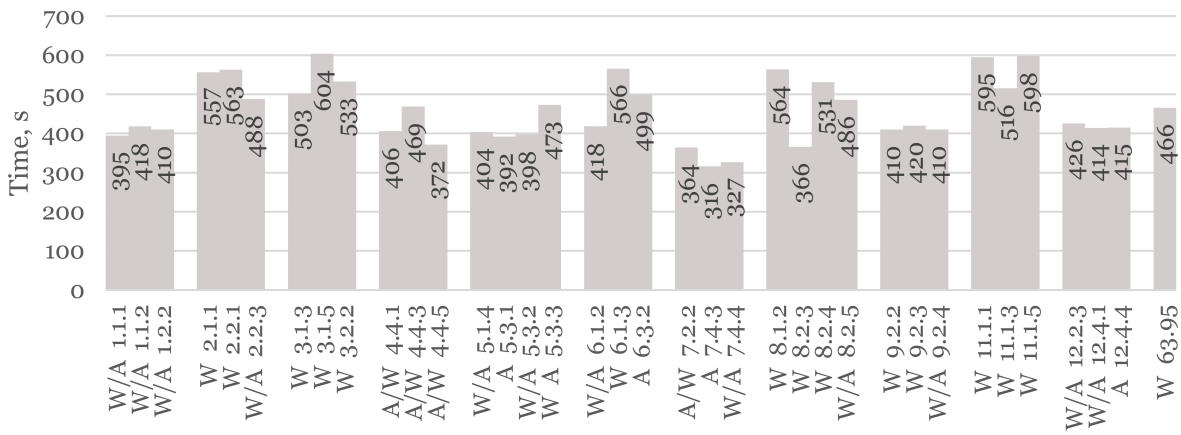


Figure 15. Time to failure and failure modes of test specimens loaded with 200 kg.

Table 3. Results of loaded finger joint cone heater tests without gypsum (load: 100 kg).

Adhesive	TTF s	Failure mode	Charring depth mm	Tension stress N/mm^2	Combined stress (tension + bending) N/mm^2	TTF, standard deviation s	Combined stress, standard deviation N/mm^2
1	532	A/W	20.9	4.07	14.7	65	0.82
2	703	W/A	25.8	5.10	25.6	45	2.25
3	660	W/A	25.8	5.10	25.6	83	2.25
4	598	A/W	21.7	4.21	16.0	30	1.69
5	582	A/W	21.9	4.26	16.5	55	3.48
6	652	A/W	25.3	4.97	24.0	37	0.00
7	511	A	18.8	3.75	11.9	78	7.27
8	699	W/A	24.2	4.72	21.3	34	3.21
9	611	A/W	24.3	4.75	21.6	113	4.18
11	715	W/A	26.5	5.32	28.4	22	4.57
12	536	A/W	20.9	4.07	14.6	1	0.27

Table 4. Results of loaded finger joint cone heater tests without gypsum (load: 200 kg).

Adhesive	TTF	Failure mode	charring depth	Tension stress	Combined stress (tension + bending)	TTF, standard deviation	Combined stress, standard deviation
	s		mm	N/mm^2	N/mm^2	s	N/mm^2
1	408	W/A	14.7	6.47	15.88	12	1.16
2	536	W	19.8	7.78	26.10	42	2.47
3	547	W	20.3	7.94	27.60	52	3.64
4	416	A/W	15.7	6.71	17.66	49	3.38
5	421	A/W	16.3	6.84	18.56	45	2.30
6	494	A/W	18.2	7.33	22.35	74	3.10
7	336	A/W	12.0	5.95	12.46	25	0.99
8	487	W	17.6	7.18	21.23	87	3.91
9	413	W	14.3	6.40	15.43	6	1.59
11	570	W	20.3	7.95	27.63	47	0.42
12	418	W/A	14.1	6.36	15.14	7	2.10

4 Testing of face bonds

4.1 Test specimen

CLT or GLT blocks were glued by adhesive manufacturers according to the instruction shown in Appendix 1. From CLT blocks, the specimens for fire testing were prepared. The size of the specimen is 100x100x60 mm (BxLxH), and thickness is measured in three cross-laminated layers (20 + 40 mm). The outermost layer is 20 mm thick. The tested bond line surface is then reduced to 50x50 mm by cutting a notch on all sides using a thin band saw (see Figure 1). Details concerning the specimen geometry are shown in Figure 15.

With the present method, the reduction of the load-bearing capacity of a face-glued adhesive bond can be assessed by heating the adhesive bond under the cone heater and then conducting a shear test immediately after the heat exposure while the adhesive bond is just behind the charred layer of wood.

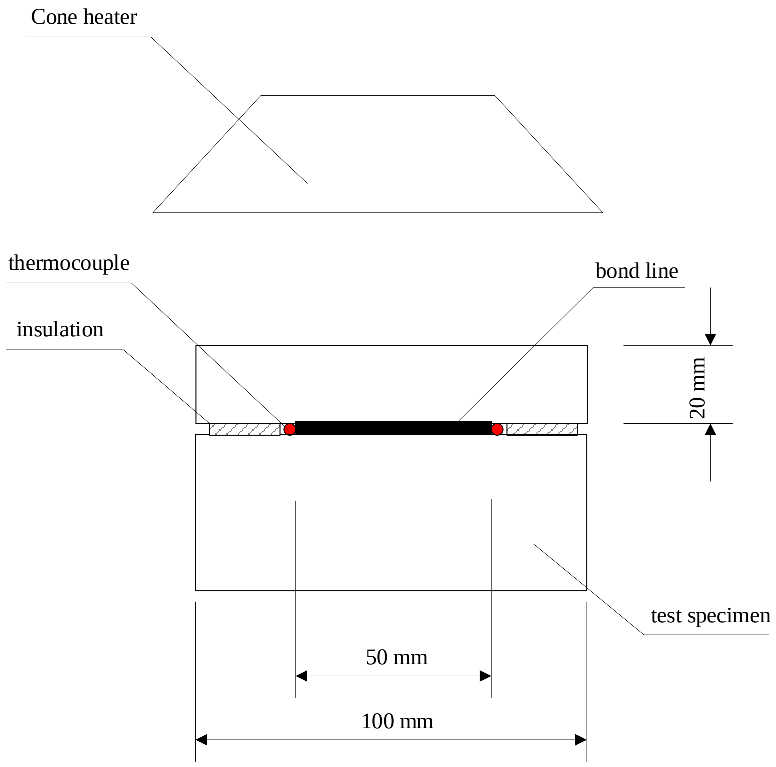


Figure 16. Side view of the test specimen under a cone heater.

Two thermocouples are placed parallel to the bond inside the notch, close to the bond line, with ceramic wool insulation protecting from the outside (see Figure 15). The specimen is protected on all four lateral sides by a gypsum plasterboard with 20 mm overlap (Gypsum board, Type F, thickness 15 mm). Test specimens were wrapped by aluminium tape on the sides to prevent charring of the sides. The final exposed surface was 80x80 mm (see Figure 16).

Figure 17. Specimen protected with plasterboard and aluminium tap.

4.2 Testing of face bonds under cone heater

In this method, the cone heater is calibrated to output 50 kW/m² heat flux using a water-cooled heat flux meter. Then, the cone heater is closed with a shutter (e.g., a CaSi board). The specimen is placed under the cone so that the bottom of the cone is 25 mm above the top of the test specimen. The time is started when the shutter is removed from the cone heater (at the start of the heat exposure). The temperature development is observed using two thermocouples measurements. The specimen is heated until an average temperature of 290°C measured by two thermocouples is reached.

Once the above temperature is reached, the specimen is removed from under the cone heater. The protective gypsum is removed from around the specimen immediately, and it is moved to the shear testing machine. This procedure takes about a minute. The specimen is then loaded in shear until failure, and the failure load and failure mode are recorded (see Figure 18). Tests were done in both Trondheim and Stockholm.

CLT specimens were glued with cross-wise grain directions of the glued lamellas. GLT specimens had similar grain directions. Shear testing was always made along the grain direction of the unburnt lamella.

Test results are given in Tables 5 and 6.

Figure 18. Shear test of the bondline.

Figure 19. Test specimens after testing (left: top view, right: side view).

Table 5. Results of cone heater and shear tests with CLT specimens.

Adhesive	Specimen	Testing place	Average temperature at the end, °C	Time, min	Shear capacity, N	Failure mode
1	1.2	Stockholm	298	23.83	26	A
	1.3	Stockholm	300	23.53	43	A
		Trondheim	300	26	52	A
		Trondheim	270	25	40	A
	CLT1	Stockholm	308	24	44	A
2	2.1	Stockholm	285	23.53	275	C
	2.2	Stockholm	292	25	327	C
		Trondheim	300	26.83	117	C
		Trondheim	256	23.3	302	C
3		Trondheim	318	29	238	C
		Trondheim	317	29	132	C
		Trondheim	300	29.78	207	C
		Trondheim	273	25.95	202	C
4		Trondheim	300	32	0	A
		Trondheim	321	29	0	A
		Trondheim	329	29	13	A
		Trondheim	305	29	0	A
5	5.1	Stockholm	293	22.17	127	A
	5.2	Stockholm	281	21	143	A
		Trondheim	300	27.63	53	A
		Trondheim	270	24.43	205	A
6	6.1	Stockholm	297	24.5	309	A/C
	6.2	Stockholm	292	22.17	254	A/C
	6.3	Stockholm	278	22.83	310	A/C
	CLT6	Stockholm	279	24	154	A/C
		Trondheim	290	24.9	226	A/C
7		Trondheim	300	29	0	A

		Trondheim	300	29	0	A
		Trondheim	300	29	0	A
8	8.1	Stockholm	291	22.5	313	C
	8.2	Stockholm	290	29.67	319	C
	CLT8	Stockholm	292	21.83	137	C
		Trondheim	300	26.5	86	C
		Trondheim	266	22.5	316	C
9	1	Stockholm	315	29	196	C
	2	Stockholm	301	27	221	C
	3	Stockholm	316	29	145	C
		Trondheim	314	26	266	C
		Trondheim	300	25.5	228	C
11		Trondheim	272	29	256	A/C
		Trondheim	300	30	276	A/C
		Trondheim	300	29.5	209	A/C
12		Trondheim	260	29	110	A
		Trondheim	284	29	60	A
		Trondheim	300	29.72	0	A
		Trondheim	294	26.85	0	A

Table 6. Results of cone heater and shear tests with GLT specimens.

Adhesive	Specimen	Testing place	Average temperature at the end, °C	Time, min	Shear capacity, N	Failure mode
1	L1.1	Stockholm	290.65	27.67	163	A/C
	L1.2	Stockholm	297.4	25	164	A/C
2	L2.1	Stockholm	298.65	32	229	C
	L2.2	Stockholm	291	25	445	C
3	L3.1	Stockholm	294.7	31	423	C
	L3.2	Stockholm	302.3	26.5	655	C
4	L4.1	Stockholm	292.15	28	0	A
	L4.2	Stockholm	290.2	26.5	0	A/C
5	L5.1	Stockholm	291.85	26.67	122	A
	L5.2	Stockholm	290.95	27	66	A
6	L6	Stockholm	295.5	25	454	A/C
	L6.2	Stockholm	294	27.67	392	C
	L6.28	Stockholm	290	25.83	350	C/A
7	L7.2	Stockholm	291.45	28.75	11	A
8	L8.1	Stockholm	297.5	21	628	A/C
	L8.2	Stockholm	291.65	23.5	303	C/A
	L8.28	Stockholm	292.05	23.25	382	C/A
9	L9.1	Stockholm	295.25	29	358	C/A

	L9.2	Stockholm	297.85	29.83	273	C
	L9.3	Stockholm	293.3	24	204	A/C
11	L11.1	Stockholm	292.65	28	347	C
	L11.2	Stockholm	292.05	27	296	C
12	L12.1	Stockholm	290.65	33.5	114	A
	L12.2	Stockholm	292.6	27.25	72	A/C
solid timber	S1 ALONG	Stockholm	294.65	25	489	
	S2 ALONG	Stockholm	297.55	23.75	396	
	S4 ACROSS	Stockholm	293.15	23	329	

Table 7. Summary of cone heater and shear tests with CLT and GLT specimens.

No	**temp**	**test time**	**Shear capacity CLT**	**No**	**temp**	**test time**	**Shear capacity GLT**
adhesive	C	min	N	adhesive	C	min	N
1	295	24.47	41	1	294	26.34	164
2	297	25.53	232	2	295	28.50	337
3	302	28.43	195	3	299	28.75	539
4	314	29.75	3	4	291	27.25	0
5	296	24.85	113	5	291	26.84	94
6	287	23.68	251	6	293	26.17	399
7	300	29.00	0	7	292	28.75	11
8	288	24.60	234	8	292	23.38	343
9	309	27.30	211	9	295	27.61	278
11	291	29.50	247	11	292	27.50	322
12	285	28.64	43	12	292	30.38	93
				Woodperp	293	23.63	291
				Woodparal	296	24.38	443

5 Discussion and analysis

In general, small-scale methods show a good correlation with each other. The correlation between CLT and GLT is shown in Figure 20. Capacities of the bond line between 2 lamellas with the same parallel grain direction are approximately 1.5 times higher than the capacities of lamellas glued with the cross-wise grain direction.

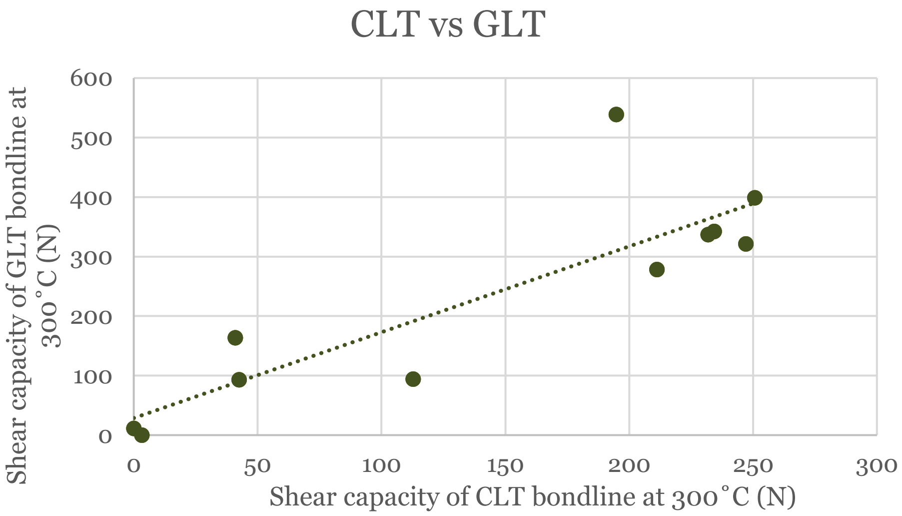


Figure 20. Comparison of shear capacities of CLT and GLT specimens.

Comparison between the shear capacities of cone heater tests of CLT specimens and tension capacities of finger jointed specimens also shows a good correlation, as shown in *Figure 21*.

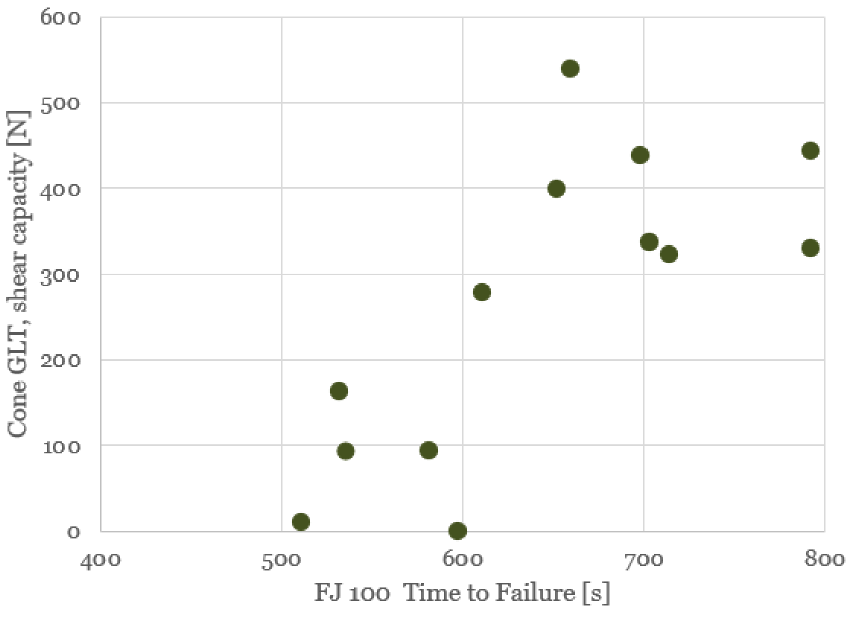


Figure 21. Comparison of shear capacities of CLT and GLT specimens.

6 Conclusions

Cone heater tests with finger jointed specimens and face bonded specimens were made with 11 selected adhesives and wood with similar properties. A total of eighty-eight finger jointed specimens were tested in fire, thirty-three of which were protected with a gypsum board and fifty-five were unprotected. A total of forty-seven face bonded CLT specimens and twenty-four GLT specimens were tested in fire. As the specimens were small, the tests were easily repeatable and didn't take much time.

Tension tests under the cone heater and at ambient temperatures differ in terms of the type of stress that is impacting the specimen. For specimens tested under the cone heater additional bending happens when the height of the cross-section decreases. Specimens tested at ambient temperatures are only affected by tension stress. So for the cone heater specimens combined stress has to be taken into account.

Face bond heating and shear tests showed that face bonds glued between lamellae with the same grain direction have approximately 1,5 times more shear capacity compared to the ones with the cross-wise grain direction.

The tests under the cone heater show a clear difference between different adhesive groups. Some of the adhesives tend to be less effective in fire than others due to the softening of the adhesive at higher temperatures, causing the specimen to fail earlier and/or lower strength.

Both small-scale methods showed a good correlation with each other. The adhesive groups appeared to fall into similar groups in terms of strength/durability in fire.

Appendix A. Instruction for glued specimens CLT and GLT

Timber 22x120 mm shall be planed to 20x120 mm.

Timber 42x120 mm shall be planed to 40x120 mm.

Knots shall be removed (at least on the one side of specimen) i.e. one outer side and in the following bond line on the inner lamellae. Bond line which will be tested should not have any knot at the glued surface.

For each adhesive system:

2 specimens of 3-ply CLT with configuration 20+40+20 mm and 40+40+40 mm and

1 specimen of 3-ply GLT shall be glued with configuration 40+40+40 mm.

Please report adhesive amount and pressing pressure. Preferably use pressing pressure of 0,8 MPa, if the pressure is not as preferable report the actual value.

Application and pressing time should be reported too. All important gluing parameters shall be given.

For each lamella density and moisture content shall be measured and reported (especially important for outermost lamellae, which will be supposed to fire testing), preferably with 430-480 kg/m^3 and moisture content of 12%.

For each adhesive system, 2 CLT and 1 GLT specimens shall be glued. The same parameters shall be used for CLT and GLT. The gluing parameters shall be kept the same as for manufacturing of other specimens to be glued in MPA Stuttgart. We also need the same information for gluing finger joints. Mark specimens as agreed earlier.

Specimens shall be sent to:

RISE Bioeconomy att Magdalena Sterley

Drottning Kristinas väg 61

114 28 Stockholm

Sweden

If it is of any help, use the following table for gluing parameters.

Adhesive no/symbol	
Mixing ratio	
Spread rate	
Pressure	Preferably 0,8 MPa, if not specify here
Open time	
Close time	
Pressing time	
Pressing temperature	
Dimensions of lamellae	
Area of glued specimen	240x360 mm (CLT) 120x500 mm (GLT)
Thickness of lamellae CLT	20+40+20 mm (1 specimen) and 40+40+40 mm (1 specimen)
Thickness of lamellae GLT	40+40+40 mm (1 specimen)
Please attach specifications on lamellae density and moisture content	

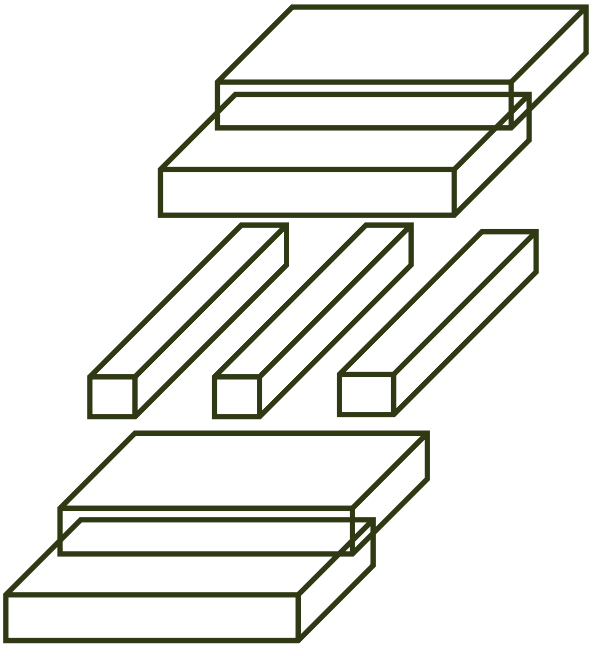
Adhesive no/symbol	
Mixing ratio	

Spread rate	
Pressure	Preferably 0,8 MPa, if not specify here
Open time	
Close time	
Pressing time	
Pressing temperature	
Dimensions of lamellae	
Area of glued specimen	240x360 mm (CLT) 120x500 mm (GLT)
Thickness of lamellae CLT	20+40+20 mm (1 specimen) and 40+40+40 mm (1 specimen)
Thickness of lamellae GLT	40+40+40 mm (1 specimen)
Please attach specifications on lamellae density and moisture content	

Adhesive no/symbol	
Mixing ratio	
Spread rate	
Pressure	Preferably 0,8 MPa, if not specify here
Open time	
Close time	
Pressing time	
Pressing temperature	
Dimensions of lamellae	
Area of glued specimen	240x360 mm (CLT) 120x500 mm (GLT)
Thickness of lamellae CLT	20+40+20 mm (1 specimen) and 40+40+40 mm (1 specimen)
Thickness of lamellae GLT	40+40+40 mm (1 specimen)
Please attach specifications on lamellae density and moisture content	

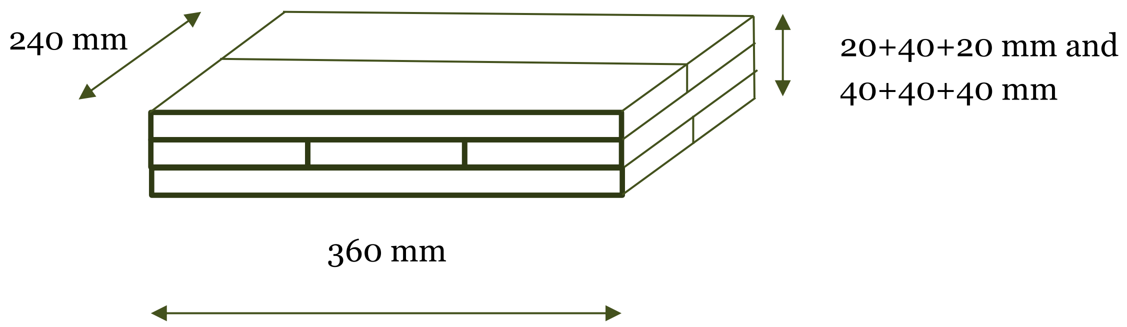
Configuration of CLT specimens

Thickness of outer lamellae 20 mm in one specimen and 40 mm in the second specimen



Thickness of inner lamella 40 mm

Thickness of outer lamellae 20 mm in one specimen and 40 mm in the second specimen



Configuration of GLT specimen