Dowel type connections in laminated bamboo with multiple slotted-in steel plates

Annex H – Test results

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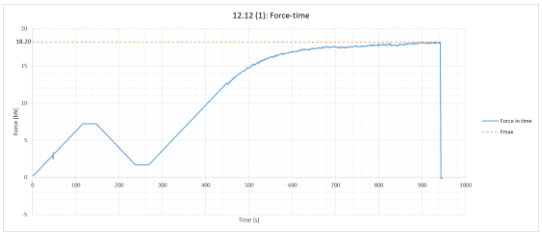
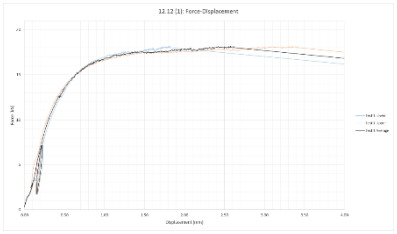
1 Tests 12.12

For these tests one slotted-in plate is used (both at the top and bottom connections). The expected failure mode is mode 1. A total of 5 tests was performed.

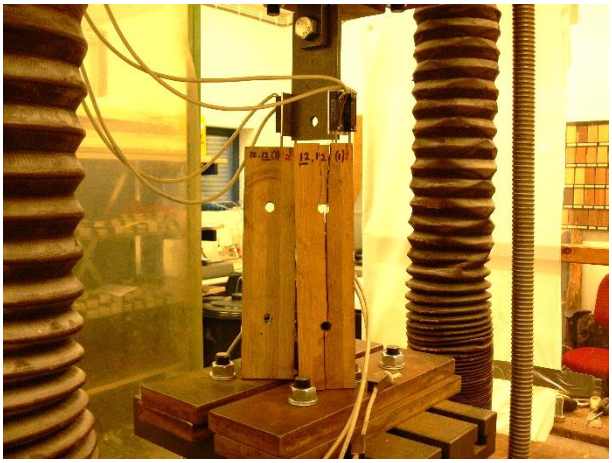
1.1 Test 12.12 (1)





Test specifications:

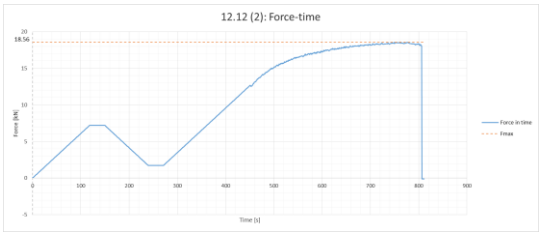
Specimen	12.12 (1)
Material thickness left:	12mm
Material thickness right:	12mm
F_{est}	18.3kN
$F_{measured}$	18.2kN
Max. Dowel angle	0°
Final testing speed	0.01mm/s
Test duration	945 seconds
Failure:	Mode 1 Plug Shear + splitting Brittle

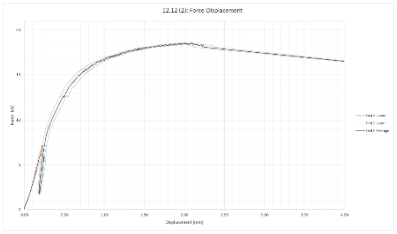


Notes

- Plug shear occurs with little embedment deformation of the bolthole. The connection strength may benefit from a larger end distance.

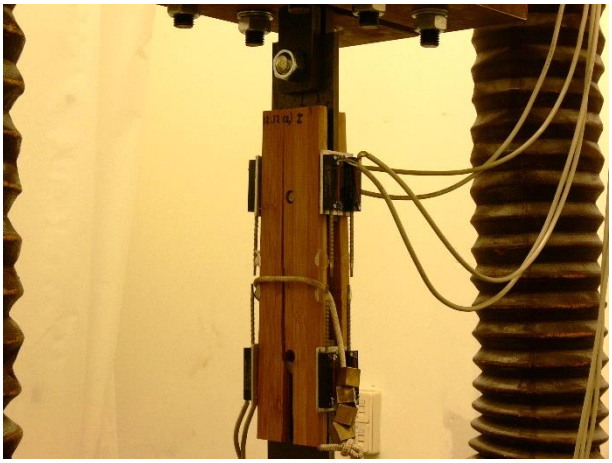
1.2 Test 12.12 (2)





Test specifications:

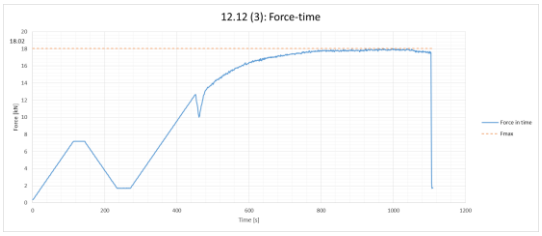
Specimen	12.12 (2)
Material thickness left:	12mm
Material thickness right:	12mm
F_{est}	18.3kN
$F_{measured}$	18.56kN
Max. Dowel angle	0°
Final testing speed	0.011mm/s
Test duration	810 seconds
Failure:	Mode 1
	Plug Shear + splitting
	Brittle

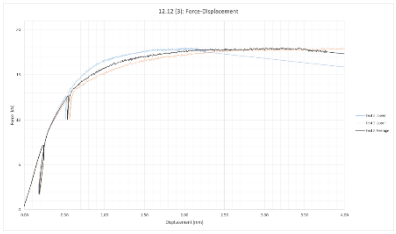


Notes

- Plug shear occurs with little embedment deformation of the bolthole. The connection strength may benefit from a larger end distance.

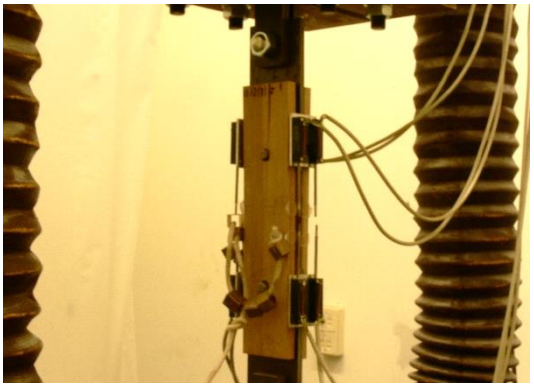
1.3 Test 12.12 (3)





Test specifications:

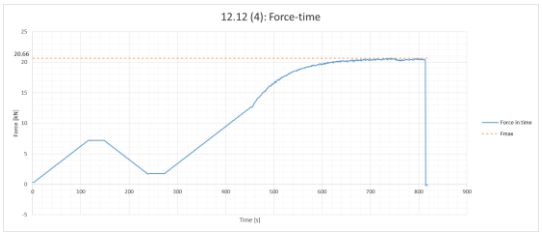
Specimen	12.12(3)
Material thickness left:	12mm
Material thickness right:	12mm
F_{est}	18.3kN
$F_{measured}$	18.02kN
Max. Dowel angle	0°
Final testing speed	0.011mm/s
Test duration	1100 seconds
Failure:	Mode 1 Plug Shear + splitting Brittle

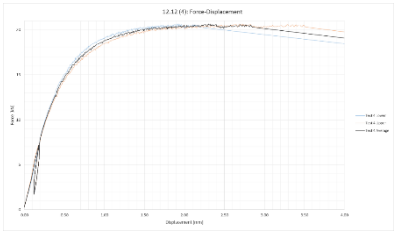


Notes

- Plug shear occurs with little embedment deformation of the bolthole. The connection strength may benefit from a larger end distance.

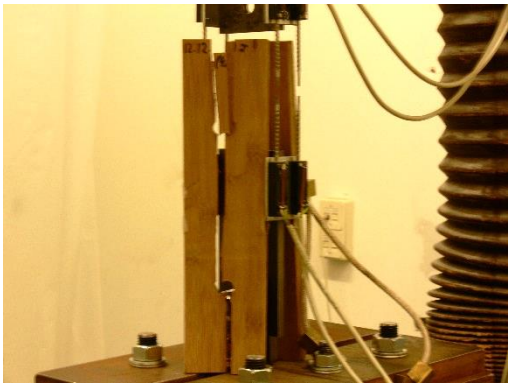
1.4 Test 12.12 (4)

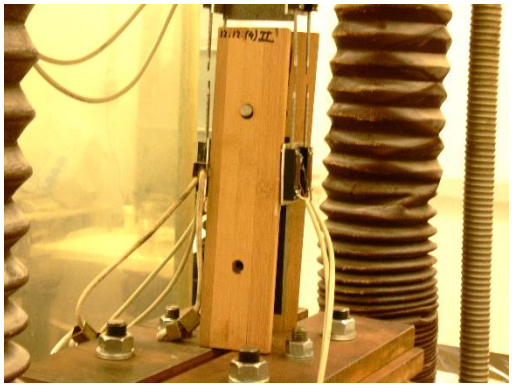




Test specifications:

Specimen	12.12 (4)
Material thickness left:	12mm
Material thickness right:	12mm
F_{est}	18.3kN
$F_{measured}$	20.66kN
Max. Dowel angle	0°
Final testing speed	0.015mm/s
Test duration	815 seconds
Failure:	Mode 1
	Plug Shear + splitting
	Brittle

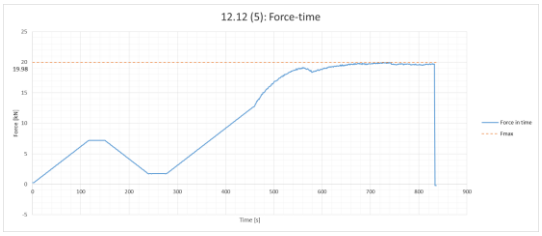


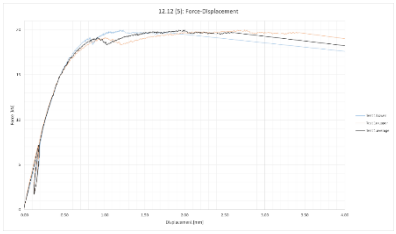


Notes

- Plug shear occurs with little embedment deformation of the bolthole. The connection strength may benefit from a larger end distance.

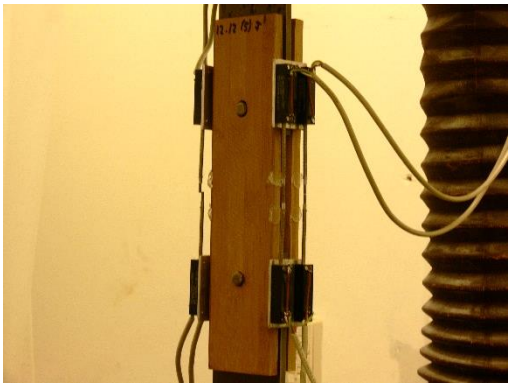
1.5 Test 12.12 (5)

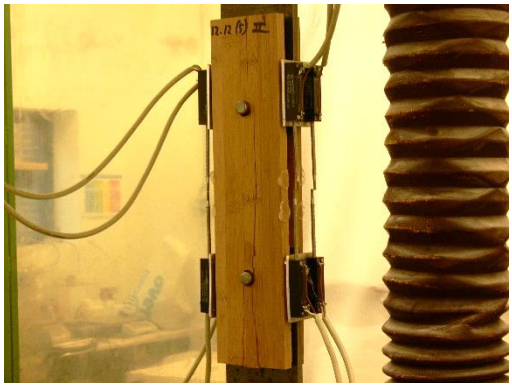




Test specifications:

Specimen	12.12 (5)
Material thickness left:	12mm
Material thickness right:	12mm
F_{est}	18.3kN
$F_{measured}$	19.98kN
Max. Dowel angle	0°
Final testing speed	0.013mm/s
Test duration	830 seconds
Failure:	Mode 1 Plug Shear + splitting Brittle





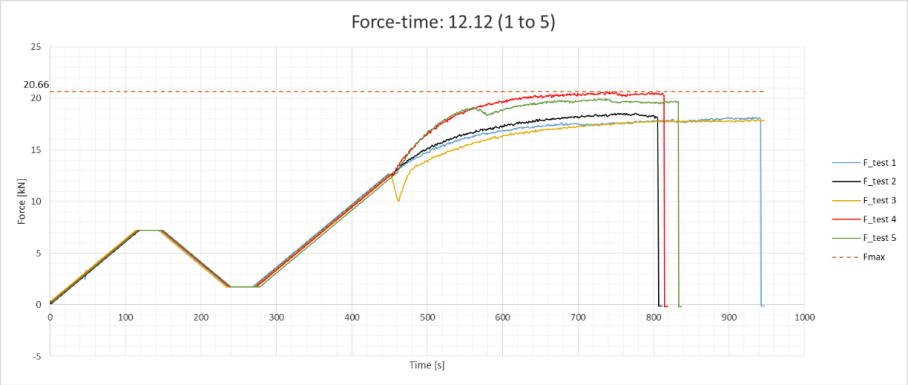
Notes

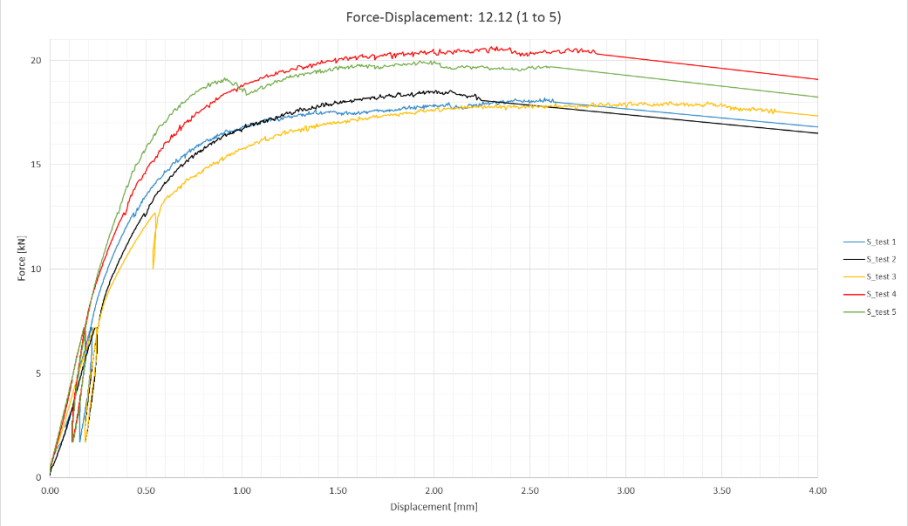
- Plug shear occurs with little embedment deformation of the bolthole. The connection strength may benefit from a larger end distance.

1.6 Tests 12.12 (1 to 5) combined plots

Specifications:

Tests 12.12 (1 to 5)
Material thickness left: 12mm
Material thickness right: 12mm
F_{est} 18.3kN





Notes:

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1.7 Tests 12.12 (1 to 5) Normal distribution

Measured test results

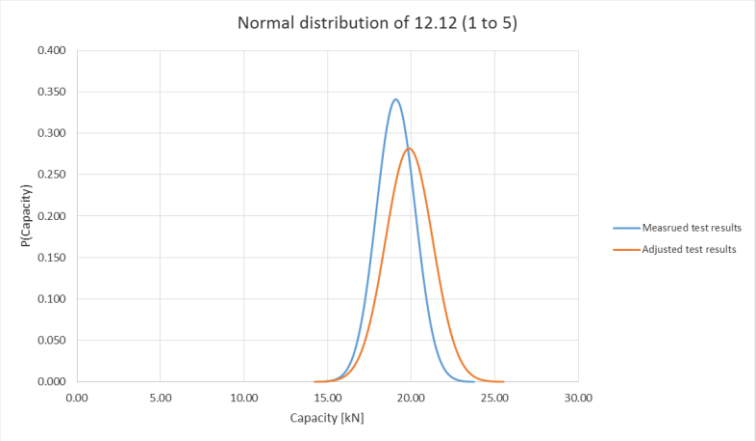
Faverage [kN]	S.Dev [kN]	COV	5-perc. [kN]
19.09	1.17	0.06	16.21

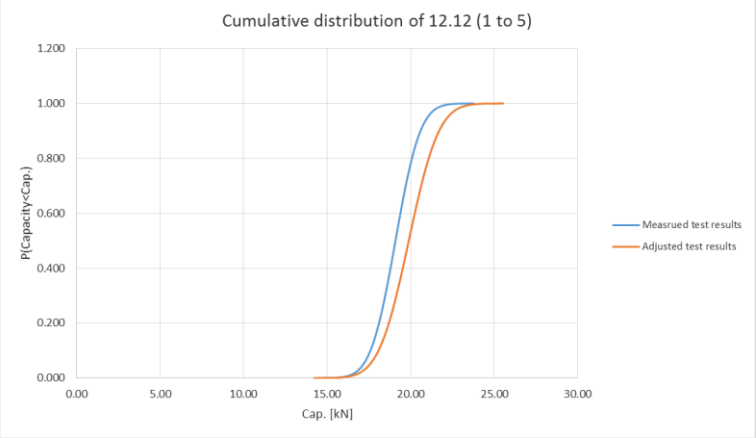
Adjusted test results

Fadjusted [kN]	S.Dev [kN]	COV	5-perc. [kN]
19.88	1.42	0.07	16.40

Specifications:

Tests	12.12 (1 to 5)
Material thickness left:	12mm
Material thickness right:	12mm
F_{est}	18.3kN
$F_{adjustedl}/F_{est}$	1.0863





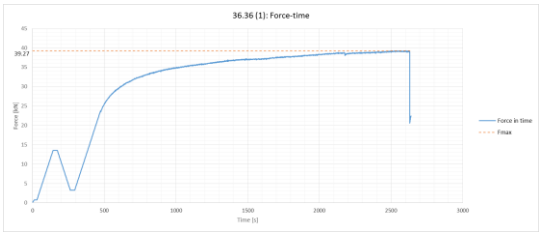
Notes:

- The resistance $F_{adjusted}$ given here is the average of the measured capacities that has been adjusted by use of the findings in 'Annex F – Probabilistic analysis of test data'. The formula found in this annex makes it possible to approximate the actual average capacity and standard deviation.
- The 5-percentile value is calculated by $x_k = \bar{x} \pm k_s * \sigma$ with $k_s = 2.46$

2 Tests 36.36

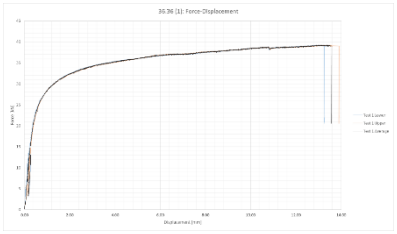
For these tests one slotted-in plate is used (both at the top and bottom connections). The expected failure mode is mode 2. A total of 5 tests was performed.

2.1 Test 36.36 (1)

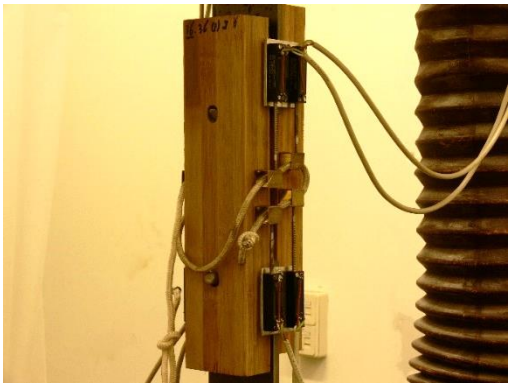


Test specifications:

Specimen	36.36 (1)
Material thickness left:	36mm
Material thickness right:	36mm
F_{est}	34.1kN
$F_{measured}$	39.27kN
Max dowel angle	43°



Final testing speed	0.013mm/s
Test duration	2630 seconds
Failure:	Mode 2
	Unexpected deformation
	Test stopped

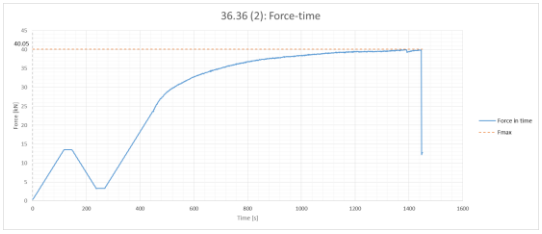


Notes

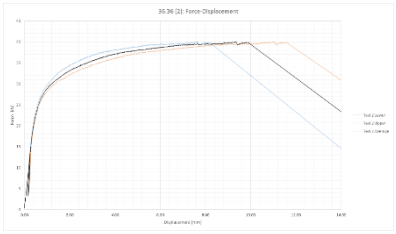
- Due to a lack of connection between the two individual pieces, a deformation occurred that was not anticipated (one piece moving up and the other one down). This resulted in just an increasement in deformation without a significant increase in measured force. Since this is no behaviour of an actual connection and for the protection of the displacement meters the test was stopped

2.2 Test 36.36 (2)

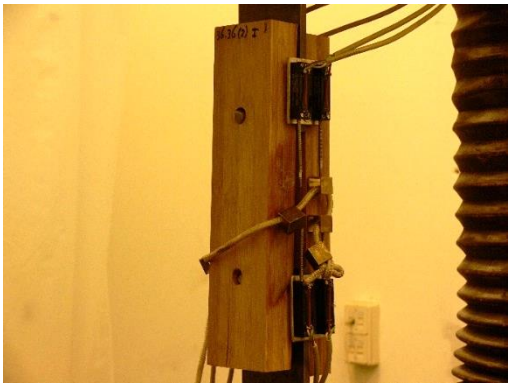
Test specifications:

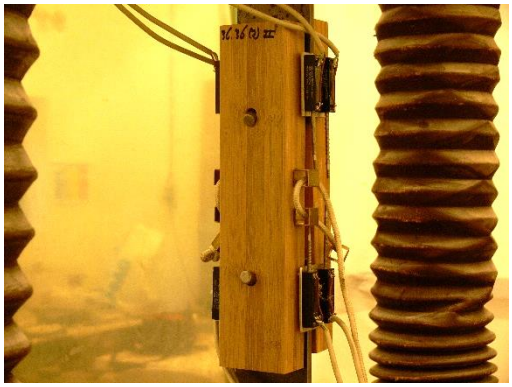


Specimen	36.36 (2)
Material thickness left:	36mm
Material thickness right:	36mm
F_{est}	34.1kN
$F_{measured}$	40.05kN
Max dowel angle	39°



Final testing speed	0.02mm/s
Test duration	1450 seconds
Failure:	Mode 2
	Unexpected deformation
	Test stopped

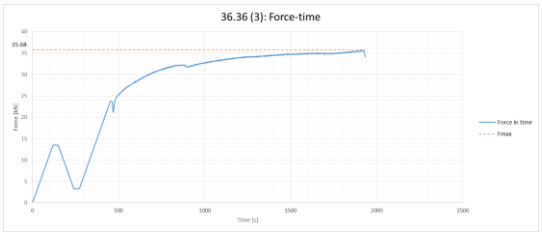


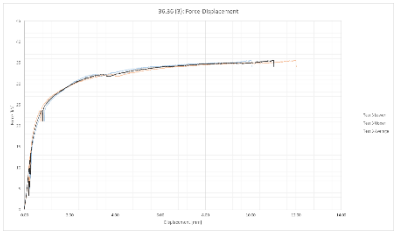


Notes

- This test piece shows the same deformation behaviour as 36.36 (1).
- From this point on, pieces of laminated bamboo (9mm thickness) will be glued between the individual members to ensure that these deformations cannot occur. For this, a PVAc glue was used.

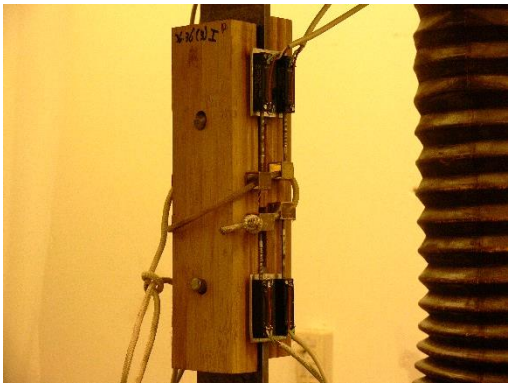
2.3 Test 36.36 (3)

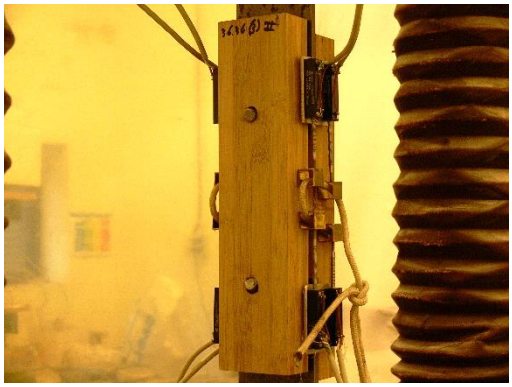




Test specifications:

Specimen	36.36 (3)
Material thickness left:	36mm
Material thickness right:	36mm
F_{est}	34.1kN
$F_{measured}$	35.68kN
Max dowel angle	35°
Final testing speed	0.015mm/s
Test duration	1920 seconds
Failure:	Mode 2
	Glue line broke
	Test stopped

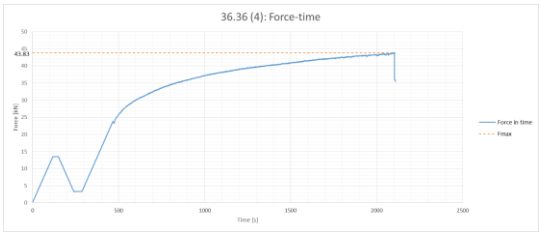


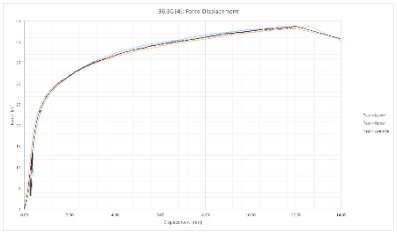


Notes

- To prevent the deformation behaviour from tests (1) and (2), a piece of laminated bamboo was glued in between the two individual members. For this a PVAc glue was used..
- At about 32kN of loading the glue line broke. This can be seen as a drop in the graph. After that the same failure behaviour as in tests (1) and (2) occurred.
- For the following tests, the length of the glued-in piece is increased so that the glue line is larger and the resistance of the glue line increases.

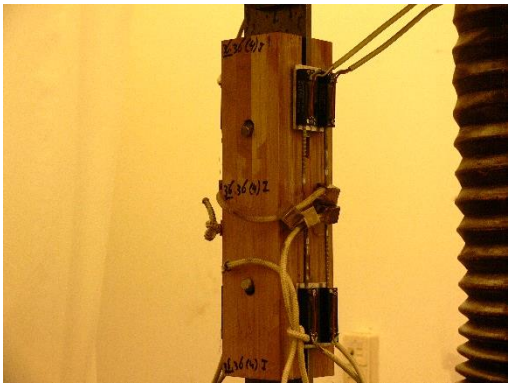
2.4 Test 36.36 (4)

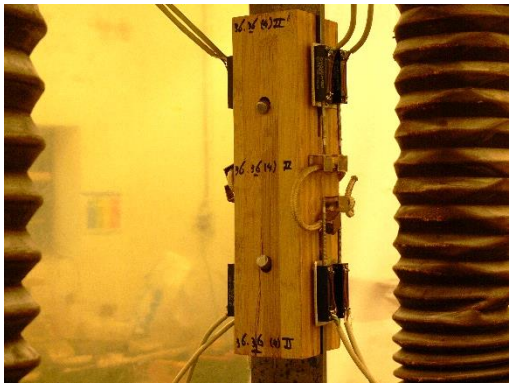


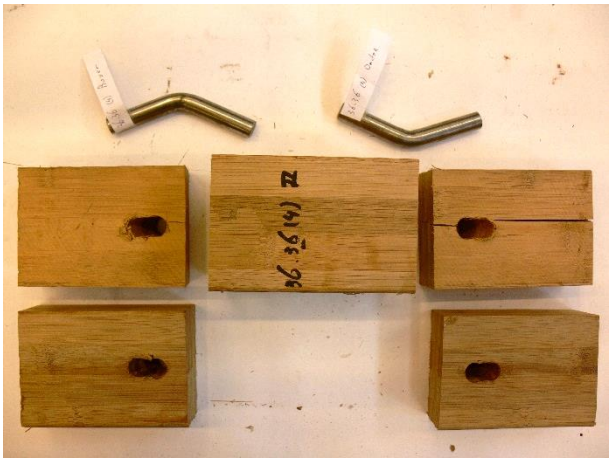


Test specifications:

Specimen	36.36 (4)
Material thickness left:	36 mm
Material thickness right:	36 mm
F_{est}	34.1kN
$F_{measured}$	43.83kN
Max dowel angle	43°
Final testing speed	0.015mm/s
Test duration	1920 seconds
Failure:	Mode 2
	Splitting + embedment
	Ductile



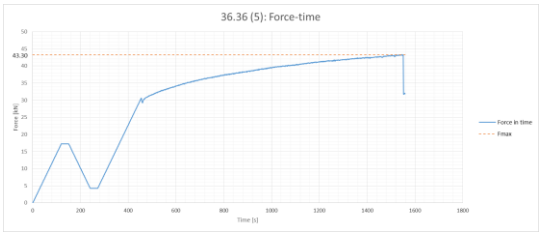


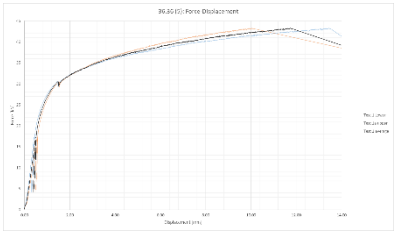


Notes

- The measured force deviates by more than 20 percent of the estimate. For the next test the estimate needs to be updated and the test protocol needs to be adapted.
- The glue line holds and a large deformation (about 11mm) can be obtained before failure occurs.

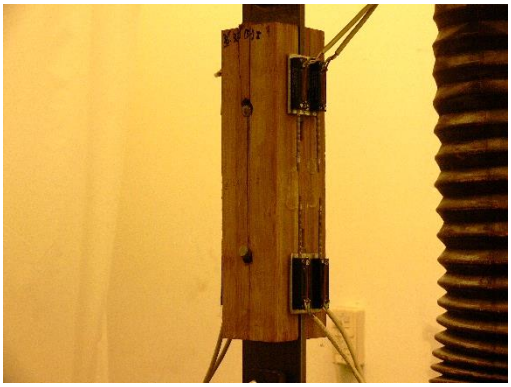
2.5 Test 36.36 (5)

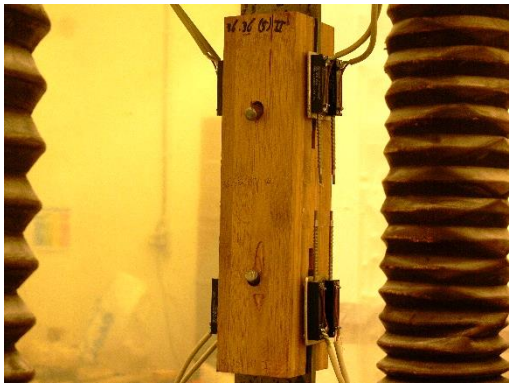




Test specifications:

Specimen	36.36 (5)
Material thickness left:	36mm
Material thickness right:	36mm
F_{est}	43.83kN
$F_{measured}$	43.30kN
Max dowel angle	43°
Final testing speed	0.02mm/s
Test duration	1550 seconds
Failure:	Mode 2
	Plug shear + embedment
	Ductile





Notes

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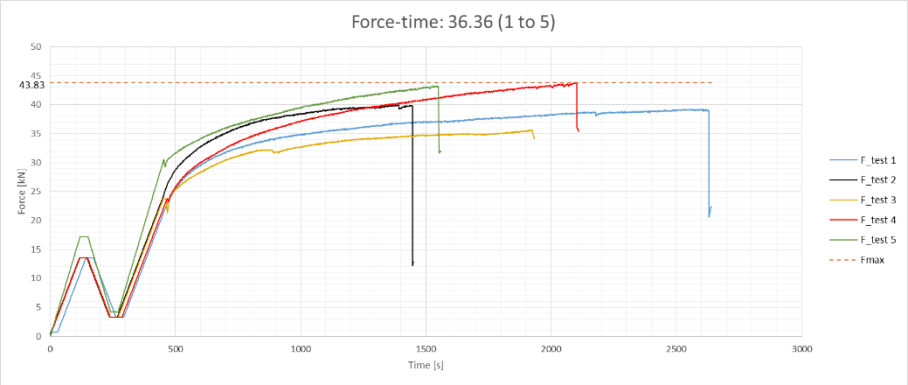
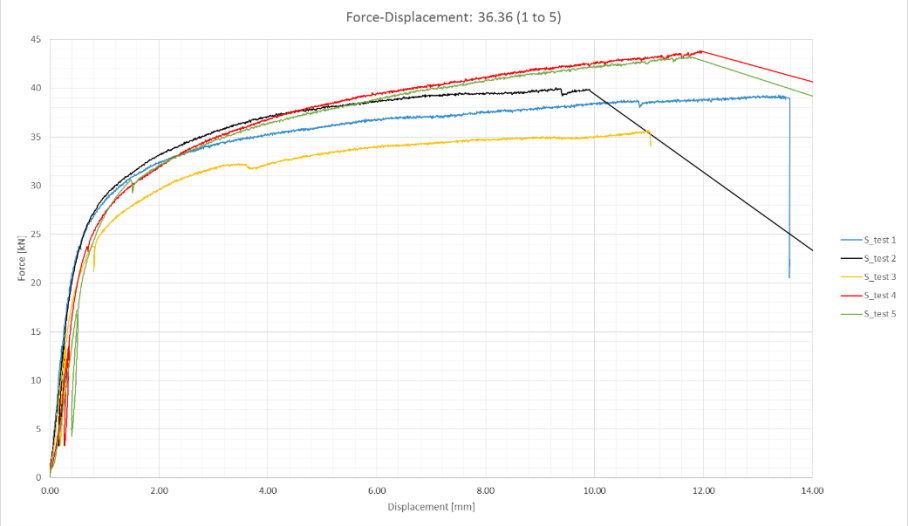
2.6 Tests 36.36 (1 to 5) combined plots

Specifications:

Tests 36.36 (1 to 5)
Material thickness left: 36mm
Material thickness right: 36mm
F_{est} 34.1kN





Notes:

- The force-time graph of test 5 lies above that of the other tests. This is due to the adaptation of the test protocol because of the large deviation between measured resistance and estimated resistance. It can be seen that this adaptation of the test protocol has little to no influence on the ultimate resistance of the test piece and primarily has an influence on the test duration.

2.7 Tests 36.36 (1 to 5) Normal distribution

Measured test results

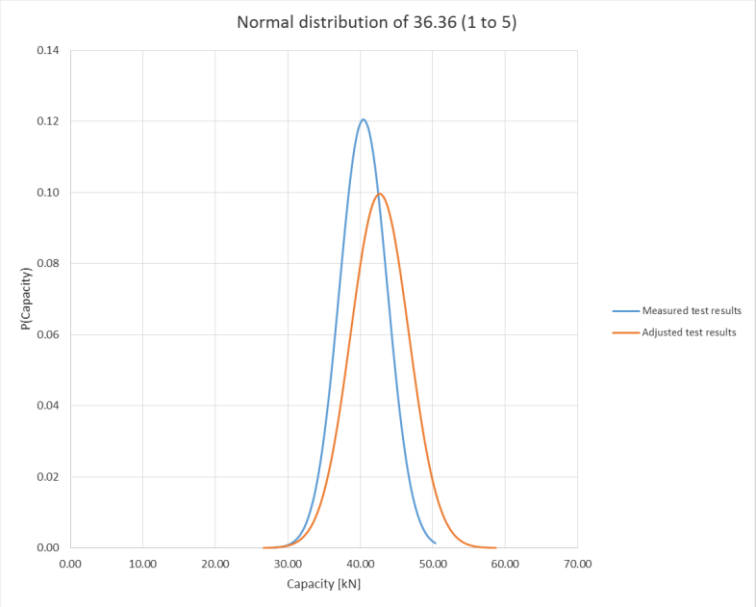
Faverage [kN]	S.Dev [kN]	COV	5-perc. [kN]
40.43	3.31	0.08	32.29

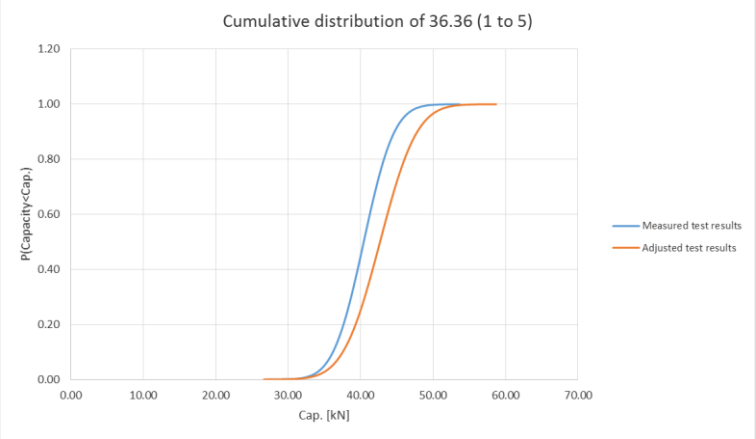
Adjusted test results

Fadjusted [kN]	S.Dev [kN]	COV	5-perc. [kN]
42.68	4.00	0.09	32.83

Specifications:

Tests	36.36 (1 to 5)
Material thickness left:	36mm
Material thickness right:	36mm
F_{est}	34.1kN
$F_{average}/F_{est}$	1.2516





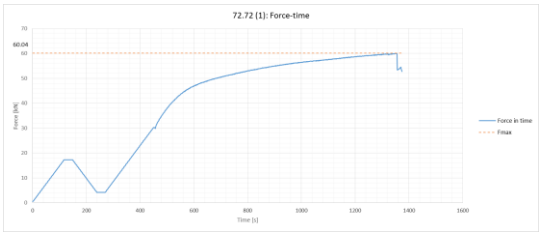
Notes:

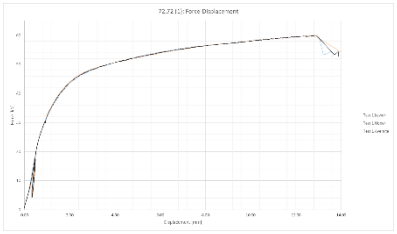
- The resistance $F_{adjusted}$ given here is the average of the measured capacities that has been adjusted by use of the findings in 'Annex F – Probabilistic analysis of test data'. The formula found in this annex makes it possible to approximate the actual average capacity and standard deviation.
- The 5-percentile value is calculated by $x_k = \bar{x} \pm k_s * \sigma$ with $k_s = 2.46$

3 Tests 72.72

For these tests one slotted-in plate is used (both at the top and bottom connections). The expected failure mode is mode 3. A total of 5 tests was performed.

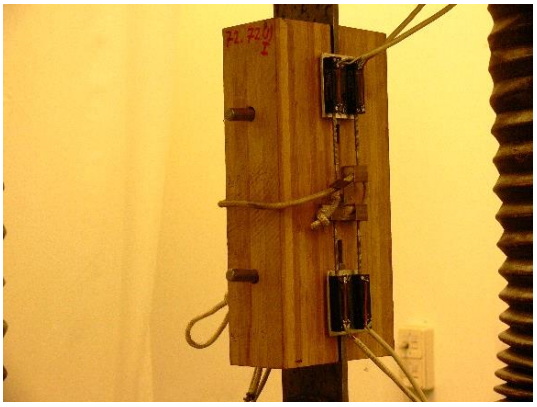
3.1 Test 72.72 (1)

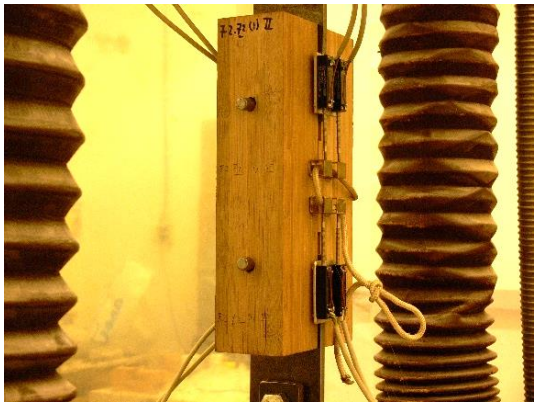


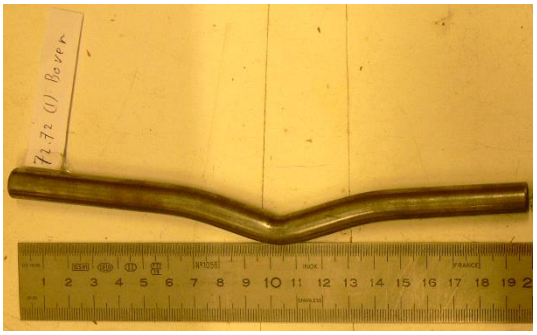


Test specifications:

Specimen	72.72 (1)
Material thickness left:	72mm
Material thickness right:	72mm
F_{est}	43.4kN
$F_{measured}$	60.04kN
Max dowel angle	39°
Final testing speed	0.03mm/s
Test duration	1360 seconds
Failure:	Mode 3
	Ductile



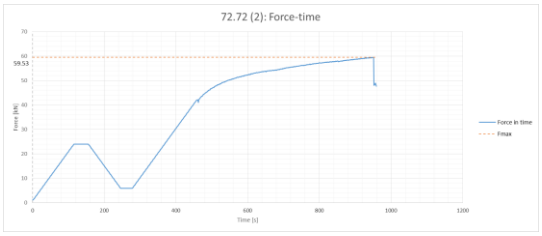


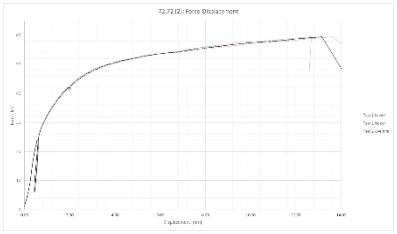


Notes

- The measured force deviates by more than 20 percent of the estimate. For the next test, the estimate needs to be updated and the test protocol needs to be adapted.
- The slotted-in plates show a large embedment deformation.

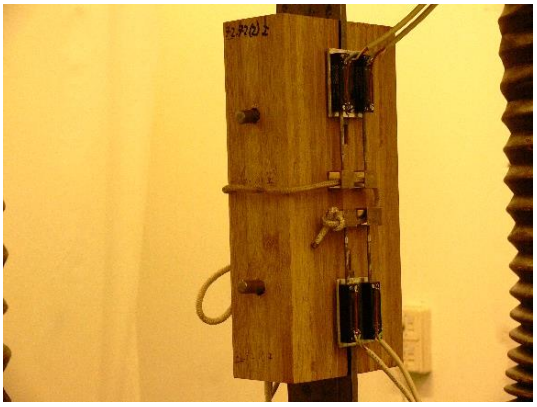
3.2 Test 72.72 (2)

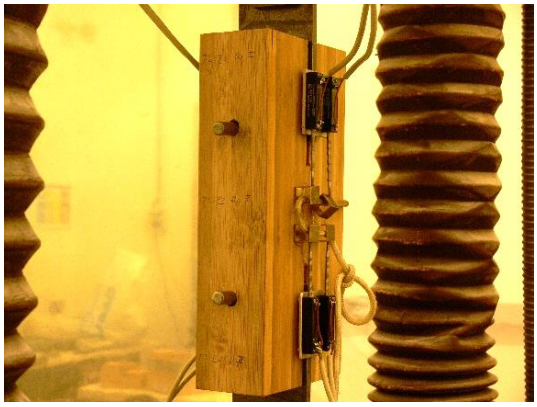


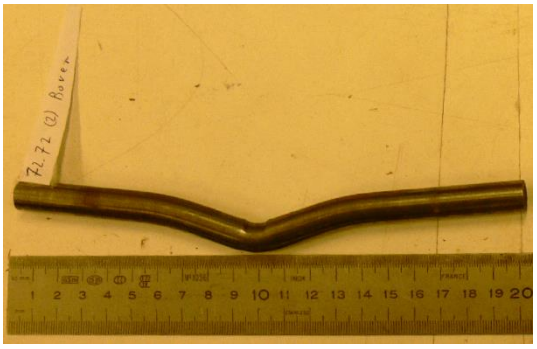


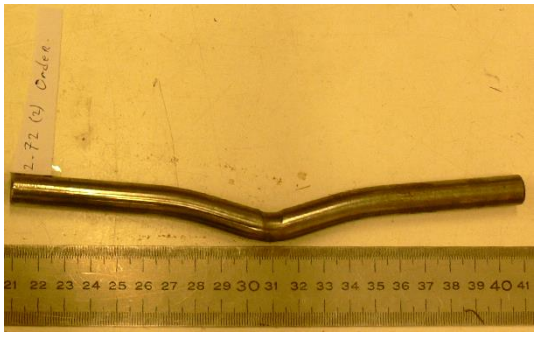
Test specifications:

Specimen	72.72 (2)
Material thickness left:	72mm
Material thickness right:	72mm
F_{est}	60.04kN
$F_{measured}$	59.53kN
Max dowel angle	38°
Final testing speed	0.05mm/s
Test duration	950 seconds
Failure:	Mode 3
	Ductile





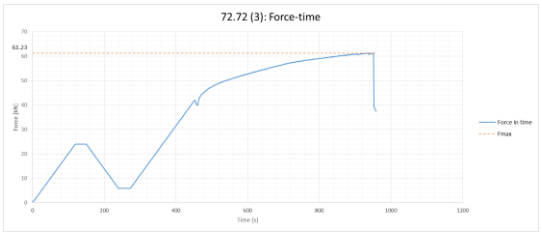


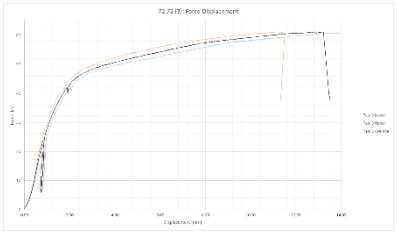


Notes

- In test (1) a large embedment deformation was seen in the slotted-in plates. After this testing variant all test pieces have to be equipped with two sets of slotted-in plates. So to make sure that the upcomming testing variants do not warp due to a difference in deformation between the sets of slotted-in plates for this test, the other pair of plates is used. By doing this, the other pair of plates will have the same embedment deformation as the pair used for test 72.72 (1).
- At a dislacement of 6,5mm a slight change of inclination can be seen in the displacement graph. It is at this point that the embedding of the steel plate has stopped.

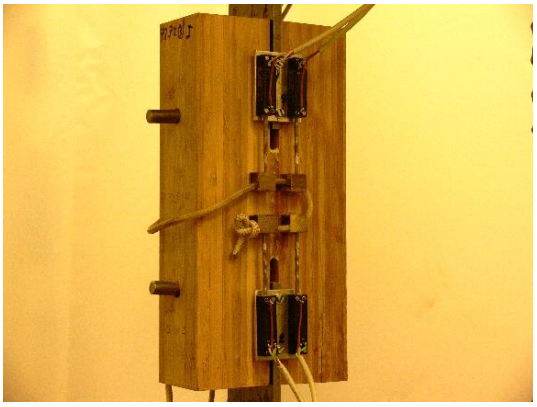
3.3 Test 72.72 (3)

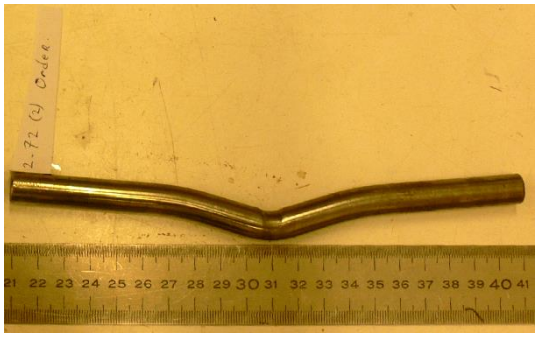




Test specifications:

Specimen	72.72 (3)
Material thickness left:	72mm
Material thickness right:	72mm
F_{est}	60.04kN
$F_{measured}$	61.23kN
Max dowel angle	45°
Final testing speed	0.05mm/s
Test duration	950 seconds
Failure:	Mode 3
	Ductile





Notes

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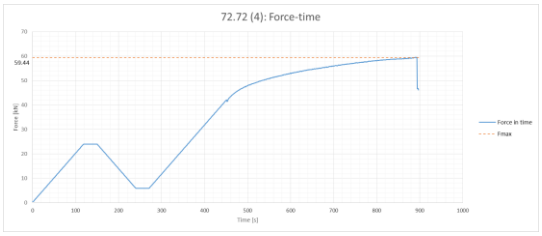
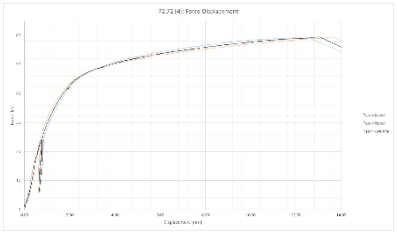
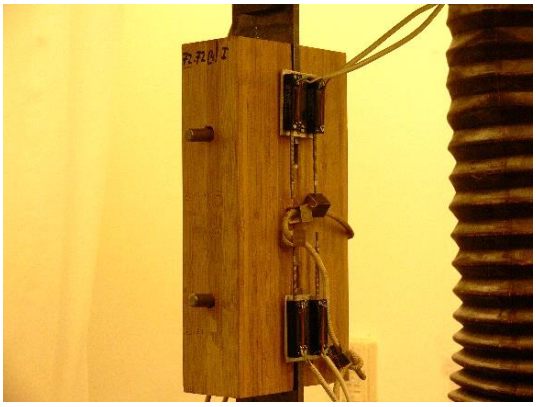
3.4 Test 72.72 (4)

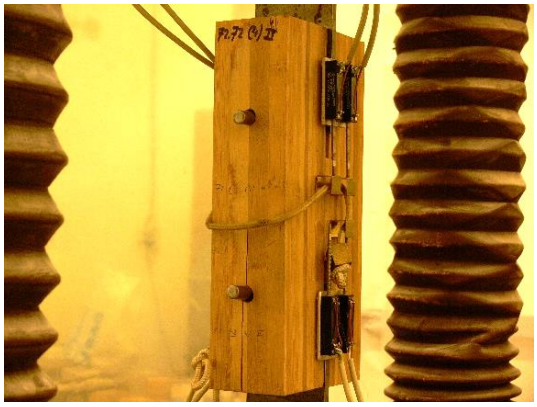




Test specifications:

Specimen	72.72 (4)
Material thickness left:	72mm
Material thickness right:	72mm
F_{est}	60.04kN
$F_{measured}$	59.44kN
Max dowel angle	42°
Final testing speed	0.055mm/s
Test duration	890 seconds
Failure:	Mode 3
	Ductile





Notes

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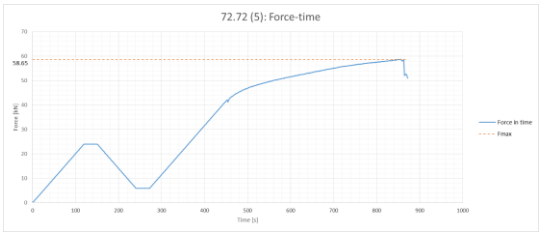
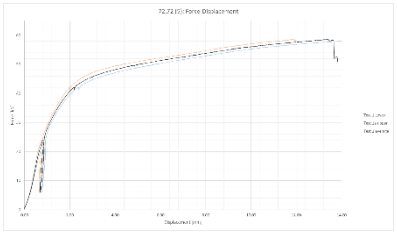
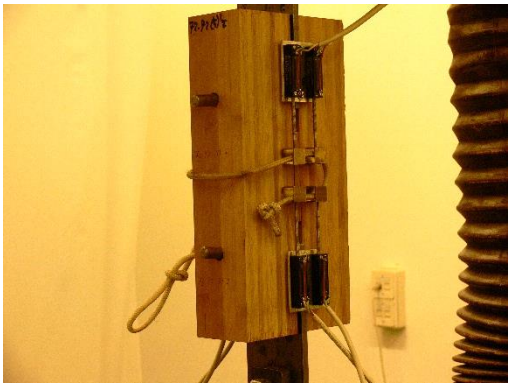
3.5 Test 72.72 (5)

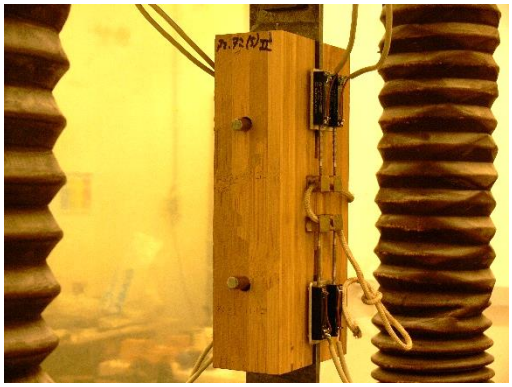




Test specifications:

Specimen	72.72 (5)
Material thickness left:	72mm
Material thickness right:	72mm
F_{est}	60.04kN
$F_{measured}$	58.65kN
Max dowel angle	44°
Final testing speed	0.06mm/s
Test duration	860 seconds
Failure:	Mode 3
	Ductile





Notes

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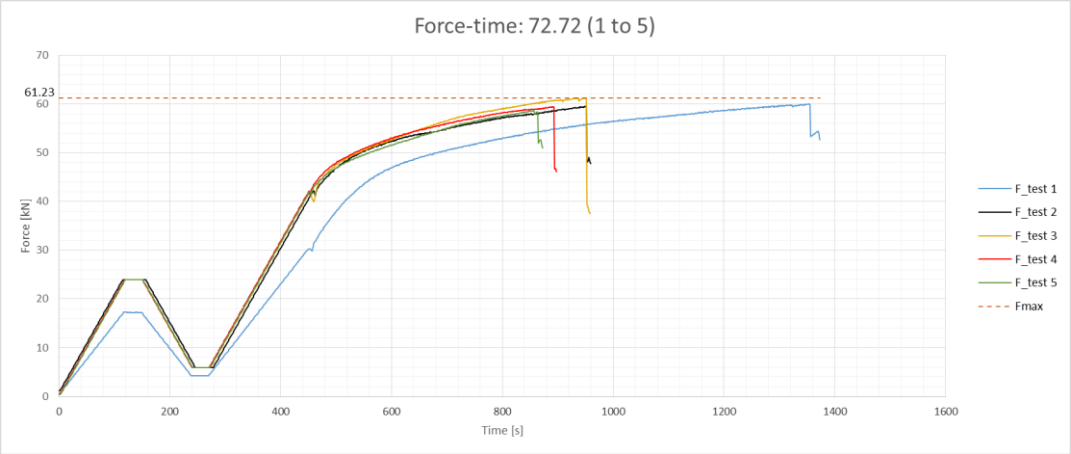
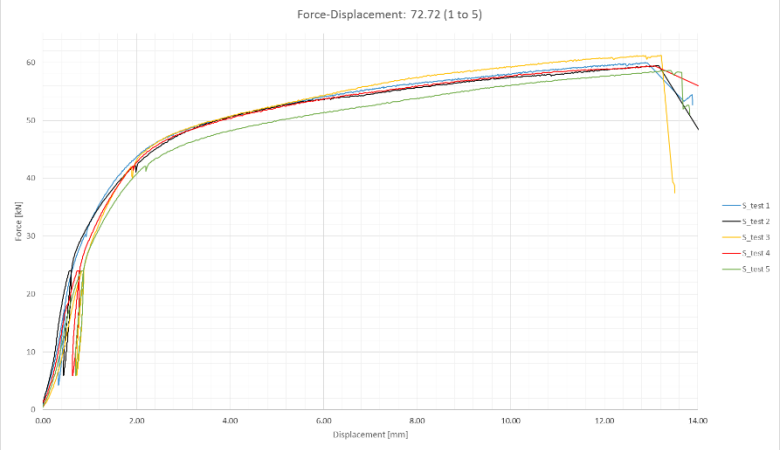
3.6 Tests 72.72 (1 to 5) combined plots

Specifications:

Tests	72.72 (1 to 5)
Material thickness left:	72mm
Material thickness right:	72mm
F_{est}	43.4kN





Notes:

- The force-time graph of test 1 lies below that of the other tests. This is due to the adaptation of the test protocol because of the large deviation between measured resistance and estimated resistance. It can be seen that this adaptation of the test protocol has little to no influence on the ultimate resistance of the test piece and primarily has an influence on the test duration.

3.7 Tests 72.72 (1 to 5) Normal distribution

Measured test results

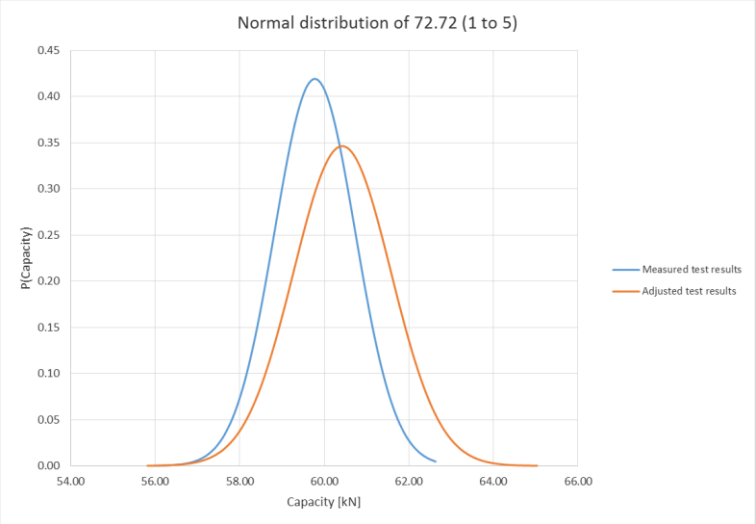
Faverage [kN]	S.Dev [kN]	COV	5-perc. [kN]
59.78	0.95	0.02	57.43

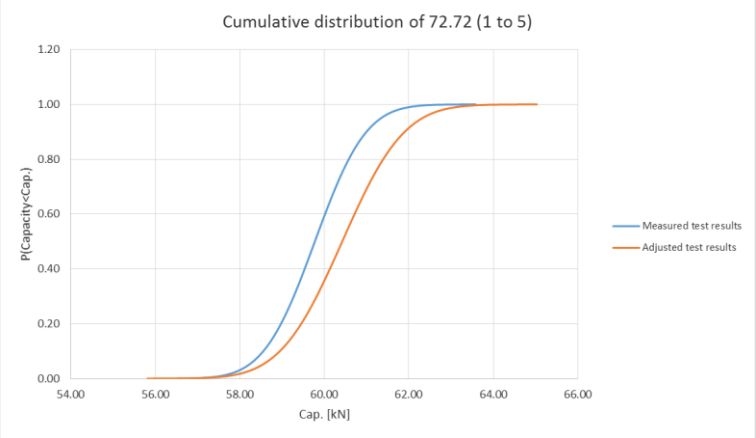
Adjusted test results

Faverage [kN]	S.Dev [kN]	COV	5-perc. [kN]
60.42	1.15	0.02	57.59

Specifications:

Tests	72.72 (1 to 5)
Material thickness left:	72mm
Material thickness right:	72mm
F_{est}	43.4kN
$F_{averagel}/F_{est}$	1.3922





Notes:

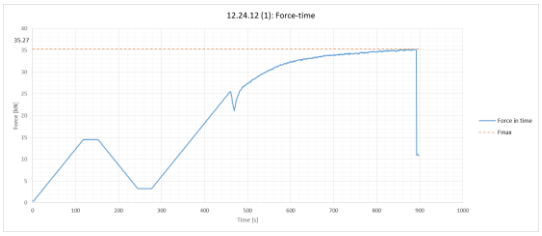
- The resistance $F_{adjusted}$ given here is the average of the measured capacities that has been adjusted by use of the findings in 'Annex F – Probabilistic analysis of test data'. The formula found in this annex makes it possible to approximate the actual average capacity and standard deviation.
- The 5-percentile value is calculated by $x_k = \bar{x} \pm k_s * \sigma$ with $k_s = 2.46$.

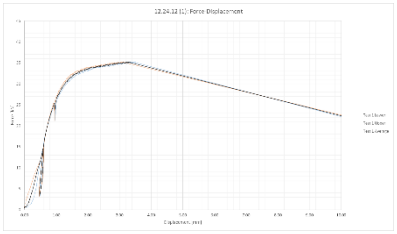
4 Tests 12.24.12

For these tests two slotted-in plates were used (both at the top and bottom connections). The expected failure mode is mode 1 in all laminated bamboo members. A total of 5 tests was performed.

For the variant a total of three laminated bamboo members are used. The middle member has double the thickness of the outer members. This results in a symmetrical loading of the slotted-in plates. Per slotted-in plate a resistance corresponding to failure mode 1 (variant 12.12) is expected. The maximum load is expected to occur at a displacement of about 2 to 4mm (also corresponding to variant 12.12).

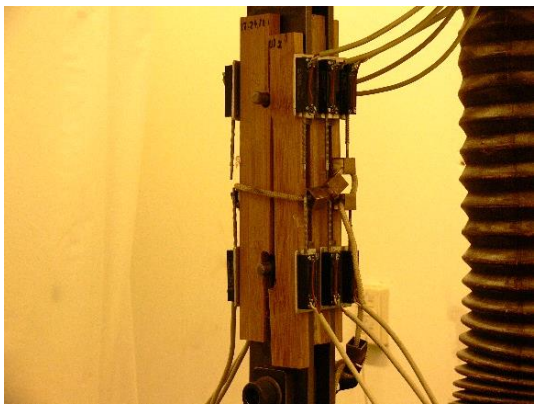
4.1 Test 12.24.12 (1)

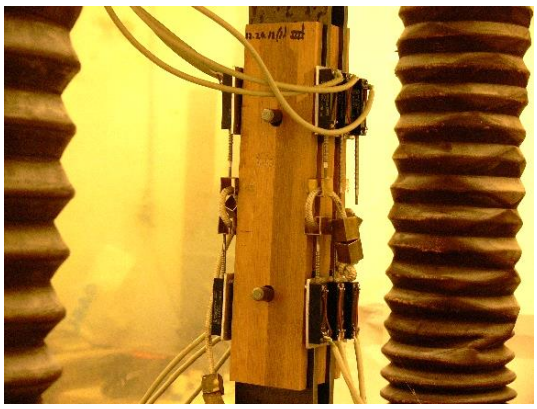




Test specifications:

Specimen	12.24.12 (1)
Material thickness left:	12mm
Material thickness middle	24mm
Material thickness right:	12mm
F_{est}	36.6kN
$F_{measured}$	35.27kN
Max dowel angle	0°
Final testing speed	0.013mm/s
Test duration	890 seconds
Failure:	Mode 1 Splitting Brittle

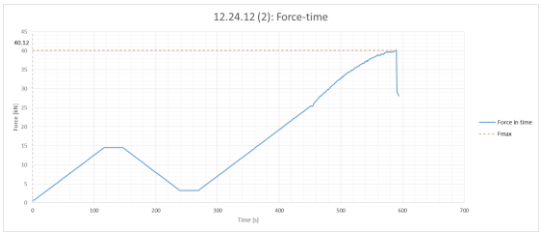


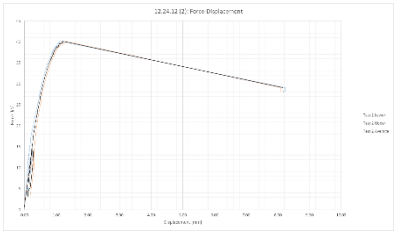


Notes

- As this test variant was tested before testing of the variants 36.36 took place, the glued-in piece of laminated bamboo is not present. During testing of this variant the unexpected failure behaviour (warping of the test piece) did not take place.

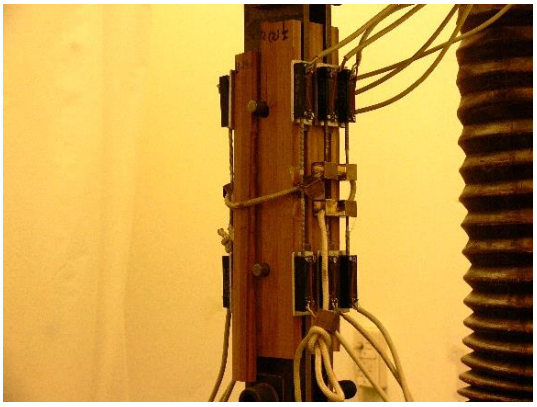
4.2 Test 12.24.12 (2)





Test specifications:

Specimen	12.24.12 (2)
Material thickness left:	12mm
Material thickness middle	24mm
Material thickness right:	12mm
F_{est}	36.6kN
$F_{measured}$	40.12kN
Max dowel angle	0°
Final testing speed	0.014mm/s
Test duration	590 seconds
Failure:	Mode 1 Splitting Brittle



Notes

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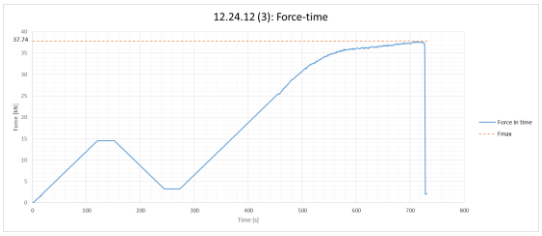
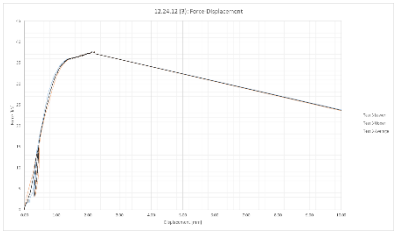
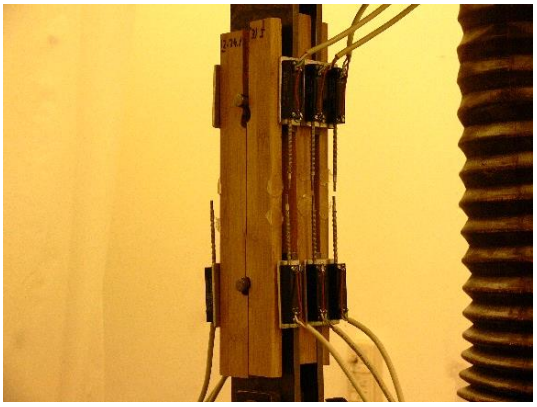
4.3 Test 12.24.12 (3)

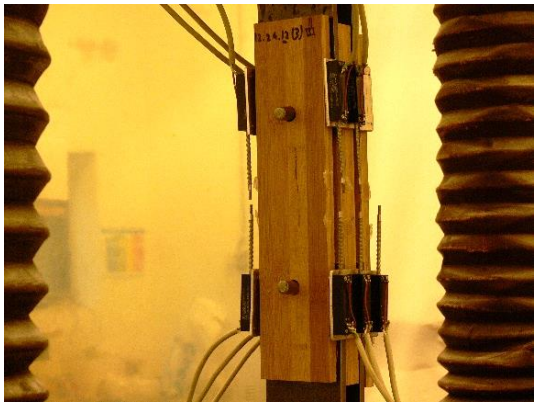


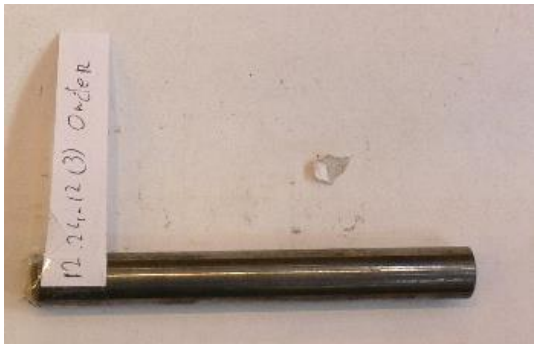


Test specifications:

Specimen	12.24.12 (3)
Material thickness left:	12mm
Material thickness middle	24mm
Material thickness right:	12mm
F_{est}	36.6kN
$F_{measured}$	37.74kN
Max dowel angle	0°
Final testing speed	0.013mm/s
Test duration	730 seconds
Failure:	Mode 1 Splitting Brittle







Notes

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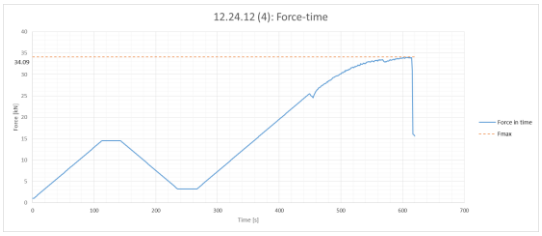
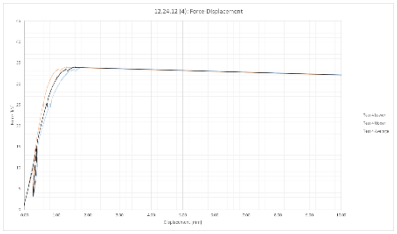
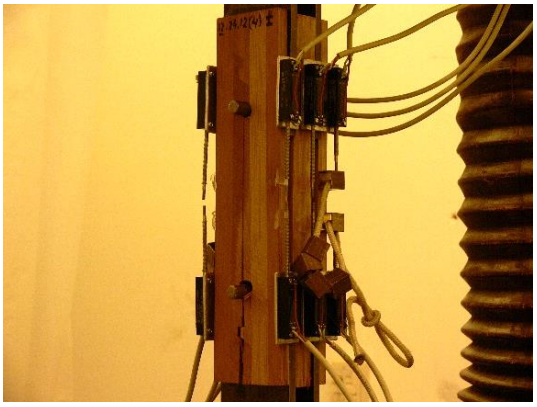
4.4 Test 12.24.12 (4)

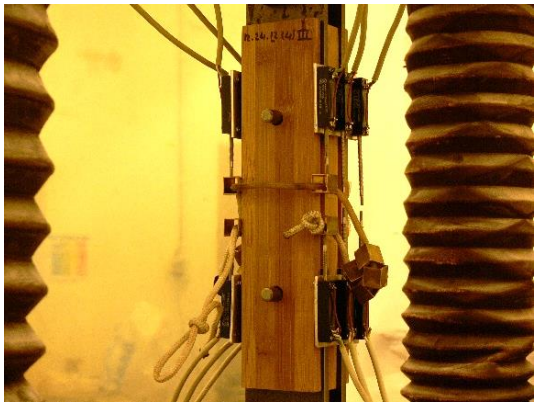


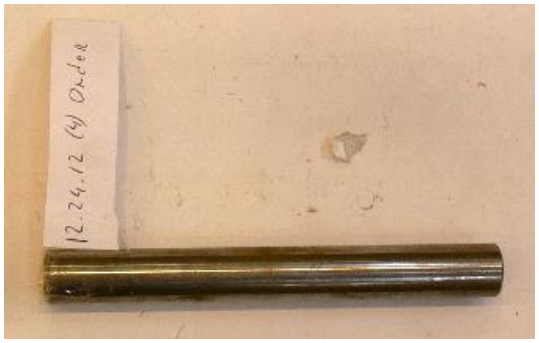


Test specifications:

Specimen	12.24.12 (4)
Material thickness left:	12mm
Material thickness middle	24mm
Material thickness right:	12mm
F_{est}	36.6kN
$F_{measured}$	34.09kN
Max dowel angle	0°
Final testing speed	0.013mm/s
Test duration	620 seconds
Failure:	Mode 1 Splitting Brittle







Notes

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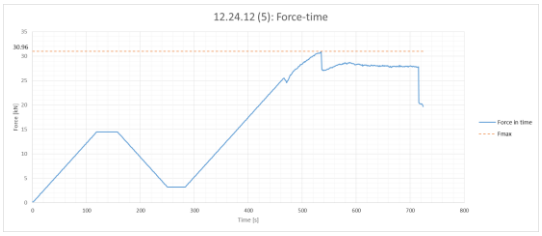
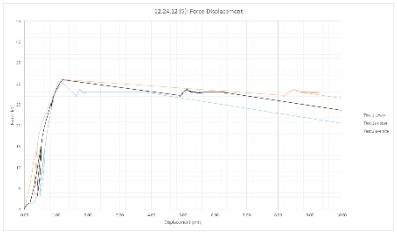
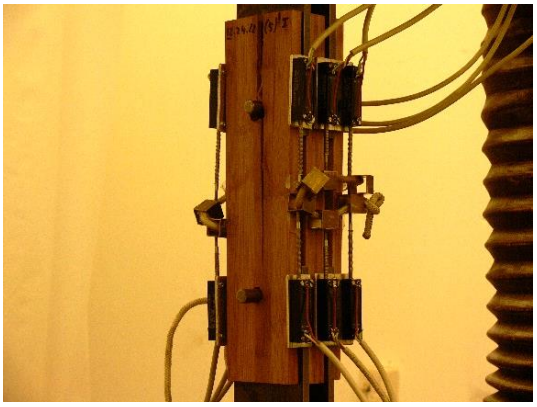
4.5 Test 12.24.12 (5)

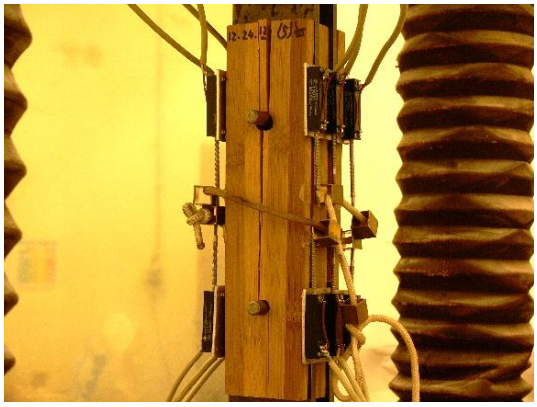


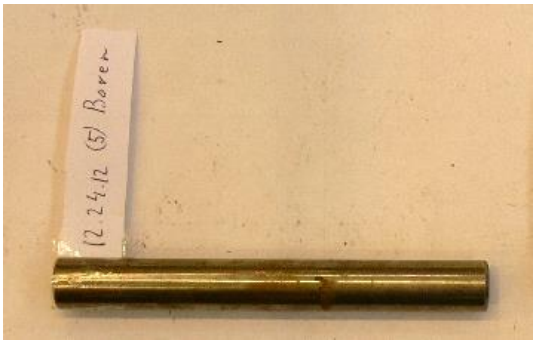


Test specifications:

Specimen	12.24.12 (4)
Material thickness left:	12mm
Material thickness middle	24mm
Material thickness right:	12mm
F_{est}	36.6kN
$F_{measured}$	30.96kN
Max dowel angle	0°
Final testing speed	0.013mm/s
Test duration	720 seconds
Failure:	Mode 1 Splitting Brittle







Notes

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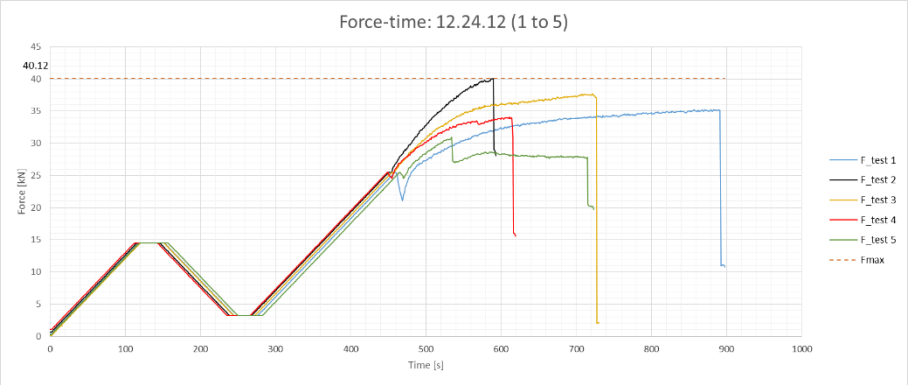
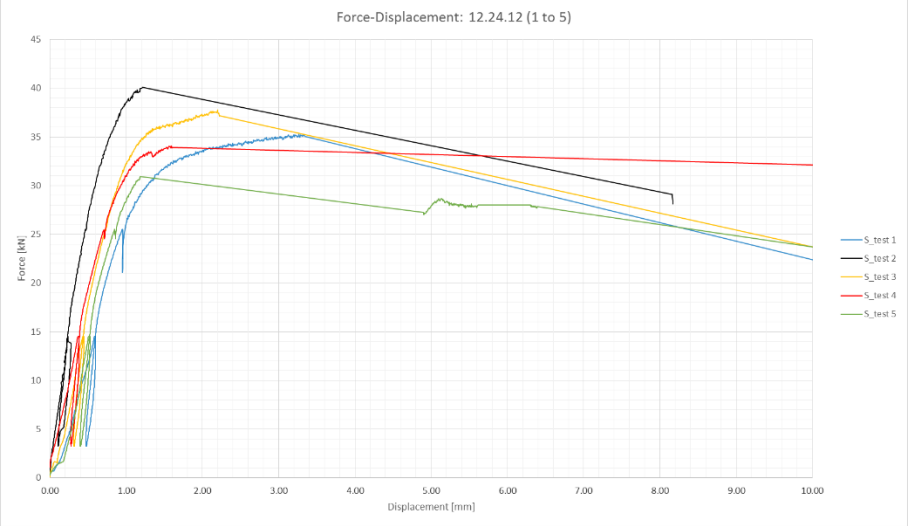
4.6 Tests 12.24.12 (1 to 5) combined plots

Specifications:

Tests	12.24.12 (1 to 5)
Material thickness left:	12mm
Material thickness middle:	24mm
Material thickness right:	12mm
F_{est}	36.6kN





Notes:

- Some force-time graphs show two distinct moments at which the resistance of the test piece drops. After the first moment of failure the tests were continued to study the post failure behaviour of the connections. Especially when looking at test 5 it is noticeable that after failure of the first member the resistance drops to about 29 kN (which corresponds to an expected resistance of three times failure mode 1).

4.7 Tests 12.24.12 (1 to 5) Normal distribution

Measured test results

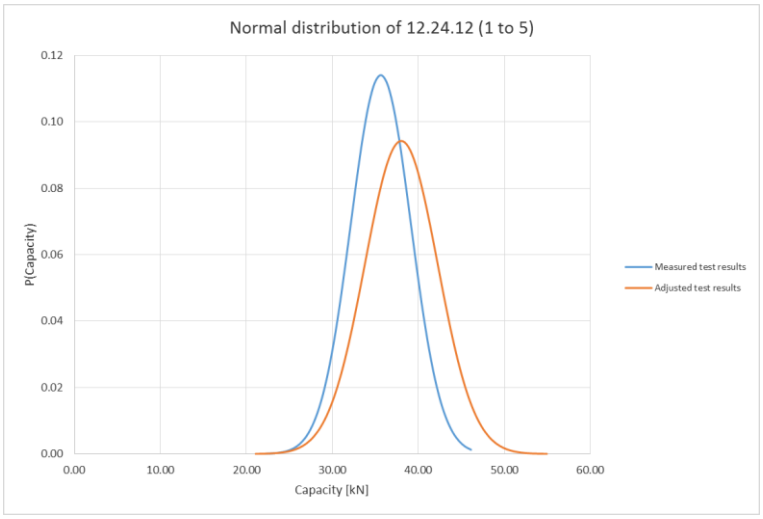
Faverage [kN]	S.Dev [kN]	COV	5-perc. [kN]
35.64	3.50	0.10	27.03

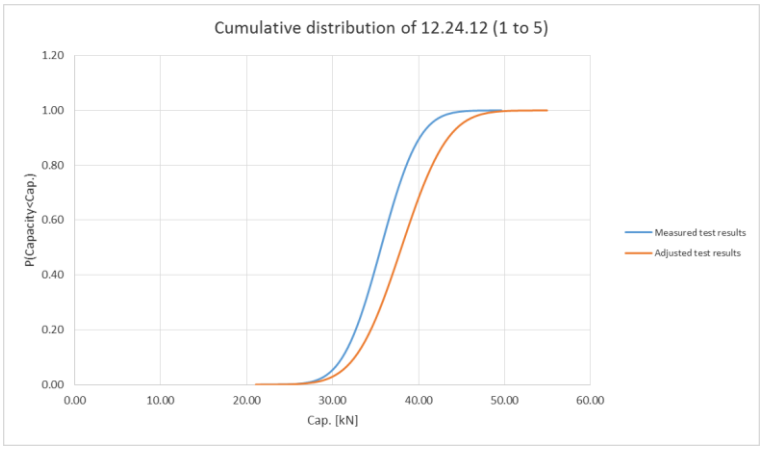
Adjusted test results

Faverage [kN]	S.Dev [kN]	COV	5-perc. [kN]
38.02	4.23	0.11	27.60

Specifications:

Tests	12.24.12 (1 to 5)
Material thickness left:	12mm
Material thickness middle:	24mm
Material thickness right:	12mm
F_{est}	36.6kN
$F_{average}/F_{est}$	1.0388





Notes:

- The resistance $F_{adjusted}$ given here is the average of the measured capacities that has been adjusted by use of the findings in 'Annex F – Probabilistic analysis of test data'. The formula found in this annex makes it possible to approximate the actual average capacity and standard deviation.
- The 5-percentile value is calculated by $x_k = \bar{x} \pm k_s * \sigma$ with $k_s = 2.46$.

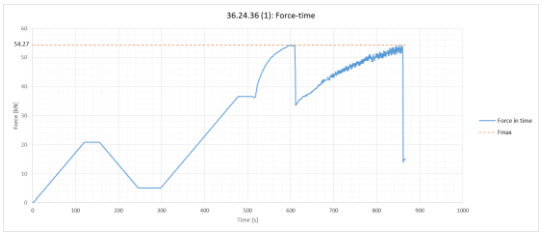
5 Tests 36.24.36

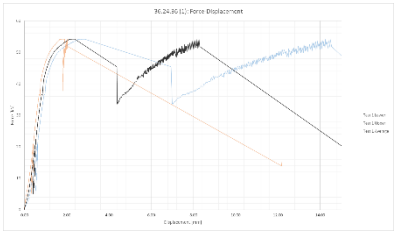
For these tests two slotted-in plates were used (both at the top and bottom connections). The expected failure modes are mode 1 in the middle member (t = 24mm) and mode 2 in the outer members (t = 36mm). A total of 5 tests was performed.

Since both expected failure modes have different deformation capacities the failure behaviour of this variant is anticipated as follows. First failure mode 1 is expected to happen in the middle member at a displacement of 2 to 4mm (corresponding to variants 12.12 and 12.24.12). At this point the dowel will not have shown much bending and the expected load should be lower than just a summation of two times failure mode 2 and one times failure mode 1 (34.1+18.3 = 52.4kN).

After the middle member breaks, a drop in the resistance of the test piece is expected. Now the deformation will start increasing until failure mode 2 occurs in the outer members at about 10 to 12mm (corresponding to variant 36.36). The expected resistance at this point should also be the same as for variant 36.36 (40.3kN). It could however be slightly higher due to some residual strength of the failed middle member.

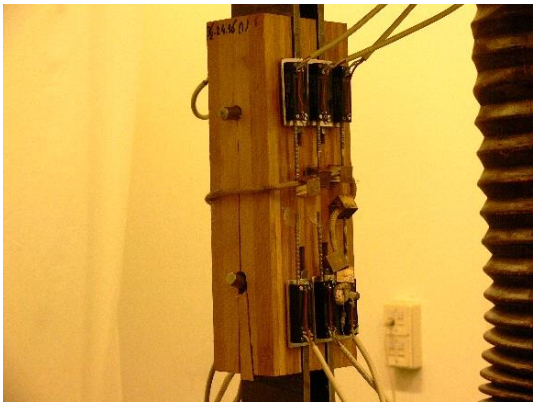
5.1 Test 36.24.36 (1)

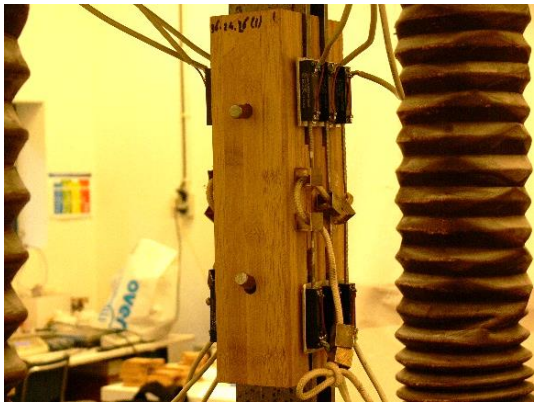




Test specifications:

Specimen	36.24.36 (1)
Material thickness left:	36mm
Material thickness middle	24mm
Material thickness right:	36mm
F_{est}	52.4kN
$F_{measured}$	54.27kN
Max dowel angle	20°
Final testing speed	0.04mm/s
Test duration	860 seconds
Failure:	Mode 1 at 2mm
	Mode 2 at 14mm





Notes

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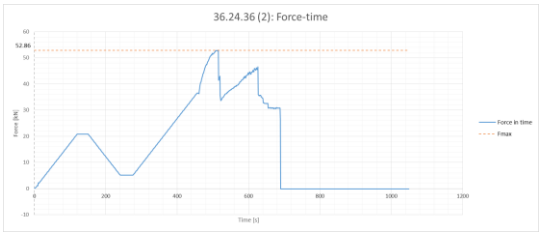
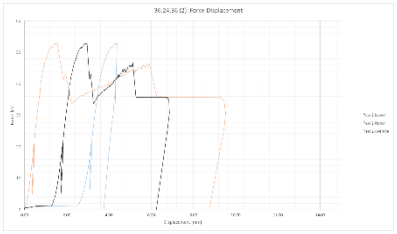
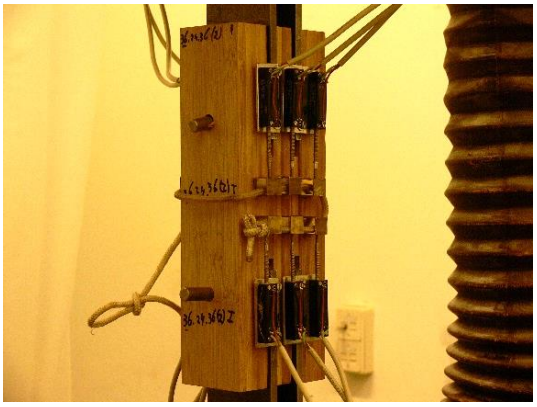
5.2 Test 36.24.36 (2)

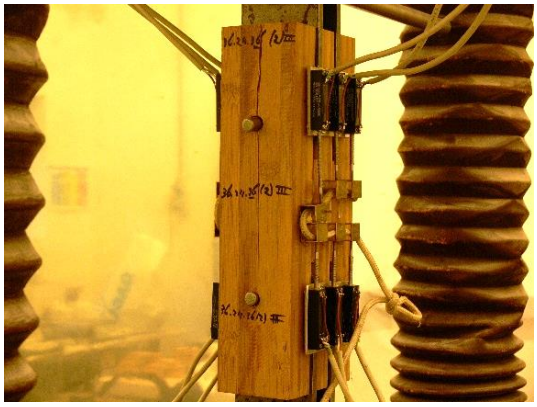




Test specifications:

Specimen	36.24.36 (2)
Material thickness left:	36mm
Material thickness middle	24mm
Material thickness right:	36mm
F_{est}	52.4kN
$F_{measured}$	52.86kN
Max dowel angle	10°
Final testing speed	0.04mm/s
Test duration	630 seconds
Failure:	Mode 1 at 3mm Mode 2 at 6mm

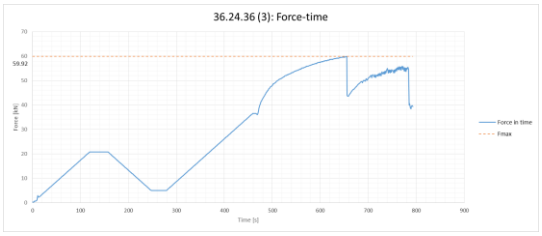


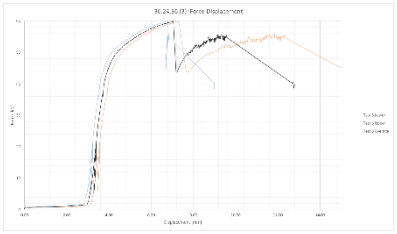


Notes

- Mode 2 had a relatively low deformation capacity.

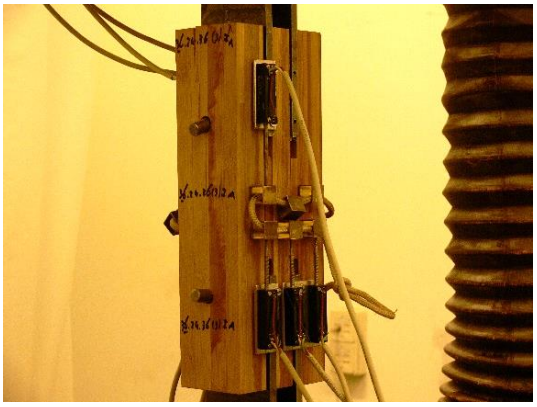
5.3 Test 36.24.36 (3)

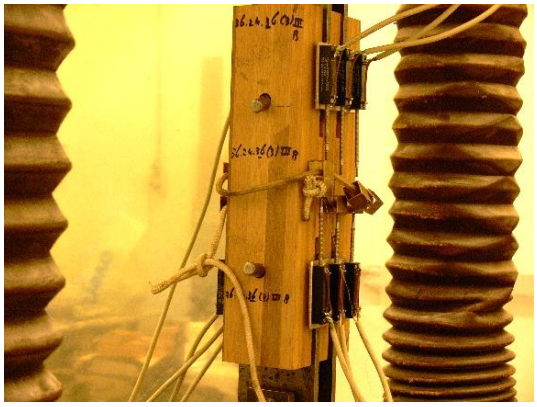




Test specifications:

Specimen	36.24.36 (2)
Material thickness left:	36mm
Material thickness middle	24mm
Material thickness right:	36mm
F_{est}	52.4kN
$F_{measured}$	59.92kN
Max dowel angle	20°
Final testing speed	0.04mm/s
Test duration	780 seconds
Failure:	Mode 1 at 7mm
	Mode 2 at 9.5mm

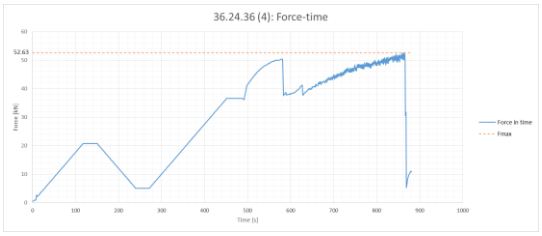


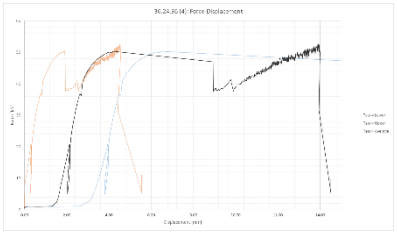


Notes

- Mode 1 had a relatively high deformation capacity.
- Mode 2 had a relatively low deformation capacity.

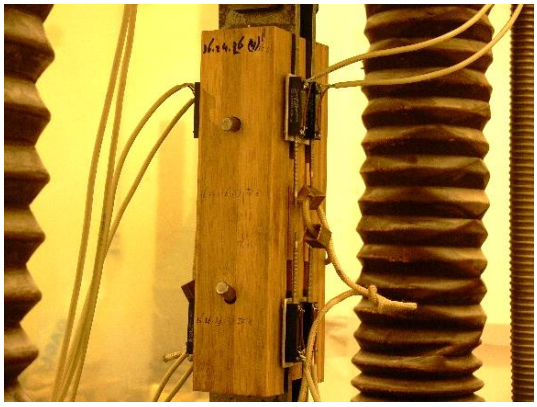
5.4 Test 36.24.36 (4)

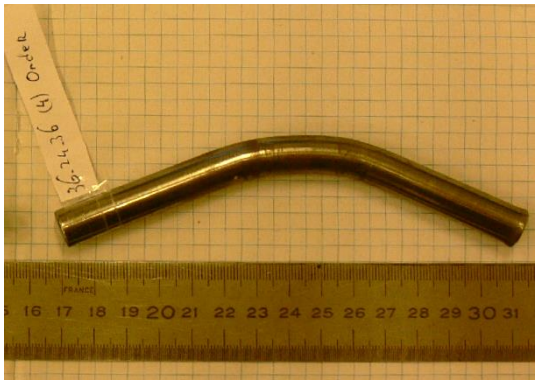




Test specifications:

Specimen	36.24.36 (2)
Material thickness left:	36mm
Material thickness middle	24mm
Material thickness right:	36mm
F_{est}	52.4kN
$F_{measured}$	52.63kN
Max dowel angle	20°
Final testing speed	0.04mm/s
Test duration	870 seconds
Failure:	Mode 1 at 4mm
	Mode 2 at 14mm

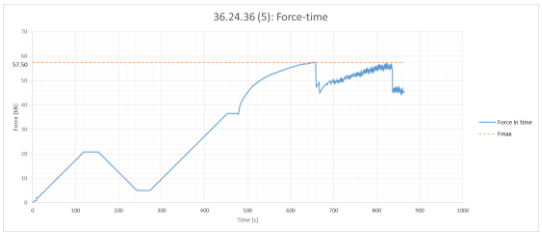


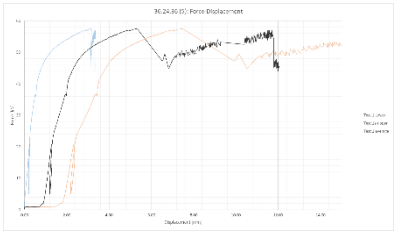


Notes

- Due to the glued-in pieces between the individual members, the displacement between the various meters does not differ anymore. Therefore, a choice was made to now only install 4 meters (one at the top and one at the bottom of the specimen at both sides). The pictures show 8 meters, four of these are activated.

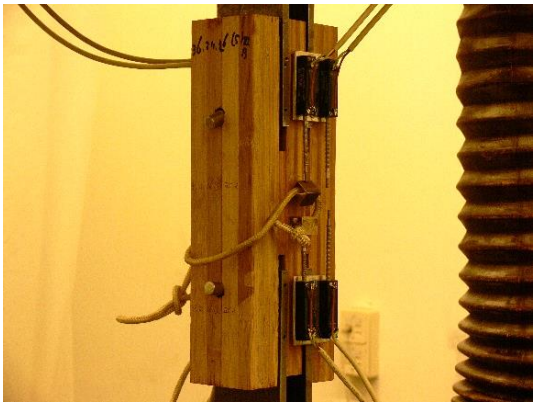
5.5 Test 36.24.36 (5)





Test specifications:

Specimen	36.24.36 (2)
Material thickness left:	36mm
Material thickness middle	24mm
Material thickness right:	36mm
F_{est}	52.4kN
$F_{measured}$	57.50kN
Max dowel angle	25°
Final testing speed	0.04mm/s
Test duration	830 seconds
Failure:	Mode 1 at 5.5mm
	Mode 2 at 11.5mm



Notes

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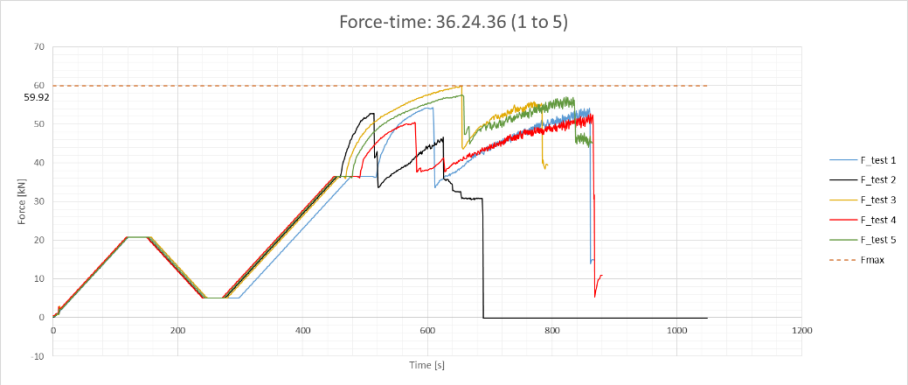
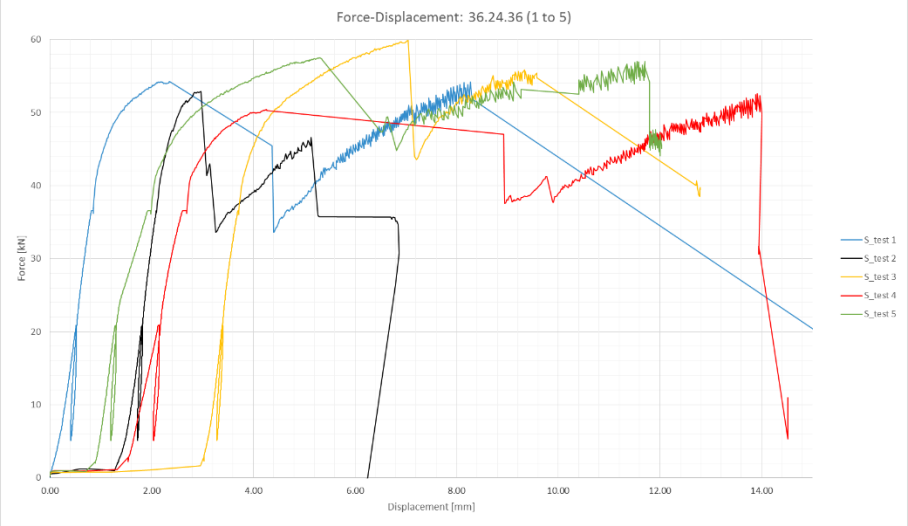
5.6 Tests 36.24.36 (1 to 5) combined plots

Specifications:

Tests	36.24.36 (1 to 5)
Material thickness left:	36mm
Material thickness middle:	24mm
Material thickness right:	36mm
F_{est}	52.4kN





Notes:

- Some force-time graphs show two distinct moments at which the resistance of the test piece drops. After the first moment of failure the tests were continued to study the post failure behaviour of the connections.
- Expected was that the first peak would be around or somewhat lower than 52.4 kN at 2 to 4 mm. This is slightly less then actually measured and is consistent with findings from other variants of failure mode 1 (variants 12.12 and 12.24.12).
- The second peak shows the failure load and deformation of failure mode 2. This load was expected to be the same as the measured capacity for variant 36.36 (40.3 kN). In the graph can be seen that the second peaks are all higher than this value. This could be explained by residual strength left in the failed middle member.

5.7 Tests 36.24.36 (1 to 5) Normal distribution

Measured test results

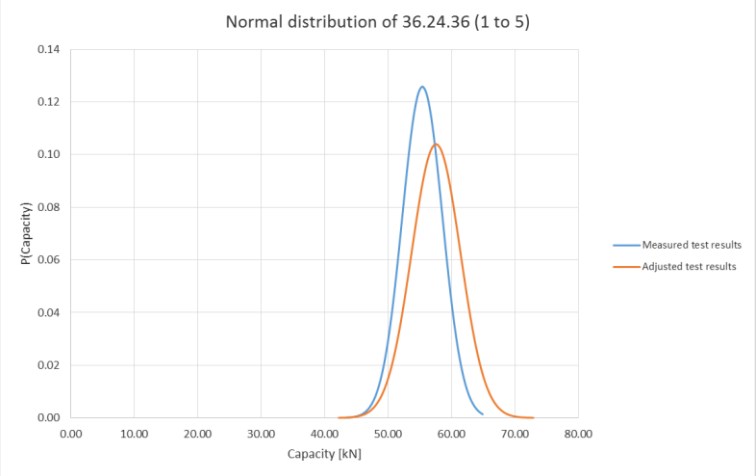
Faverage [kN]	S.Dev [kN]	COV	5-perc. [kN]
55.43	3.17	0.06	47.64

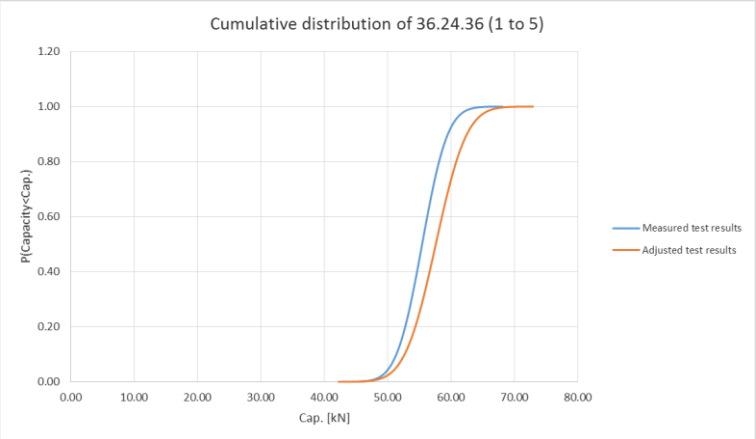
Adjusted test results

Faverage [kN]	S.Dev [kN]	COV	5-perc. [kN]
57.59	3.84	0.07	48.15

Specifications:

Tests	36.24.36 (1 to 5)
Material thickness left:	36mm
Material thickness middle:	24mm
Material thickness right:	36mm
F_{est}	52.4kN
$F_{average}/F_{est}$	1.0990





Notes:

- The resistance $F_{adjusted}$ given here is the average of the measured capacities that has been adjusted by use of the findings in 'Annex F – Probabilistic analysis of test data'. The formula found in this annex makes it possible to approximate the actual average capacity and standard deviation.
- The 5-percentile value is calculated by $x_k = \bar{x} \pm k_s * \sigma$ with $k_s = 2.46$.

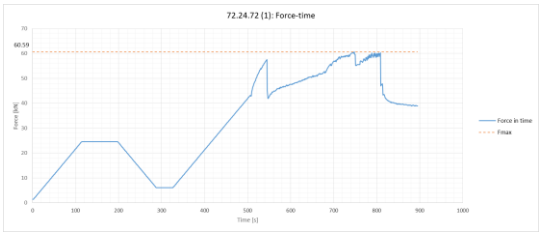
6 Tests 72.24.72

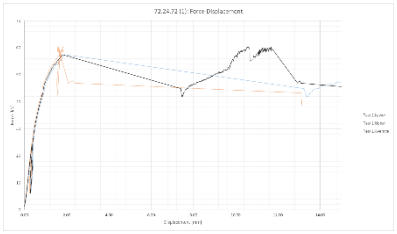
For these tests two slotted-in plates were used (both at the top and bottom connections). The expected failure modes are mode 1 in the middle member (t = 24mm) and mode 3 in the outer members (t = 72mm). A total of 5 tests was performed.

Since both expected failure modes have different deformation capacities the failure behaviour of this variant is anticipated as follows. First failure mode 1 is expected to happen in the middle member at a displacement of 2 to 4 mm (corresponding to variants 12.12 and 12.24.12). At this point the dowel will not have shown much bending and the expected load should be lower than just a summation of two times failure mode 3 and two times failure mode 1 (43.4+18.3 = 61.8kN).

After the middle member breaks, a drop in the resistance of the test piece is expected. Now the deformation will start increasing until failure mode 3 occurs in the outer members at about 10 to 12mm (corresponding to variant 72.72). The expected resistance at this point should also be the same as for variant 72.72 (59.78kN). It could however be slightly higher due to some residual strength of the failed middle member.

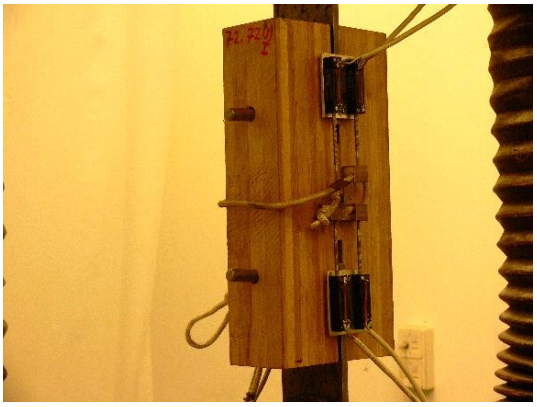
6.1 Test 72.24.72 (1)

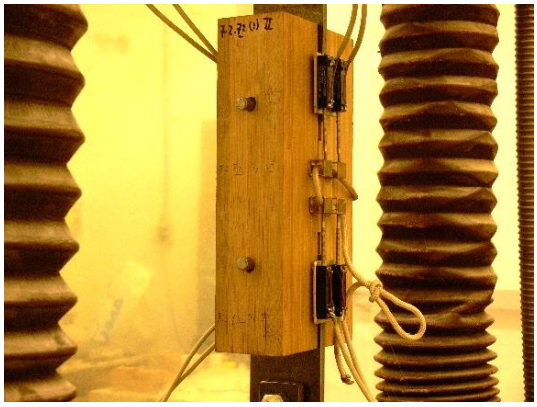




Test specifications:

Specimen	72.24.72 (1)
Material thickness left:	72mm
Material thickness middle	24mm
Material thickness right:	72mm
F_{est}	61.8kN
$F_{measured}$	60.59kN
Max dowel angle	35°
Final testing speed	0.06mm/s
Test duration	810 seconds
Failure:	Mode 1 at 2mm
	Mode 3 at 11mm

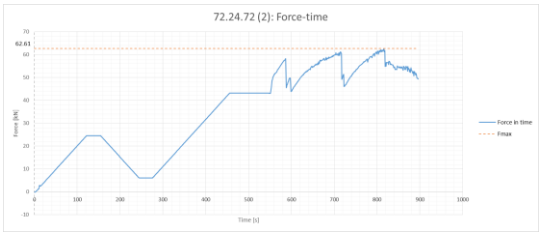




Notes

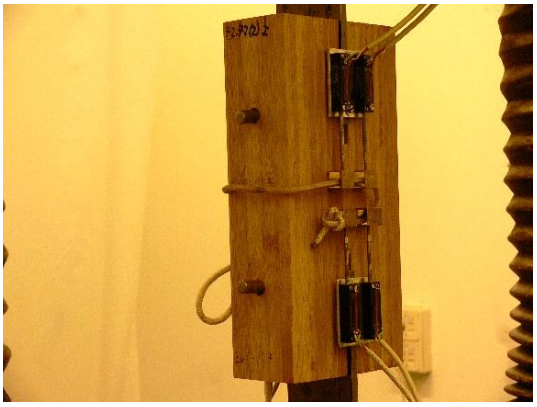
- Due to a large shock as a consequence of the first failure, a lot of blocks from the displacement meters fell off during testing. For the upcomming tests all 8 displacement meters will be installed to prevent loss of data.
- The embedment deformation of the slotted-in plates has increased slightly. Due to this increased deformation, the thickness of the slotted-in plates (around the dowel hole) has also increased. To account for this increase in thickness also the glued in pieces of bamboo have to be made thicker (from 9 to 12mm). This increase ensures that the slotted-in plates can still be inserted in between the individual members of the test pieces.

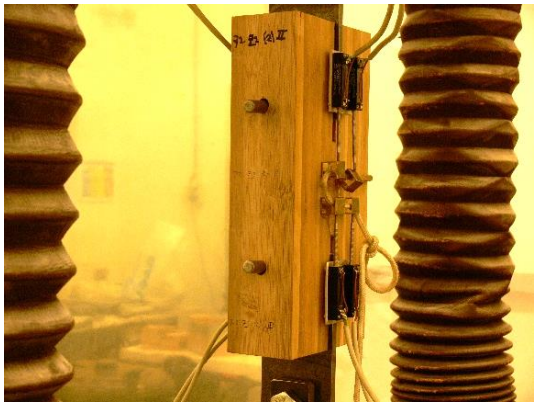
6.2 Test 72.24.72 (2)



Test specifications:

Specimen	72.24.72 (2)
Material thickness left:	72mm
Material thickness middle	24mm
Material thickness right:	72mm
F_{est}	61.8kN
$F_{measured}$	62.61kN
Max dowel angle	36°
Final testing speed	0.06mm/s
Test duration	820 seconds
Failure:	Mode 1 at 2mm
	Mode 3 at 10mm

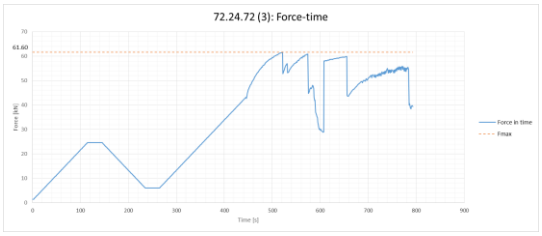




Notes

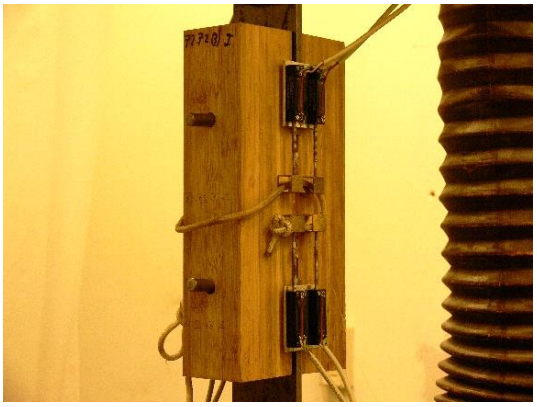
- After the first peak (failure) the test specimen shows a lot of residual strength. The maximum measured force is reached long after the initial moment of failure at a displacement more than two times as high.
- An initial increase in deformation shows that the test specimen had some backlash at the start of the test.
- This specimen is still made using thin glued-in pieces.

6.3 Test 72.24.72 (3)



Test specifications:

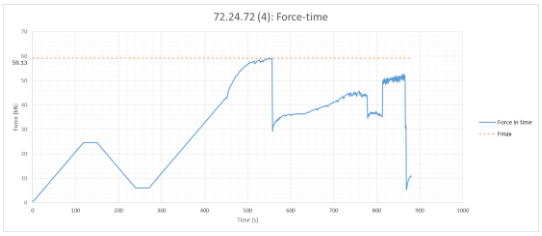
Specimen	72.24.72 (3)
Material thickness left:	72mm
Material thickness middle	24mm
Material thickness right:	72mm
F_{est}	61.8kN
$F_{measured}$	61.60kN
Max dowel angle	44°
Final testing speed	0.06mm/s
Test duration	780 seconds
Failure:	Mode 1 at 3mm
	Mode 3 at 9.5mm

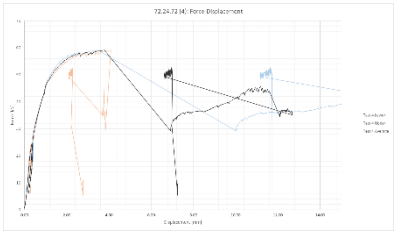


Notes

- As with the previous specimens, there is a lot of residual strength left after the first moment of failure.
- This specimen is still made using thin glued-in pieces.

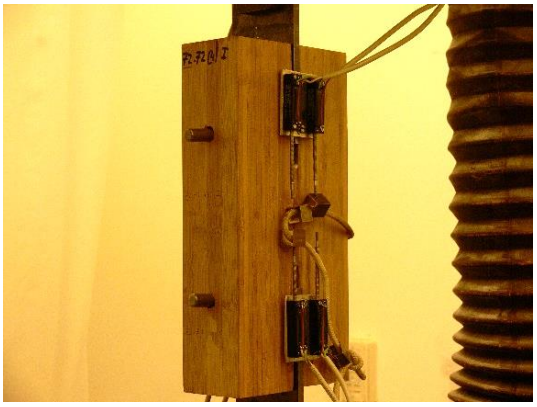
6.4 Test 72.24.72 (4)

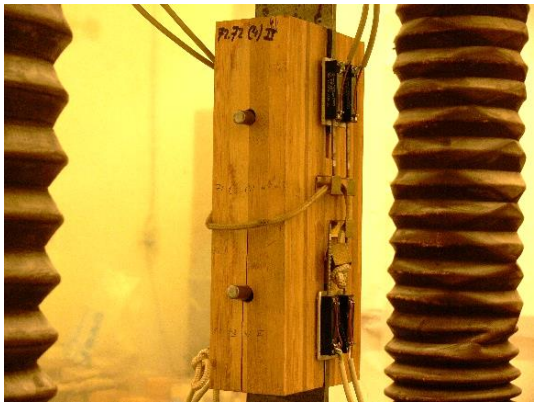




Test specifications:

Specimen	72.24.72 (4)
Material thickness left:	72mm
Material thickness middle	24mm
Material thickness right:	72mm
F_{est}	61.8kN
$F_{measured}$	59.13kN
Max dowel angle	40°
Final testing speed	0.06mm/s
Test duration	860 seconds
Failure:	Mode 1 at 4mm
	Mode 3 at 11mm

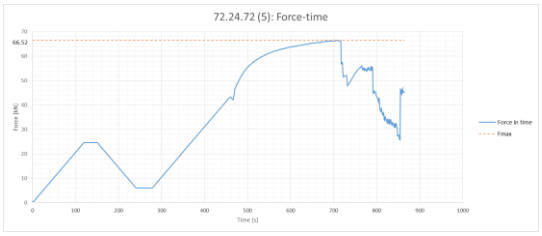


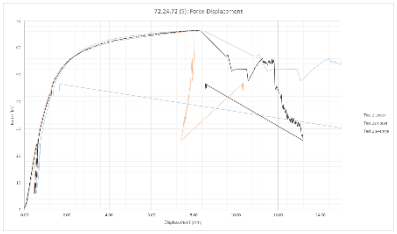


Notes

- As with the previous specimens, there is a lot of residual strength left after the first moment of failure.
- This specimen is the first to be made with thick glued-in pieces (t = 12 mm).

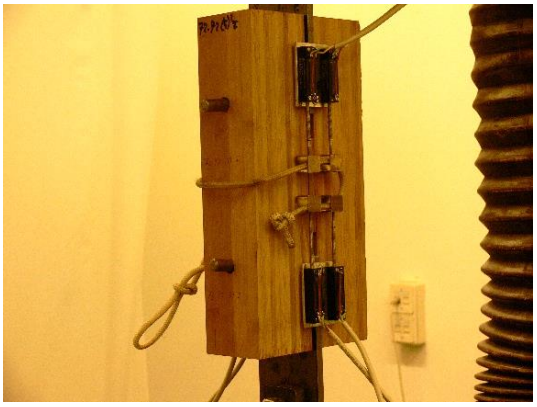
6.5 Test 72.24.72 (5)

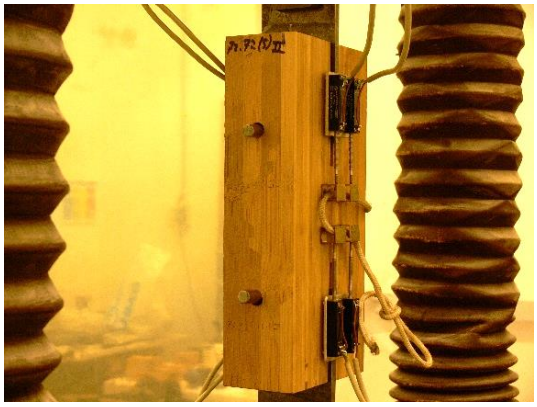




Test specifications:

Specimen	72.24.72 (5)
Material thickness left:	72mm
Material thickness middle	24mm
Material thickness right:	72mm
F_{est}	61.8kN
$F_{measured}$	66.52kN
Max dowel angle	45°
Final testing speed	0.06mm/s
Test duration	860 seconds
Failure:	Mode 1 at 8mm
	Mode 3 at 12mm





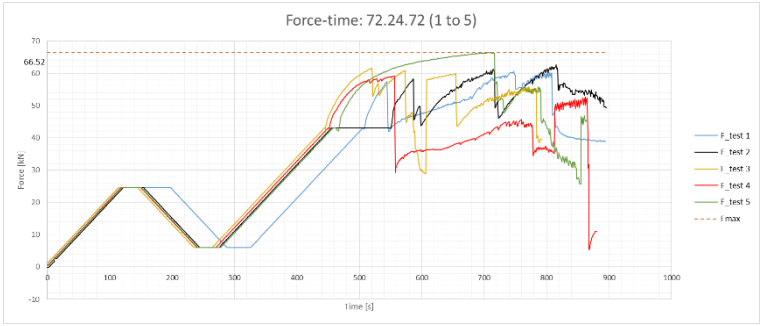
Notes

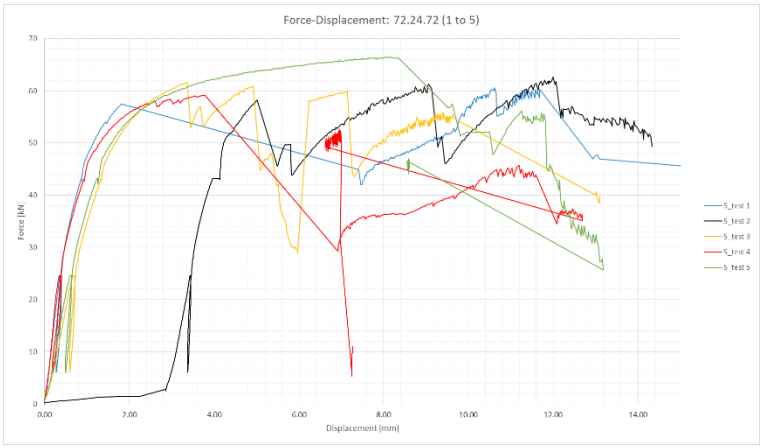
- As with the previous specimens, there is a lot of residual strength left after the first moment of failure.
- Failure mode 1 shows a lot of deformation capacity.
- Thick glued in pieces (t = 12 mm).

6.6 Tests 72.24.72 (1 to 5) combined plots

Specifications:

Tests	72.24.72 (1 to 5)
Material thickness left:	72mm
Material thickness middle:	24mm
Material thickness right:	72mm
F_{est}	61.80kN





Notes:

- All force-time graphs show several distinct moments at which the resistance of the test piece drops. After the first moment of failure the tests were continued to study the post failure behaviour of the connections. This showed that all test pieces had a lot of residual strength after the first moment of failure.
- Expected was that the first peak would be around 61.8 kN at 2 to 4 mm. This is slightly less then actually measured and is consistent with findings from other variants of failure mode 1 (variants 12.12 and 12.24.12).
- The second peak shows the failure load and deformation of failure mode 2. This load was expected to be the same as the measured capacity for variant 72.72 (59.78 kN). In the graph can be seen that the second peaks are all slightly higher than this value (except for test 4 which shows some strange beaviour probably resulting from measurement errors). This could be explained by residual strength of the failed middle member.

6.7 Tests 72.24.72 (1 to 5) Normal distribution

Measured test results

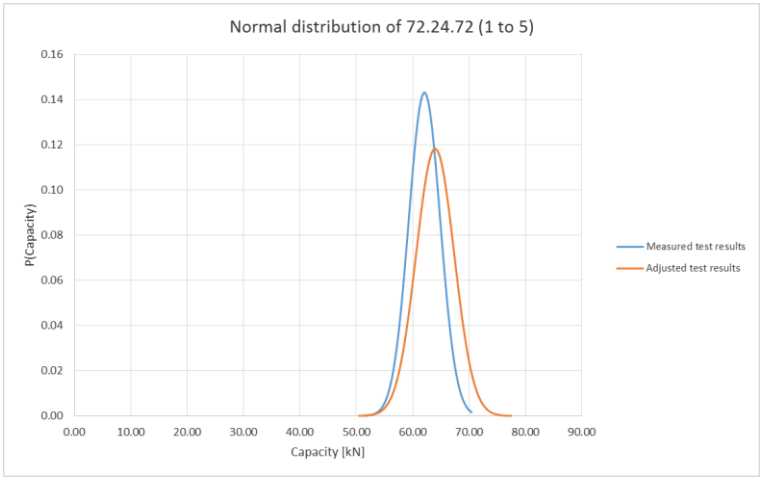
Faverage [kN]	S.Dev [kN]	COV	5-perc. [kN]
62.09	2.79	0.04	55.23

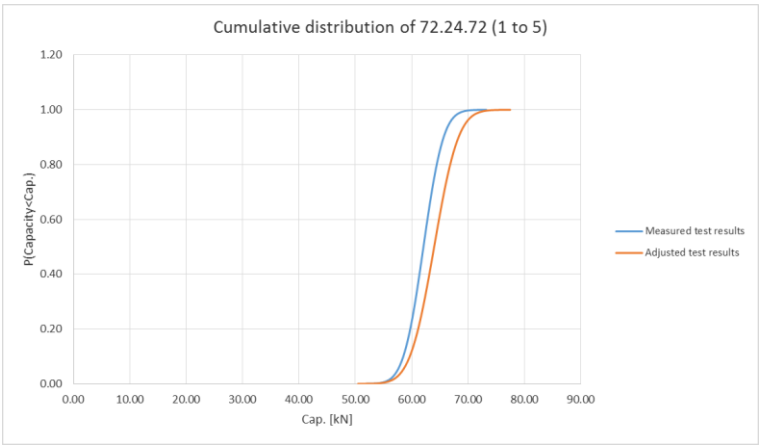
Adjusted test results

Faverage [kN]	S.Dev [kN]	COV	5-perc. [kN]
63.99	3.37	0.05	55.69

Specifications:

Tests	72.24.72 (1 to 5)
Material thickness left:	72mm
Material thickness middle:	24mm
Material thickness right:	72mm
F_{est}	61.80kN
$F_{average}/F_{est}$	1.0354





Notes:

- The resistance $F_{adjusted}$ given here is the average of the measured capacities that has been adjusted by use of the findings in 'Annex F – Probabilistic analysis of test data'. The formula found in this annex makes it possible to approximate the actual average capacity and standard deviation.
- The 5-percentile value is calculated by $x_k = \bar{x} \pm k_s * \sigma$ with $k_s = 2.46$.

7 Tests 12.144.12

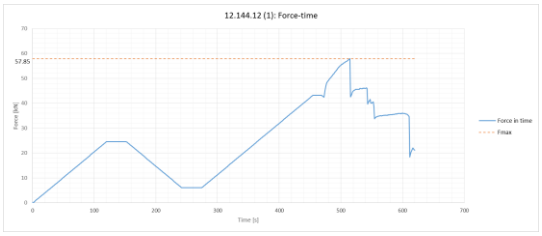
For these tests two slotted-in plates were used (both at the top and bottom connections). The expected failure modes are mode 3 in the middle member (t = 144mm) and mode 1 in the outer members (t = 12mm). A total of 5 tests was performed.

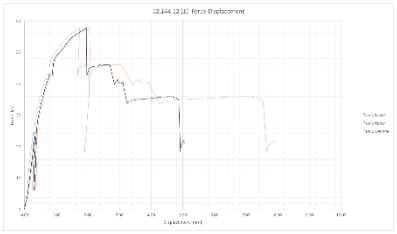
Since both expected failure modes have different deformation capacities, the failure behaviour of this variant is anticipated as follows. First failure mode 1 is expected to happen in the outer members at a displacement of 2 to 4mm (corresponding to variants 12.12 and 12.24.12). At this point the dowel will not have shown much bending and the expected load should be lower than just a summation of two times failure mode 1 and two times failure mode 3 (18.3+43.4 = 61.8kN).

After one or both of the outer members break a drop in the resistance of the test piece is expected. Now the deformation will start increasing until failure mode 3 occurs in the middle member at about 10 to 12mm (corresponding to variant 72.72). The expected resistance at this point should also be the same as for variant 72.72 (59.78kN). It could however be slightly higher due to some residual strength of the failed outer members.

In the previous is referred to the middle member (singular). In reality the middle member (with a thickness of 144mm) is composed of two individual members with a thickness of 72mm. Ideally the middle member would consist of just one bamboo piece but due to the dimensions of the available bamboo beams this was not possible. The two pieces of 72mm thickness were glued together using a PVAc wood glue.

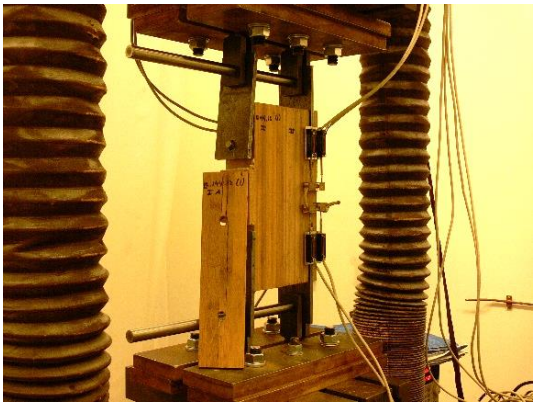
7.1 Test 12.144.12 (1)

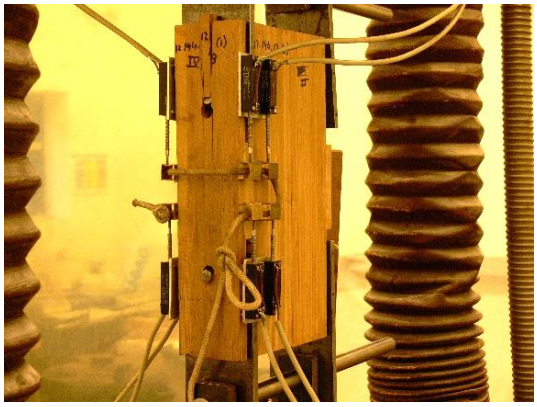




Test specifications:

Specimen	12.144.12 (1)
Material thickness left:	12mm
Material thickness middle	144mm
Material thickness right:	12mm
F_{est}	61.8kN
$F_{measured}$	57.85kN
Max dowel angle	13°
Final testing speed	0.06mm/s
Test duration	610 seconds
Failure:	Mode 1 at 2mm
	Test stopped

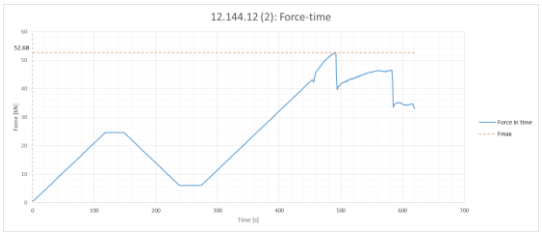


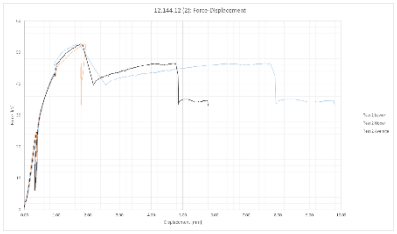


Notes

- The first peak of the force displacement diagram is at 57.85kN. This is in line with the expectation of the failure load being slightly lower than 61.8kN.
- After the first peak a few smaller drops in the resistance can be seen. This is caused by the cracking of the outer plates. Finally at 36kN a sharp drop is seen. This is caused by the splitting of plate 1 after which the plate darted away. Now the dowel has no resistance anymore from the outer plat and is free to start bending. The bending of the dowel and the lack of the outer plate allowed the slotted-in plate to rotate. As the slotted-in plate was not designed to resist this kind of loading and the plates were needed to conduct the remainder of the tests, this test had to be stopped to prevent failure of the slotted-in plates.

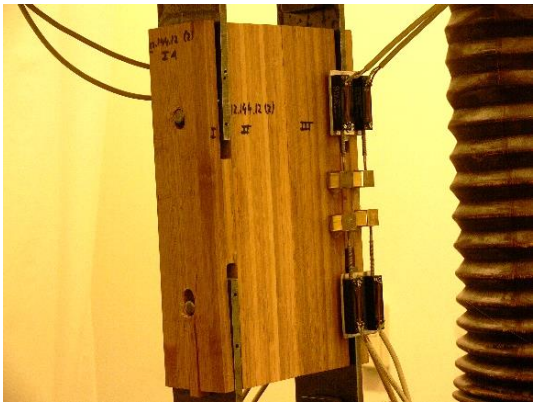
7.2 Test 12.144.12 (2)





Test specifications:

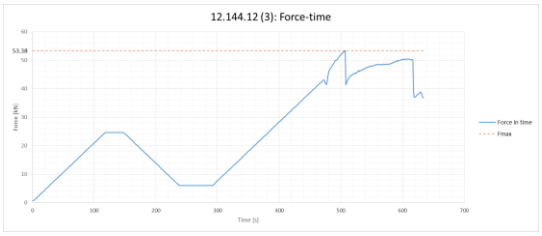
Specimen	12.144.12 (2)
Material thickness left:	12mm
Material thickness middle	144mm
Material thickness right:	12mm
F_{est}	61.8kN
$F_{measured}$	52.68kN
Max dowel angle	14°
Final testing speed	0.06mm/s
Test duration	620 seconds
Failure:	Mode 1 at 2mm
	Test stopped

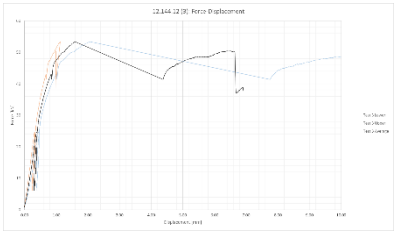


Notes

- As with test (1) of this series, the test had to be stopped to protect the slotted-in plates from failure.
- Due to the deformation of the dowel within the thick middle member, a large ammount of force was necessary to remove the dowel from the test piece. This caused the middle members to crack and split (the same phenomenon can be seen in all further tests).

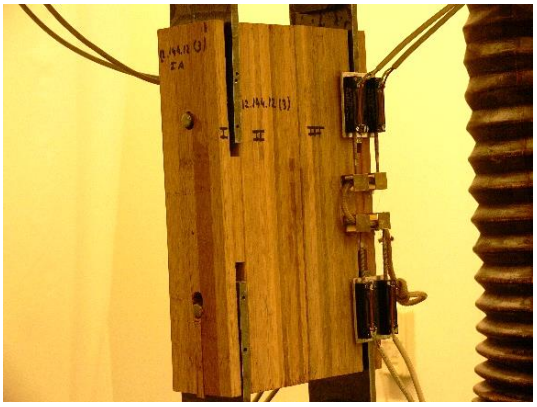
7.3 Test 12.144.12 (3)





Test specifications:

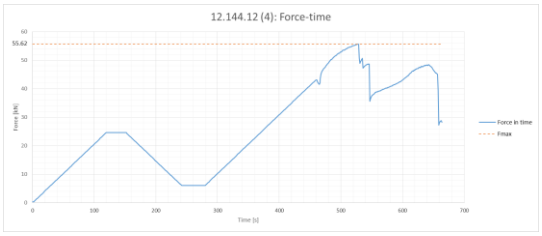
Specimen	12.144.12 (3)
Material thickness left:	12mm
Material thickness middle	144mm
Material thickness right:	12mm
F_{est}	61.8kN
$F_{measured}$	53.38kN
Max dowel angle	16°
Final testing speed	0.06mm/s
Test duration	620 seconds
Failure:	Mode 1 at 1.5mm
	Test stopped

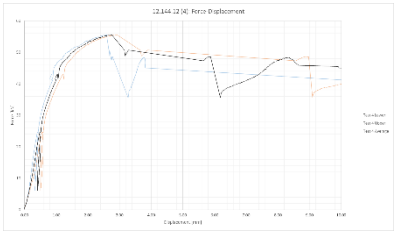


Notes

- As with test (1) of this series, the test had to be stopped to protect the slotted-in plates from failure.

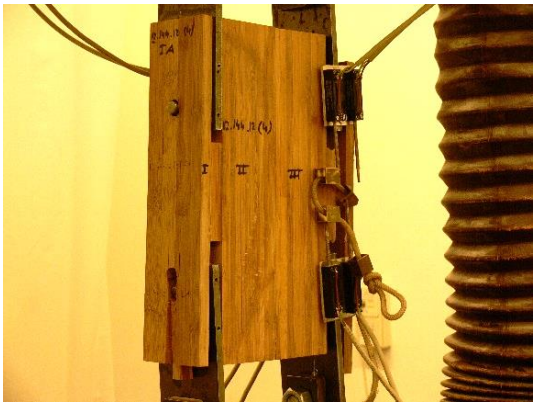
7.4 Test 12.144.12 (4)

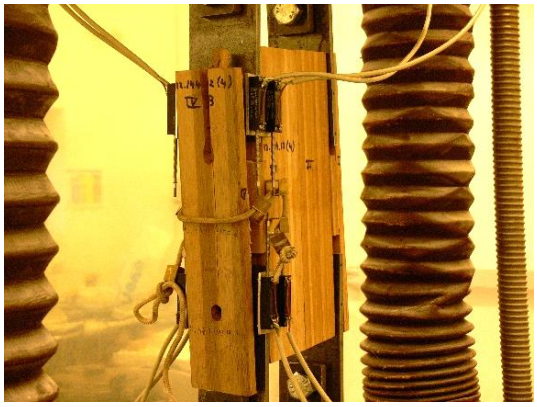




Test specifications:

Specimen	12.144.12 (4)
Material thickness left:	12mm
Material thickness middle	144mm
Material thickness right:	12mm
F_{est}	61.8kN
$F_{measured}$	55.62kN
Max dowel angle	16°
Final testing speed	0.06mm/s
Test duration	660 seconds
Failure:	Mode 1 at 3mm
	Test stopped

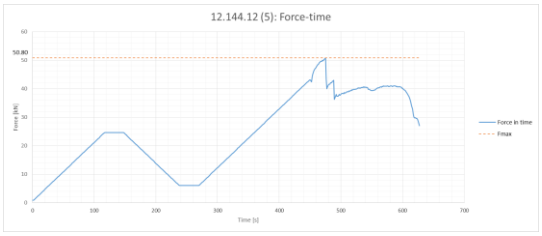


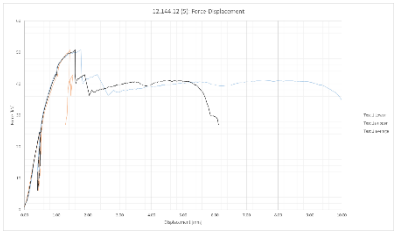


Notes

- As with test (1) of this series, the test had to be stopped to protect the slotted-in plates from failure.

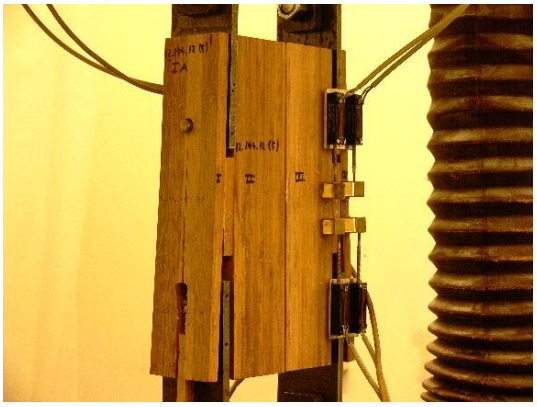
7.5 Test 12.144.12 (5)

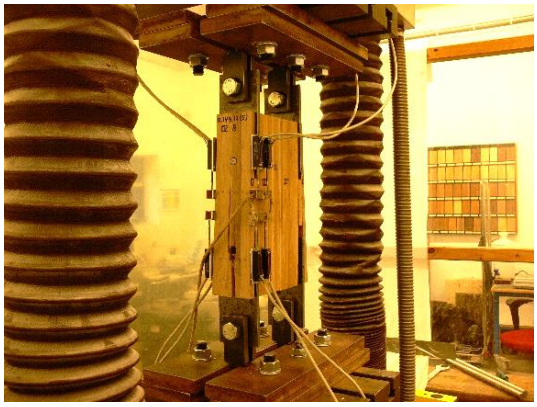




Test specifications:

Specimen	12.144.12 (5)
Material thickness left:	12mm
Material thickness middle	144mm
Material thickness right:	12mm
F_{est}	61.8kN
$F_{measured}$	50.80kN
Max dowel angle	18°
Final testing speed	0.06mm/s
Test duration	620 seconds
Failure:	Mode 1 at 1.5mm Test stopped





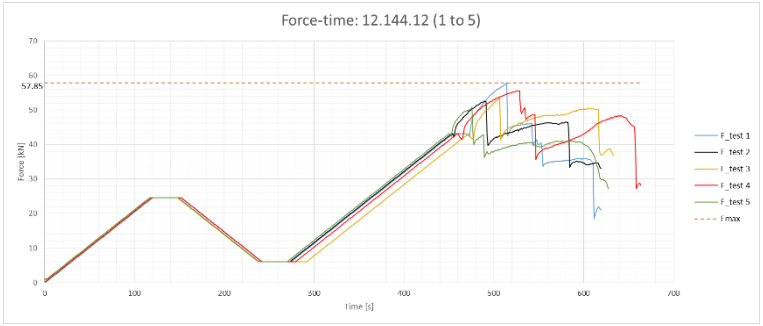
Notes

- As with test (1) of this series, the test had to be stopped to protect the slotted-in plates from failure.

7.6 Tests 12.144.12 (1 to 5) combined plots

Specifications:

Tests	12.144.12 (1 to 5)
Material thickness left:	12 mm
Material thickness middle:	144mm
Material thickness right:	12mm
F_{est}	61.80kN



Notes:

- All force-time graphs show several distinct moments at which the resistance of the test piece drops. After the first moment of failure the tests were continued to study the post failure behaviour of the connections. This showed that all test pieces had residual strength after the first moment of failure.
- Expected was that the first peak would be around 61.8 kN at 2 to 4 mm. This is slightly more than actually measured and is consistent with the expectation that the actual reistance should be less than a summation of failure modes 1 and 3 (this due to the difference in deformation capacity between the two failure modes).
- From a comparison with series 72.24.72 can be seen that the measured average resistance here is lower. Although both series 72.24.72 and 12.144.12 have the expected failure behaviour of two times mode 1 and two times mode 3, they differ from each other in the locations at which these failure modes occur. In this series of 12.144.12 failure mode 1 occurred in the outer members and caused the slotted-in plates to rotate. Since the slotted-in plates are not designed to withstand this sort of behaviour this eventually led to a weaker connection than when failure mode 1 occurred in the middle members, as in series 72.24.72.

7.7 Tests 12.144.12 (1 to 5) Normal distribution

Measured test results

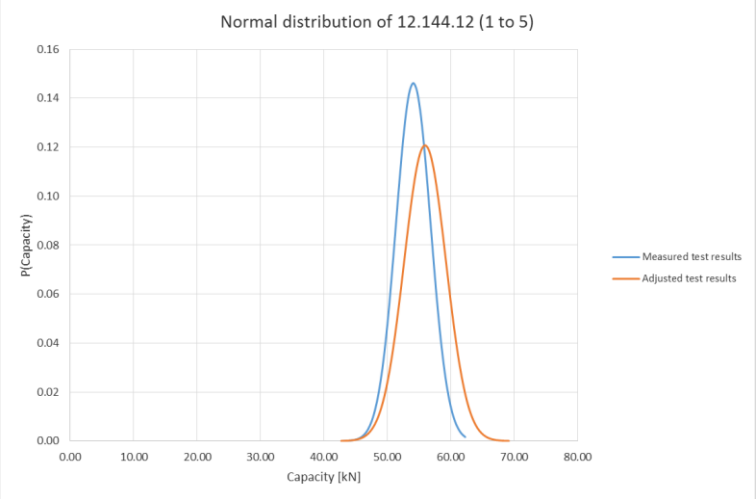
Faverage [kN]	S.Dev [kN]	COV	5-perc. [kN]
54.07	2.73	0.05	47.35

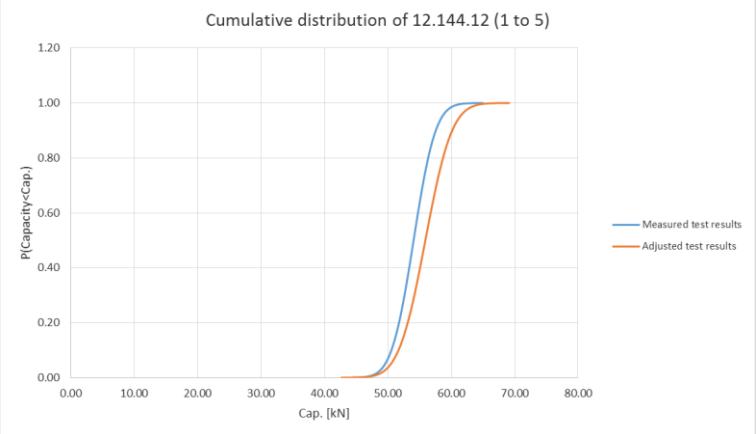
Adjusted test results

Faverage [kN]	S.Dev [kN]	COV	5-perc. [kN]
55.92	3.30	0.06	47.80

Specifications:

Tests	12.144.12 (1 to 5)
Material thickness left:	12 mm
Material thickness middle:	144mm
Material thickness right:	12mm
F_{est}	61.80kN
$F_{average}/F_{est}$	0.9049





Notes:

- The resistance $F_{adjusted}$ given here is the average of the measured capacities that has been adjusted by use of the findings in 'Annex F – Probabilistic analysis of test data'. The formula found in this annex makes it possible to approximate the actual average capacity and standard deviation.
- The 5-percentile value is calculated by $x_k = \bar{x} \pm k_s * \sigma$ with $k_s = 2.46$.

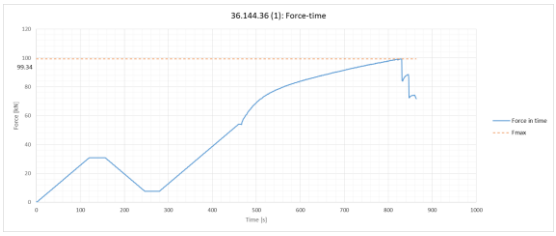
8 Tests 36.144.36

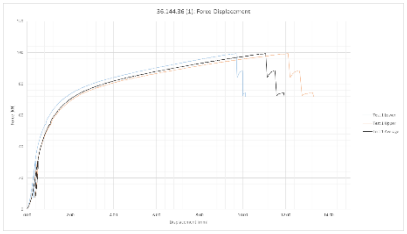
For these tests two slotted-in plates were used (both at the top and bottom connections). The expected failure modes are mode 3 in the middle member (t = 144mm) and mode 2 in the outer members (t = 36mm). A total of 5 tests was performed.

Since both expected failure modes have different deformation capacities, the failure behaviour of this variant is anticipated as follows. First failure mode 2 is expected to happen in the outer members at a displacement of 10 to 12mm (corresponding to variant 36.36). At this point the dowel will have shown a large deformation but not enough to fully reach the resistance of failure mode 3 in the middle member. Theoretically the expected load at this point should thus be somewhat lower than just a summation of two times failure mode 2 and two times failure mode 3 (34.1+43.4 = 77.5kN). However, as already seen with variants 36.36 and 36.24.36 the actual failure load of mode 2 is higher than anticipated. This would mean that the failure load for this variant should also be higher than expected.

In the previous is referred to the middle member (singular). In reality the middle member (with a thickness of 144mm) is composed of two individual members with a thickness of 72mm. Ideally the middle member would consist of just one bamboo piece but due to the dimensions of the available bamboo beams this was not possible. The two pieces of 72mm thickness were glued together using a PVAc wood glue.

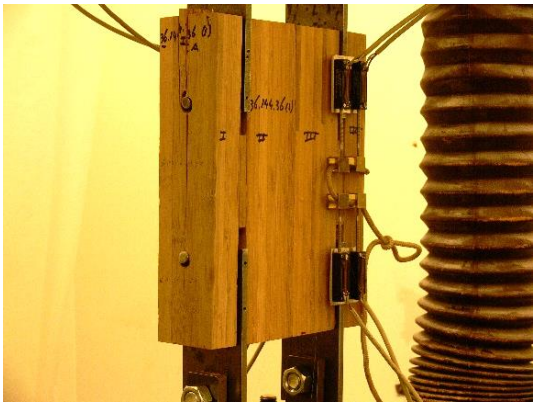
8.1 Test 36.144.36 (1)

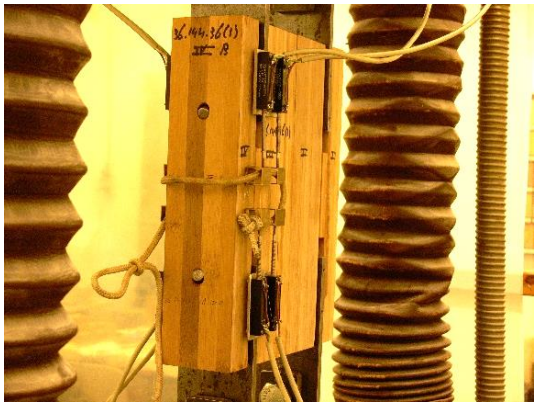




Test specifications:

Specimen	36.144.36 (1)
Material thickness left:	36 mm
Material thickness middle	144mm
Material thickness right:	36mm
F_{est}	77.5kN
$F_{measured}$	99.34kN
Max dowel angle	45°
Final testing speed	0.06mm/s
Test duration	850 seconds
Failure:	Mode 2 at 11mm

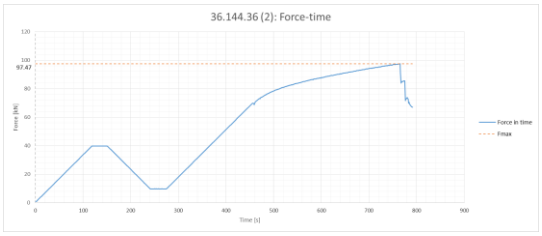


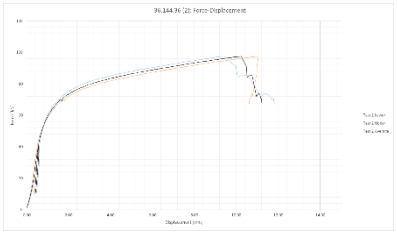


Notes

- In the picture above can be seen that the dowels showed a large bending angle. Due to this large deformation, a considerable ammount of force was necessary to extract the dowels from the failed test piece. In the process the middle members had to be split in half.
- The measured resistance of the test piece is more than 20% higher than expected. For the next tests, the expected capacity thus needs to be adapted. The expected capacity of the following test pieces is taken as 99.34kN.

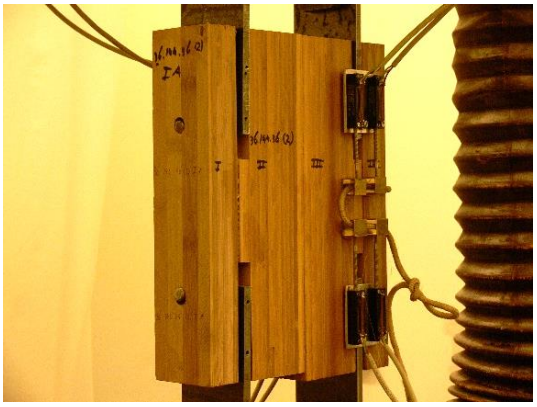
8.2 Test 36.144.36 (2)

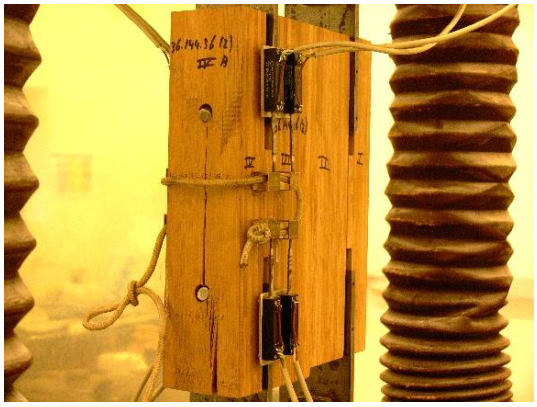


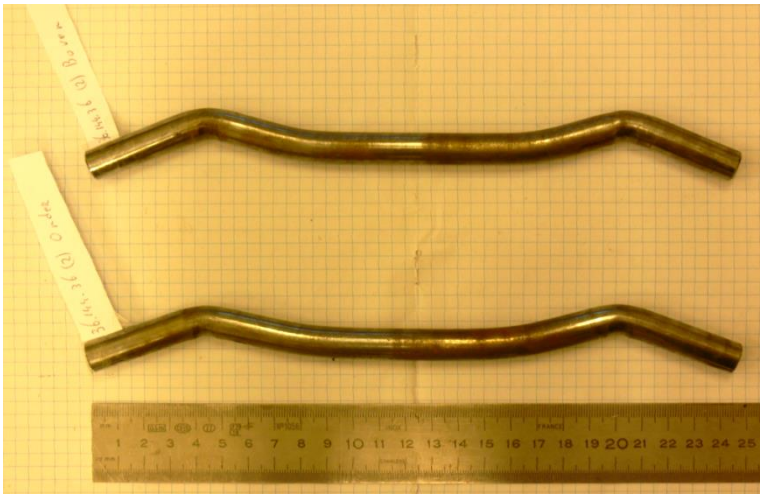


Test specifications:

Specimen	36.144.36 (2)
Material thickness left:	36mm
Material thickness middle	144mm
Material thickness right:	36mm
F_{est}	99.34kN
$F_{measured}$	97.47kN
Max dowel angle	36°
Final testing speed	0.06mm/s
Test duration	780 seconds
Failure:	Mode 2 at 10mm



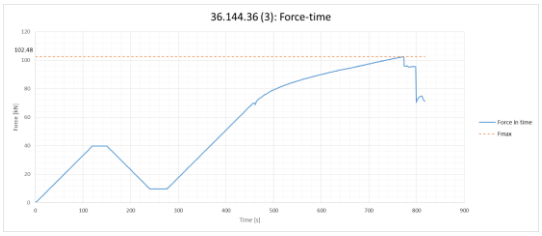


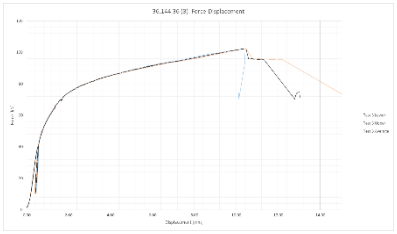


Notes

- The adapted expected capacity of 99.34kN suffices.

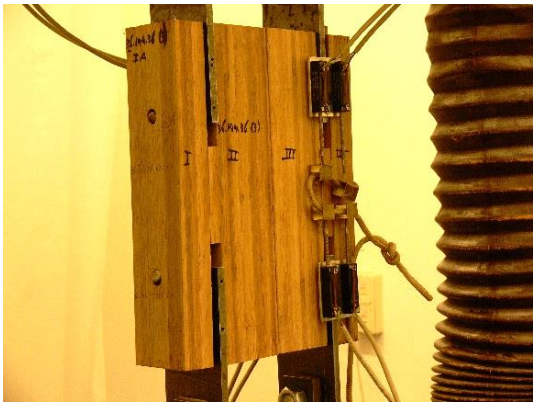
8.3 Test 36.144.36 (3)

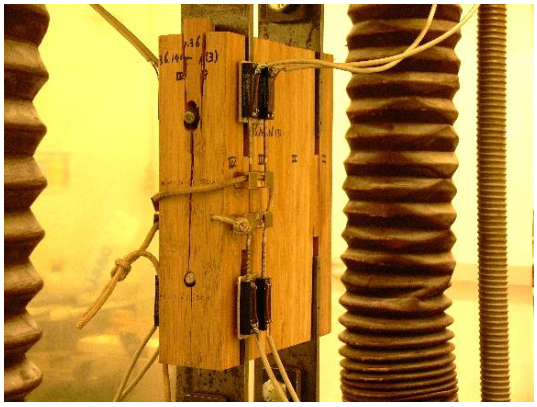


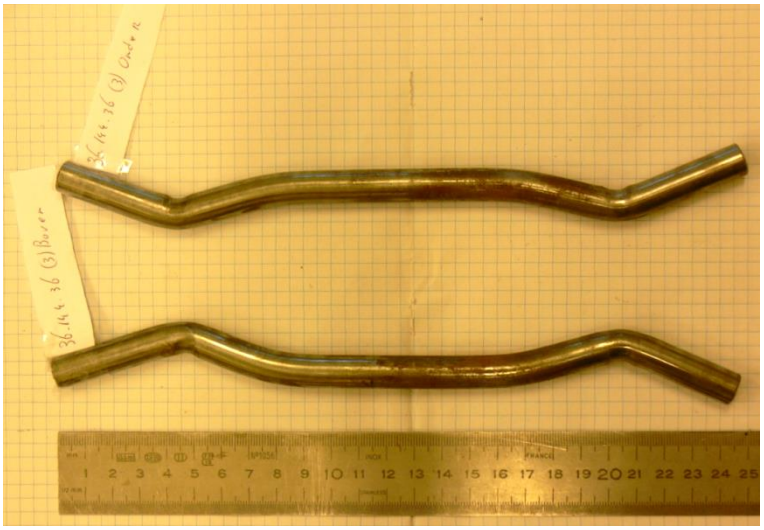


Test specifications:

Specimen	36.144.36 (3)
Material thickness left:	36mm
Material thickness middle	144mm
Material thickness right:	36mm
F_{est}	99.34kN
$F_{measured}$	102.48kN
Max dowel angle	36°
Final testing speed	0.06mm/s
Test duration	800 seconds
Failure:	Mode 2 at 10.5mm







Notes

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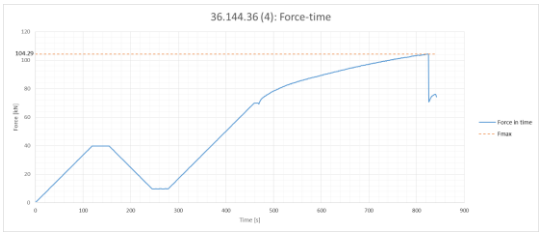
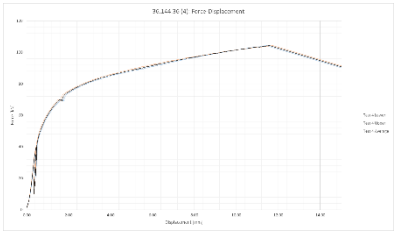
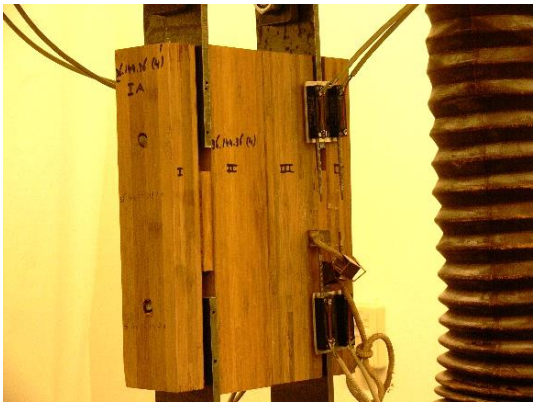
8.4 Test 36.144.36 (4)

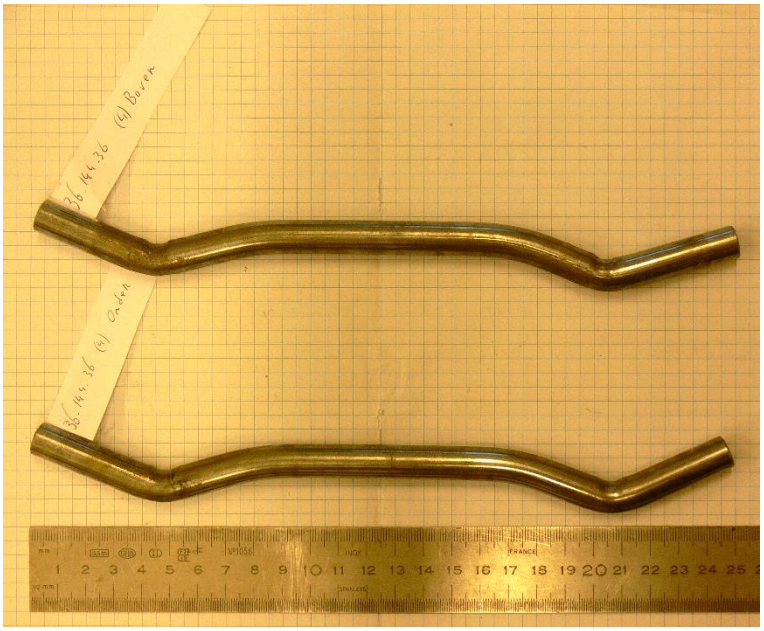




Test specifications:

Specimen	36.144.36 (4)
Material thickness left:	36mm
Material thickness middle	144mm
Material thickness right:	36mm
F_{est}	99.34kN
$F_{measured}$	104.29kN
Max dowel angle	36°
Final testing speed	0.06mm/s
Test duration	820 seconds
Failure:	Mode 2 at 11.5mm





Notes

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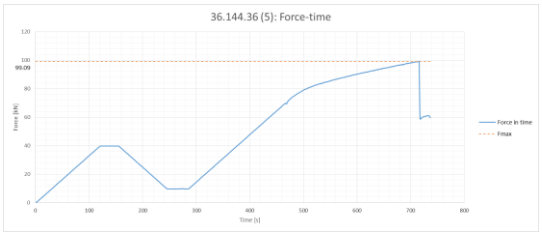
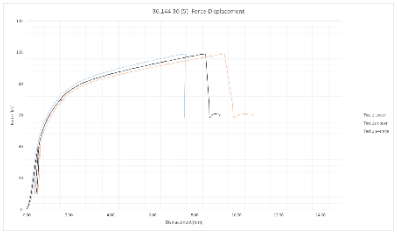
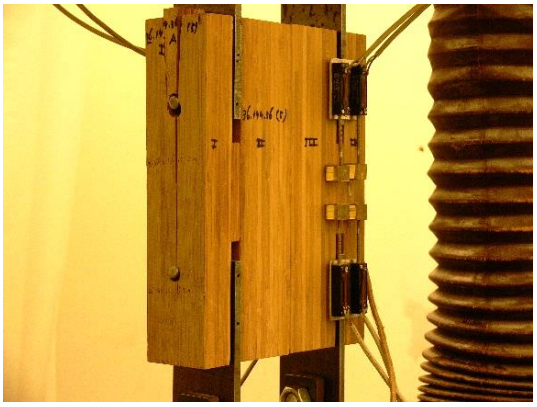
8.5 Test 36.144.36 (5)





Test specifications:

Specimen	36.144.36 (5)
Material thickness left:	36mm
Material thickness middle	144mm
Material thickness right:	36mm
F_{est}	99.34kN
$F_{measured}$	99.09kN
Max dowel angle	32°
Final testing speed	0.06mm/s
Test duration	720 seconds
Failure:	Mode 2 at 8.5mm



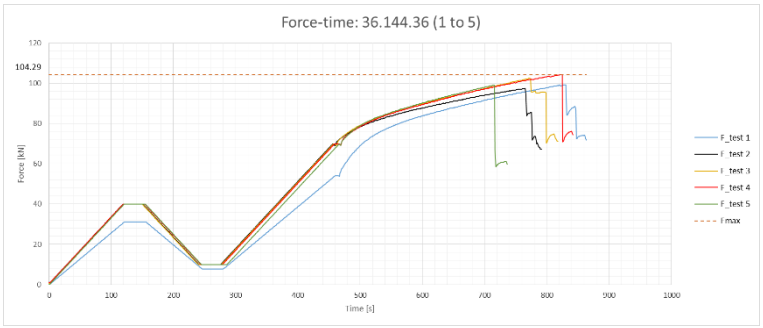
Notes

- This specimen had a relatively low deformation capacity.

8.6 Tests 36.144.36 (1 to 5) combined plots

Specifications:

Tests	36.144.36 (1 to 5)
Material thickness left:	36mm
Material thickness middle:	144mm
Material thickness right:	36mm
F_{est}	77.5kN



Notes:

- Expected was that the capacity of the test pieces would be slightly below 77.5 kN. However, the measured capacity was well above this value. This is consistent with the findings for the other mode 2 variants (36.36 and 36.24.36). It is plausible that the embedment strength, with which the expected capacity was calculated, is too low. Since the embedment capacity is based on preliminary tests, wich all showed splitting behaviour at failure (a phenomenon that is largely prevented in an actual embedment test), the used value for the embedment strenght is most likely underestimated.

8.7 Tests 36.144.36 (1 to 5) Normal distribution

Measured test results

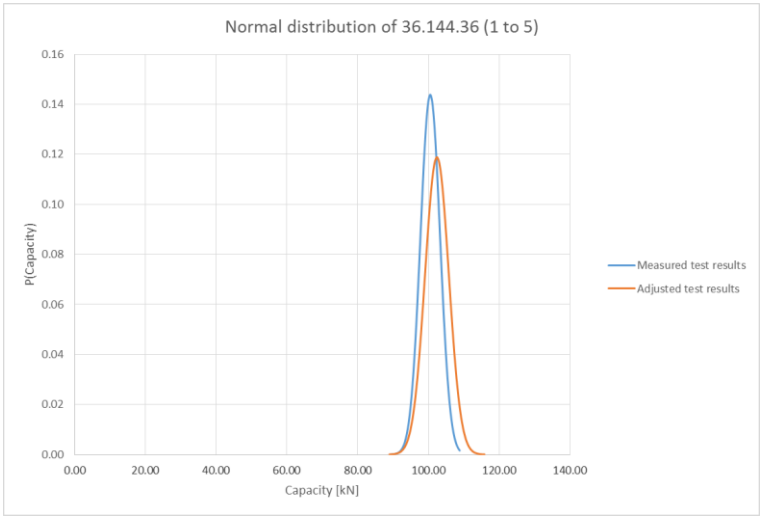
Faverage [kN]	S.Dev [kN]	COV	5-perc. [kN]
100.53	2.77	0.03	93.71

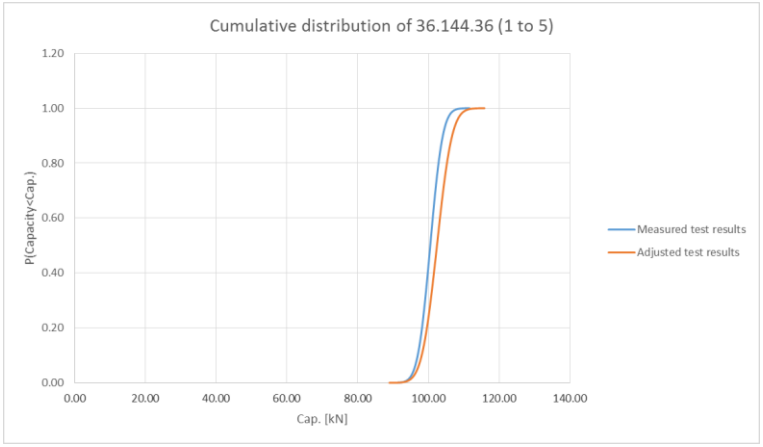
Adjusted test results

Faverage [kN]	S.Dev [kN]	COV	5-perc. [kN]
102.42	3.36	0.03	94.17

Specifications:

Tests	36.144.36 (1 to 5)
Material thickness left:	36 mm
Material thickness middle:	144 mm
Material thickness right:	36 mm
F_{est}	77.5 kN
$F_{average}/F_{est}$	1.3215





Notes:

- The resistance $F_{adjusted}$ given here is the average of the measured capacities that has been adjusted by use of the findings in 'Annex F – Probabilistic analysis of test data'. The formula found in this annex makes it possible to approximate the actual average capacity and standard deviation.
- The 5-percentile value is calculated by $x_k = \bar{x} \pm k_s * \sigma$ with $k_s = 2.46$.

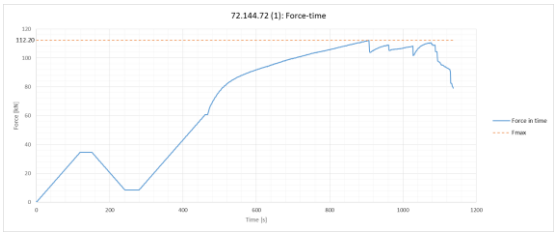
9 Tests 72.144.72

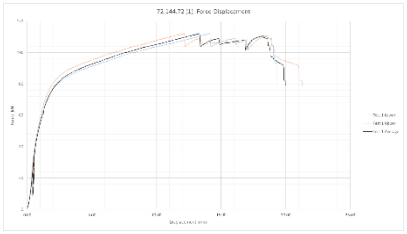
For these tests two slotted-in plates were used (both at the top and bottom connections). The expected failure mode is mode 3 in all members. So mode 3 in as well the middle member (t = 144mm) and mode 3 in the outer members (t = 72mm). A total of 5 tests was performed.

Since the expected failure mode is the same for all members, the deformation capacity of all members is also expected to be the same. This means that all members are expected to reach their maximum capacity at the same deformation and that the maximum capacity of the entire connection should be equal to a summation of four times the failure load of mode 3. This is equal to two times the expected failure load of 43.4kN from variant 72.72, which is 86.9kN (rounded off to one decimal).
During testing of variant 72.72 it was found that the actual capacity of the test piece was 59.78kN instead of the expected 43.4kN. Given this information one would expect the capacity of the specimens 72.144.72 also to be higher than expected and more likely to be about equal to two times 59.78kN. Which would result in an expected yield load of 119.56kN.

In the previous is referred to the middle member (singular). In reality the middle member (with a thickness of 144mm) is composed of two individual members with a thickness of 72mm. Ideally the middle member would consist of just one bamboo piece but due to the dimensions of the available bamboo beams this was not possible. The two pieces of 72mm thickness were glued together using a PVAc wood glue.

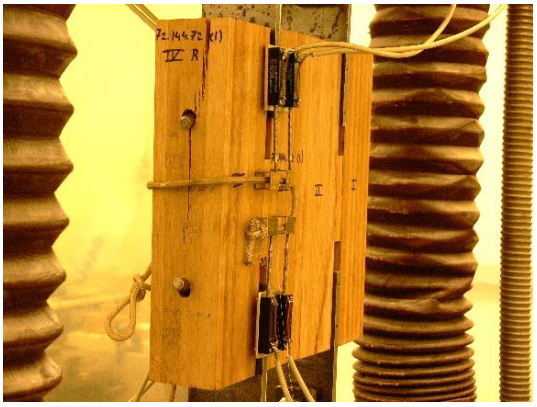
9.1 Test 72.144.72 (1)

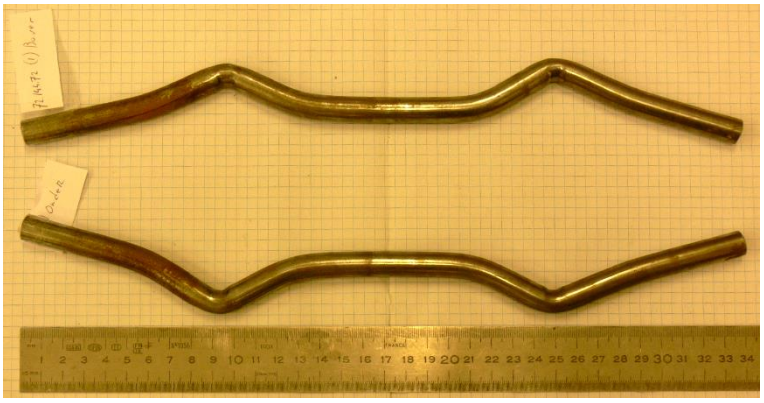




Test specifications:

Specimen	72.144.72 (1)
Material thickness left:	72mm
Material thickness middle	144mm
Material thickness right:	72mm
F_{est}	86.9kN
$F_{measured}$	112.20kN
Max dowel angle	50°
Final testing speed	0.06mm/s
Test duration	1130 seconds
Failure:	Mode 3 at 13.5mm

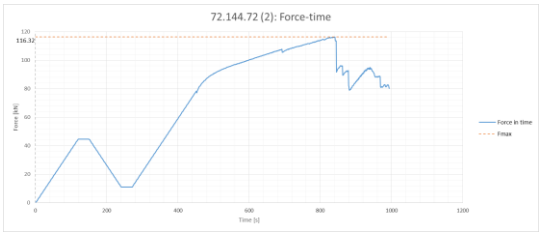


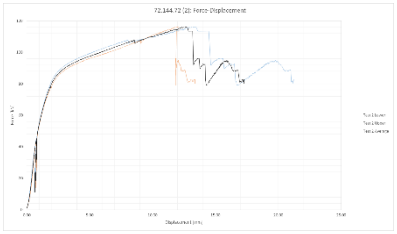


Notes

- The test piece shows a lot of reidual strength after the first peak in the force-displacement graph. The first peak appears at about 13.5mm. After that, the resistance of the test piece drops but is close to the level at which the first crack appears. At a displacement of about 18.5 mm the test piece finally breaks.
- The measured capacity is well above the calculated capacity. The estimation for the following tests has to be adapted and will be taken as 112.20kN.

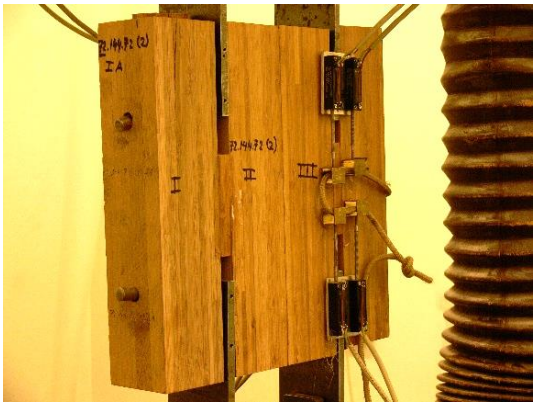
9.2 Test 72.144.72 (2)

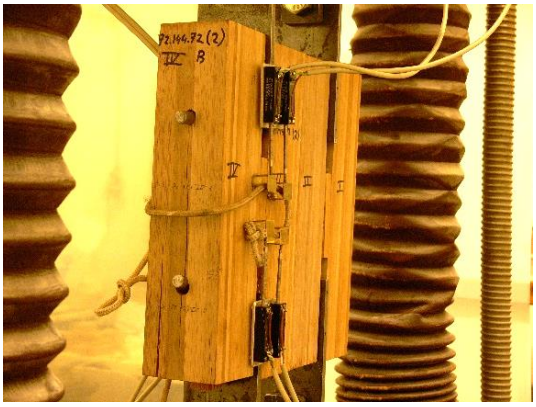


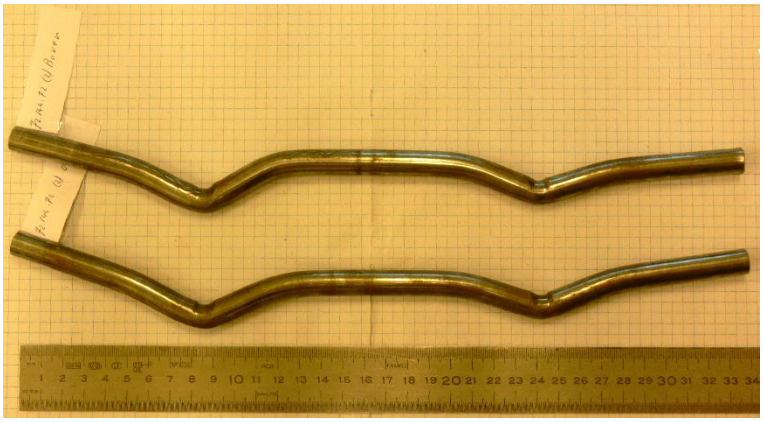


Test specifications:

Specimen	72.144.72 (2)
Material thickness left:	72mm
Material thickness middle	144mm
Material thickness right:	72mm
F_{est}	112.20kN
$F_{measured}$	116.32kN
Max dowel angle	47°
Final testing speed	0.06mm/s
Test duration	970 seconds
Failure:	Mode 3 at 13mm



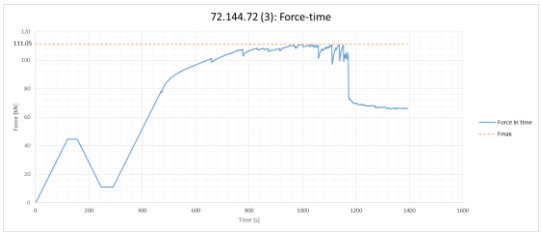


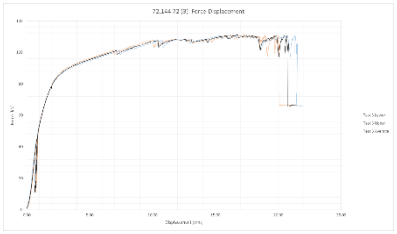


Notes

- The estimated capacity of 112.20kN suffices.

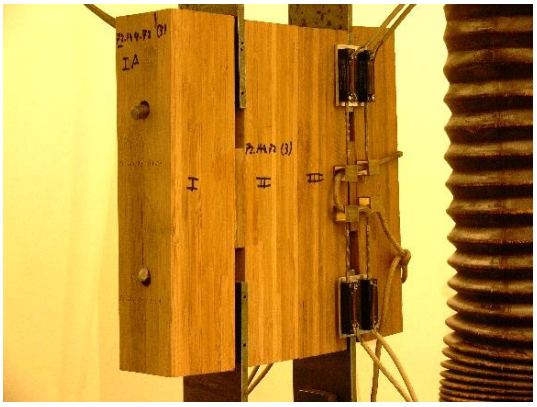
9.3 Test 72.144.72 (3)

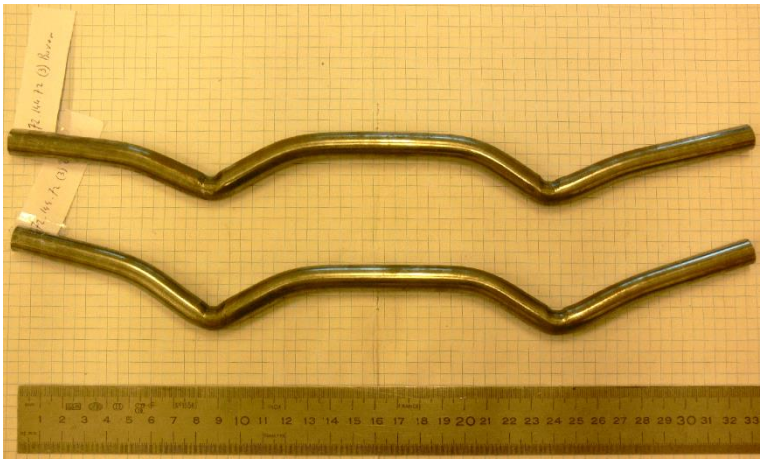




Test specifications:

Specimen	72.144.72 (3)
Material thickness left:	72mm
Material thickness middle	144mm
Material thickness right:	72mm
F_{est}	112.20kN
$F_{measured}$	111.05kN
Max dowel angle	60°
Final testing speed	0.06mm/s
Test duration	1170 seconds
Failure:	Mode 3 at 10.5mm

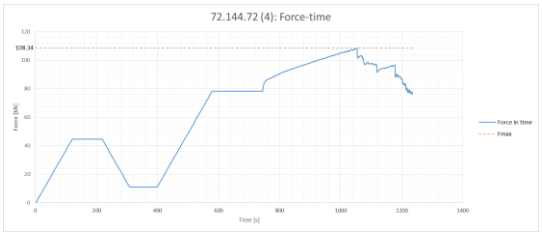


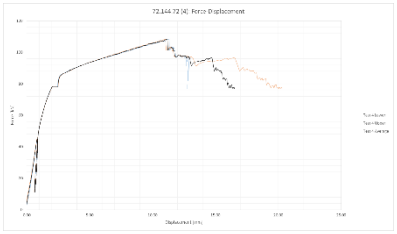


Notes

- Although the first crack appeared at a relatively low displacement of 10.5mm, this specimen showed a very large deformation capacity in comparison to the other specimens of this series.
- A large dowel bending angle was reached during this test.

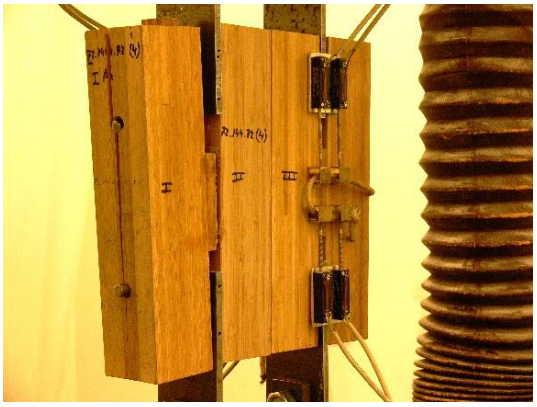
9.4 Test 72.144.72 (4)

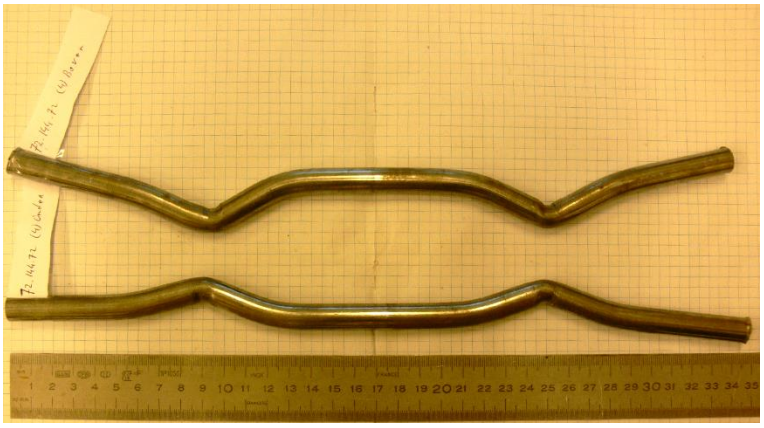




Test specifications:

Specimen	72.144.72 (4)
Material thickness left:	72mm
Material thickness middle	144mm
Material thickness right:	72mm
F_{est}	112.20kN
$F_{measured}$	108.34kN
Max dowel angle	50°
Final testing speed	0.06mm/s
Test duration	1180 seconds
Failure:	Mode 3 at 11mm





Notes

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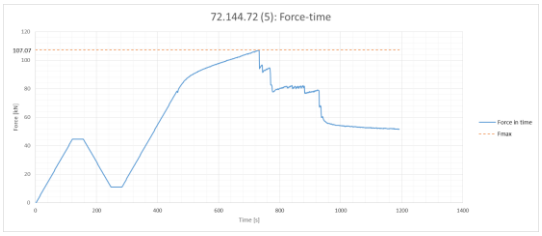
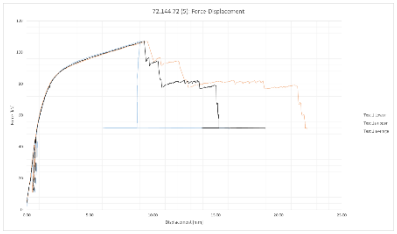
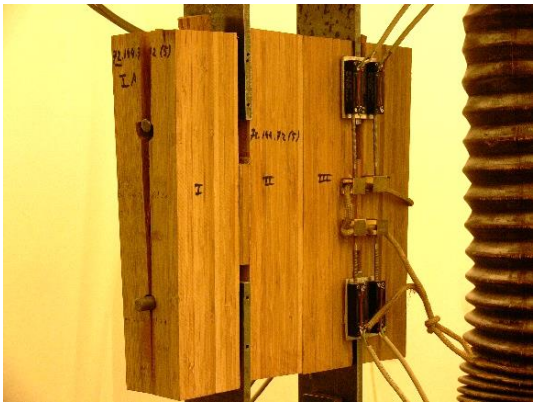
9.5 Test 72.144.72 (5)

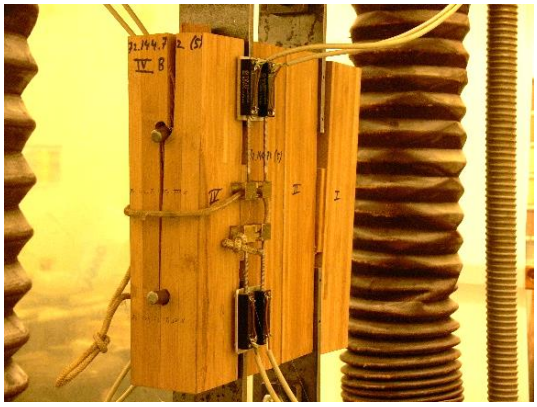


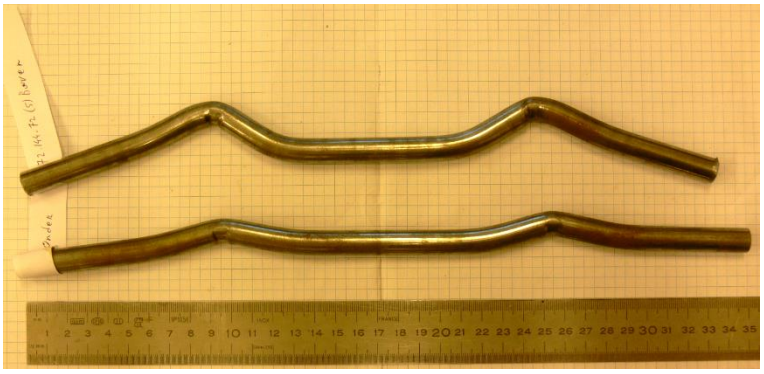


Test specifications:

Specimen	72.144.72 (5)
Material thickness left:	72 mm
Material thickness middle	144 mm
Material thickness right:	72 mm
F_{est}	112.20 kN
$F_{measured}$	107.07 kN
Max dowel angle	59°
Final testing speed	0.06mm/s
Test duration	930 seconds
Failure:	Mode 3 at 9.5mm







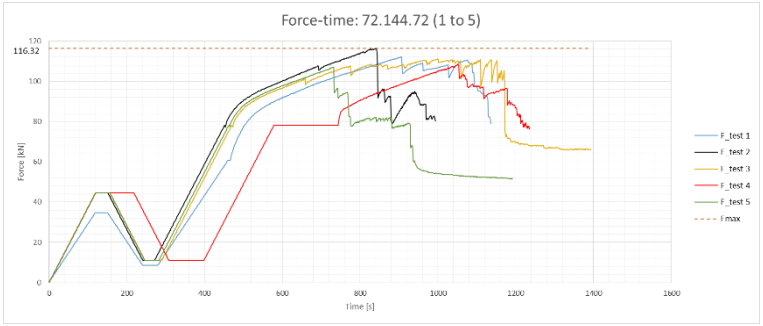
Notes

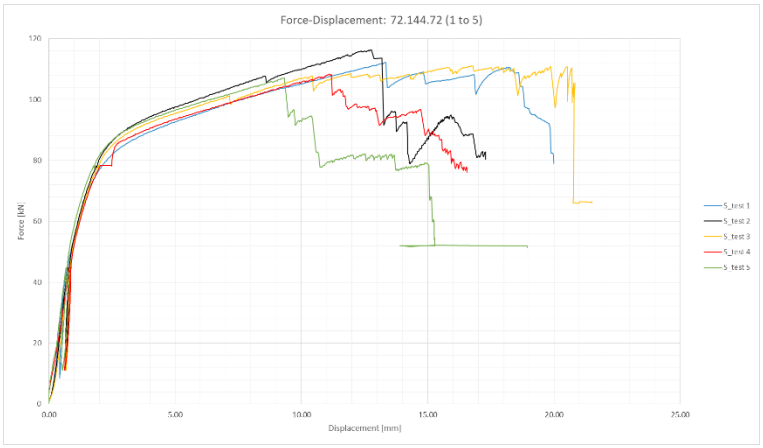
- This specimen had a relatively low deformation capacity.

9.6 Tests 72.144.72 (1 to 5) combined plots

Specifications:

Tests	72.144.72 (1 to 5)
Material thickness left:	72mm
Material thickness middle:	144mm
Material thickness right:	72mm
F_{est}	86.9kN





Notes:

- The expected capacity based on theoretical calculation formulas was 86.9 kN. The measured capacity was well above this value. This is consistent with findings for the other mode 3 variants (72.72 and 72.24.72). It is plausible that the embedment strength, with which the expected capacity was calculated, is too low. Since the embedment capacity is based on preliminary tests, wich all showed splitting behaviour at failure (a phenomenon that is largely prevented in an actual embedment test), the used value for the embedment strenght is most likely underestimated.

9.7 Tests 72.144.72 (1 to 5) Normal distribution

Measured test results

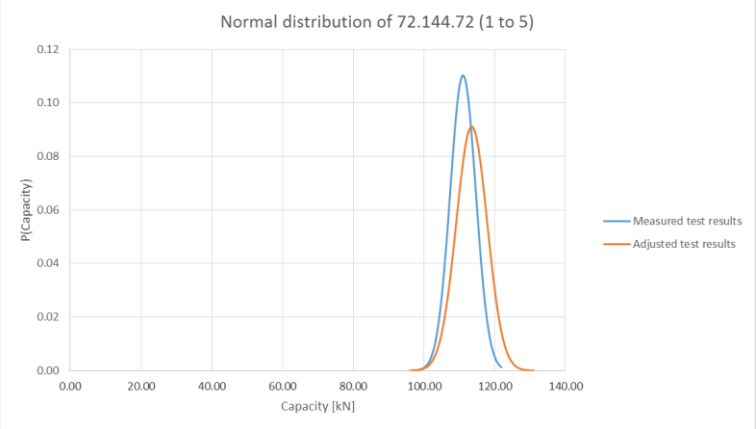
Faverage [kN]	S.Dev [kN]	COV	5-perc. [kN]
111.00	3.62	0.03	102.10

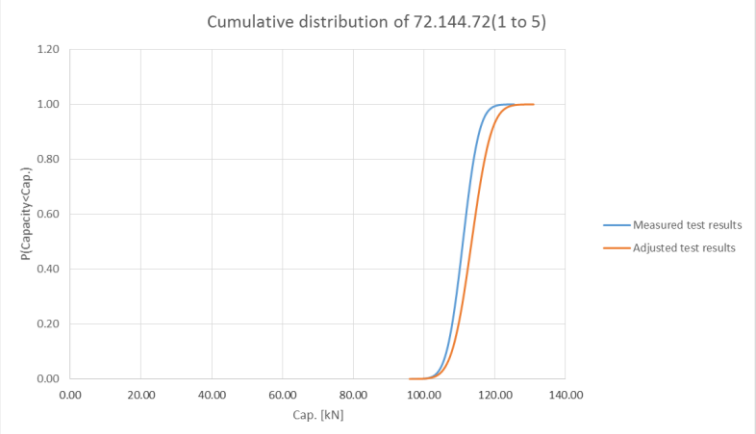
Adjusted test results

Faverage [kN]	S.Dev [kN]	COV	5-perc. [kN]
113.46	4.38	0.04	102.69

Specifications:

Tests	72.144.72 (1 to 5)
Material thickness left:	72mm
Material thickness middle:	144mm
Material thickness right:	72mm
F_{est}	86.9kN
$F_{average}/F_{est}$	1.3056





Notes:

- The resistance $F_{adjusted}$ given here is the average of the measured capacities that has been adjusted by use of the findings in 'Annex F – Probabilistic analysis of test data'. The formula found in this annex makes it possible to approximate the actual average capacity and standard deviation.
- The 5-percentile value is calculated by $x_k = \bar{x} \pm k_s * \sigma$ with $k_s = 2.46$.