Moisture monitoring in buildings in different micro-climate environments

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Content

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- How
- Monitoring examples
  - Model house made of TM wood in Mozirje
  - WWII partisan hospital Franja
  - Prešern house in Vrba
  - Hayrack in Koprivnik

Decay of wood in building applications

Wood + water = decay

- Fungi requires water for
  - Growth
  - Diffusion of enzymes and degraded products
  - Working of enzymes

Wood MC

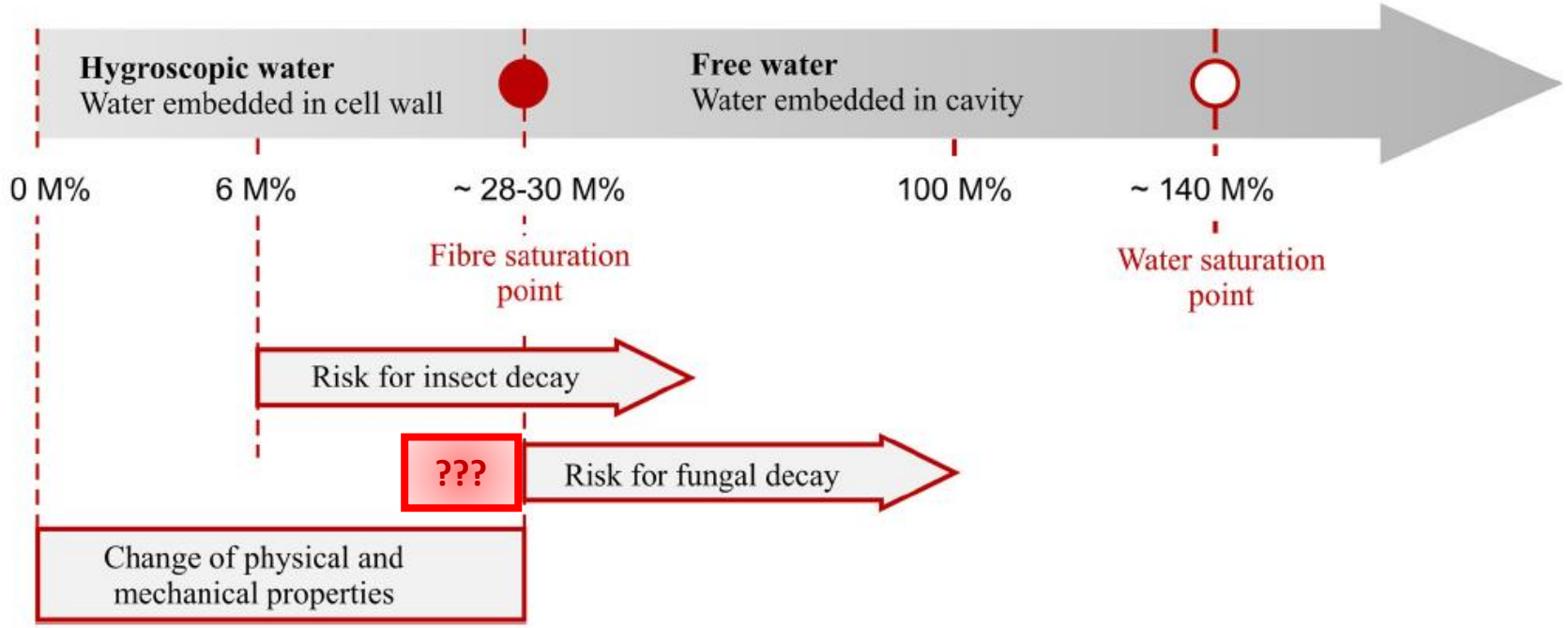


Fig. 1 Range of wood moisture content and influence on its properties and vulnerability

Optimal MC

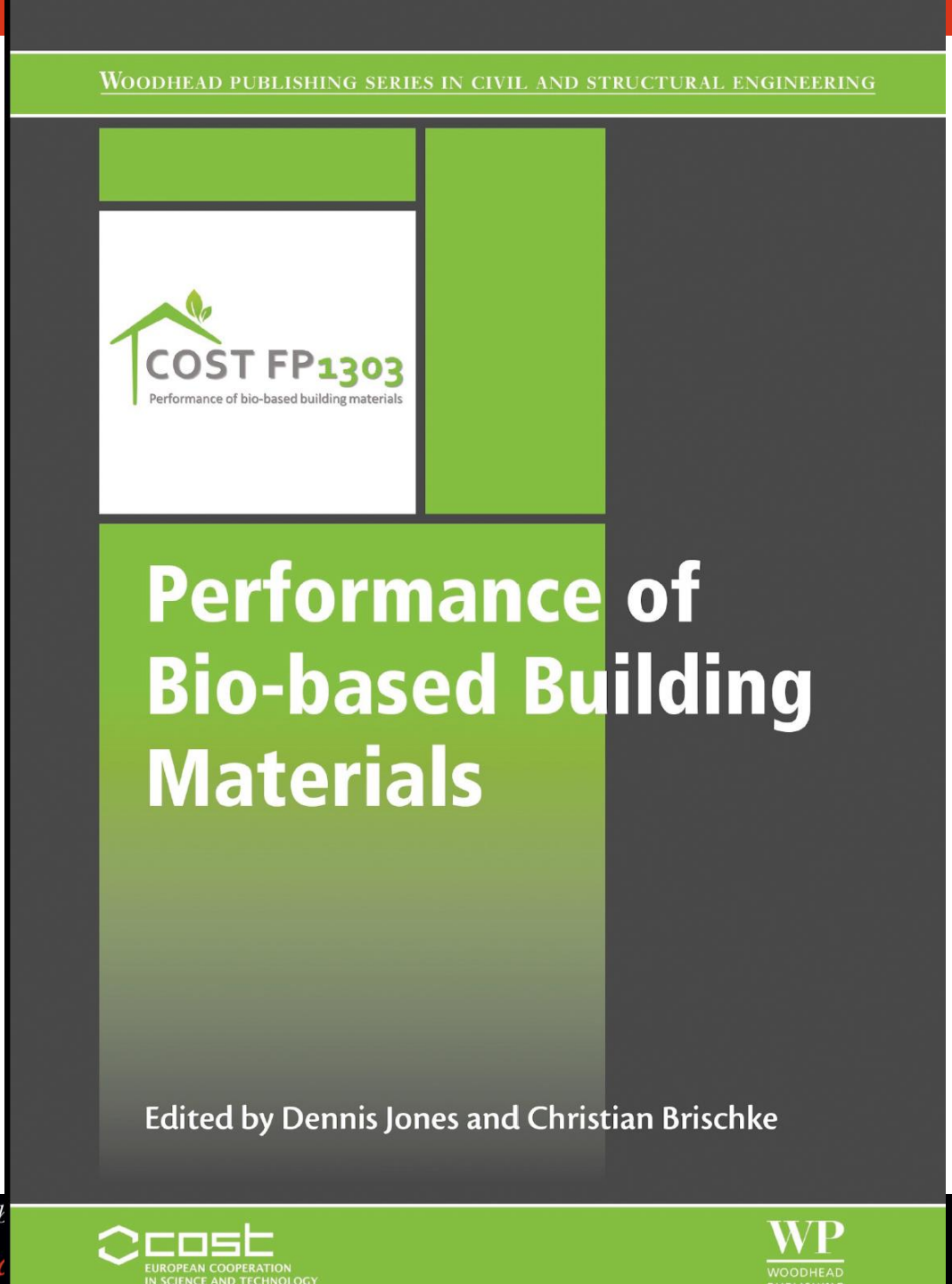
Fungus	Moisture content [%]			Source
	Min.	Opt.	Max.	
Coniophora puteana	21.5	36.4 – 210.0	> 200	Huckfeldt and Schmidt (2006)
	22.3 – 29.7	29.0 – 76.1	n.a.	Meyer and Brischke (2015)
	27.4	64.3	n.a.	Stienen et al. (2014)
Serpula lacrymans	26.2	45.0 – 208.0	> 200	Huckfeldt and Schmidt (2006)
Donkioporia expansa	27.0	34.4 – 126.0	> 200	Huckfeldt and Schmidt (2006)
	18.9 – 52.3	57.6 – 120.0	n.a.	Meyer and Brischke (2015)
	34.9	74.3	n.a.	Stienen et al. (2014)
Gloeophyllum trabeum	30.7	45.7 – 179.0	> 200	Huckfeldt and Schmidt (2006)
	16.3 – 37.1	47.3 – 172.8	n.a.	Meyer and Brischke (2015)
Trametes versicolor	14.6 – 42.2	46.6 – 113.1	n.a.	Meyer and Brischke (2015)

Brischke and Unger, 2017

Minimal MC?

Wood species	FSP[1]	Minimum MC with ML ≥2 %[2]			
		C. puteana	*T. versicolor*	*G. trabeum*	*D. expansa*
	[%]	[%]	[%]	[%]	[%]
Scots pine sapwood	34.6	28.5	21.4	16.3	18.9
Scots pine heartwood	27.2	24.1	30.3	37.1	n.a.
Spruce	30.3	25.9	28.4	26.4	21.6
Larch	34.5	26.1	31.0	31.1	49.6
Douglas fir	29.3	27.4	42.2	28.8	52.3
Beech	33.8	29.7	14.6	29.2	22.5
English oak	39.8	23.0	33.8	n.a.	32.2
Black locust	22.9	22.3	39.4	n.a.	n.a.

Meyer and Brischke, 2015



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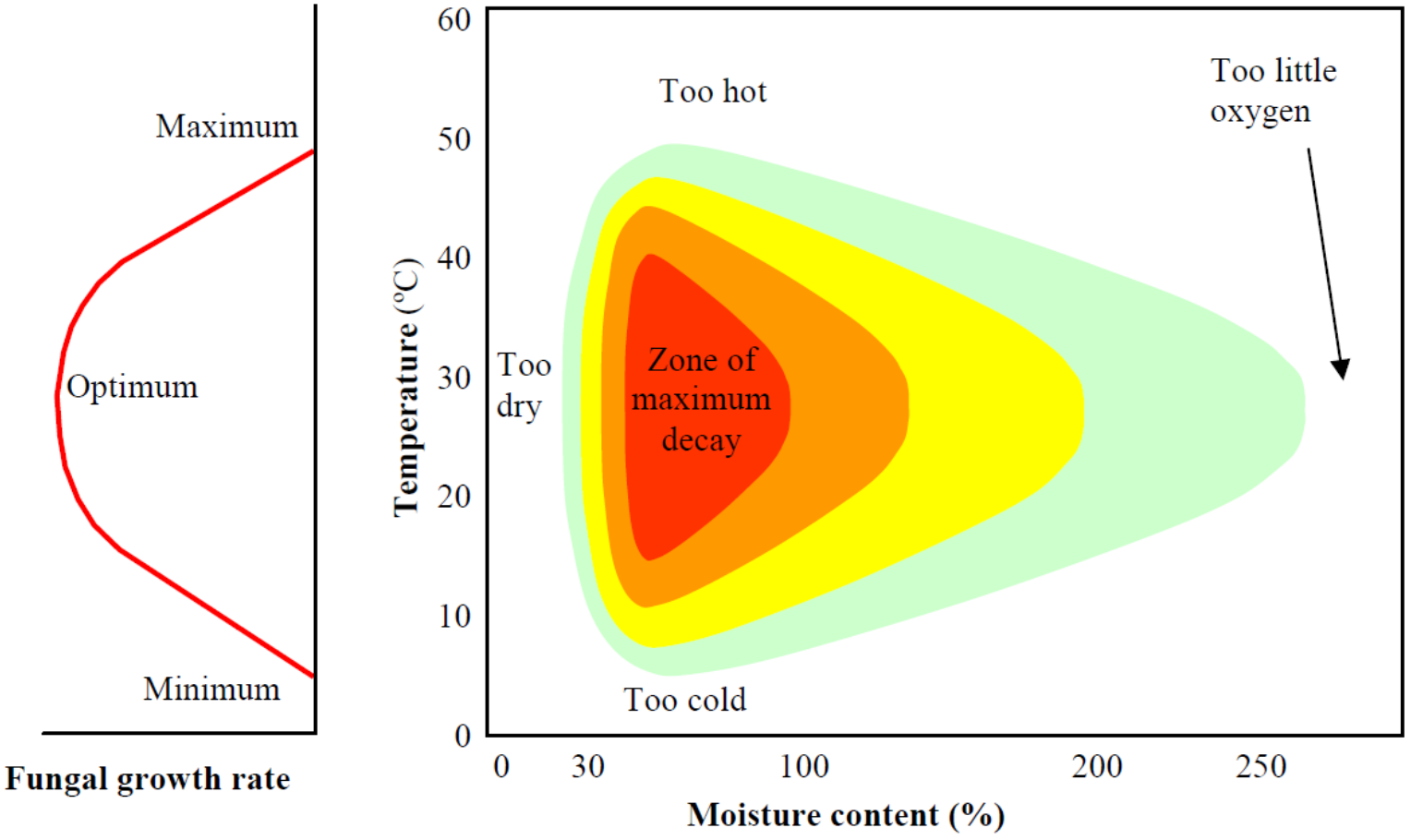
MC and temperature

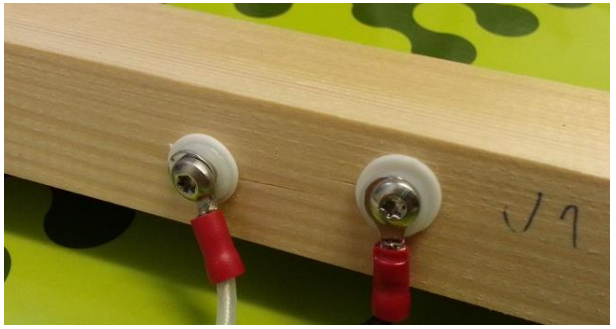


Aim

- To monitor the moisture performance of the building materilas in real applications
- To determine material climate in real applications
- To link the material climate and development of decay

Technical equipment

- Scanntronik equipment
  - Gigamodule – MC
  - RH and temperature sensors
  - Themofox – data logger



Monitored objects

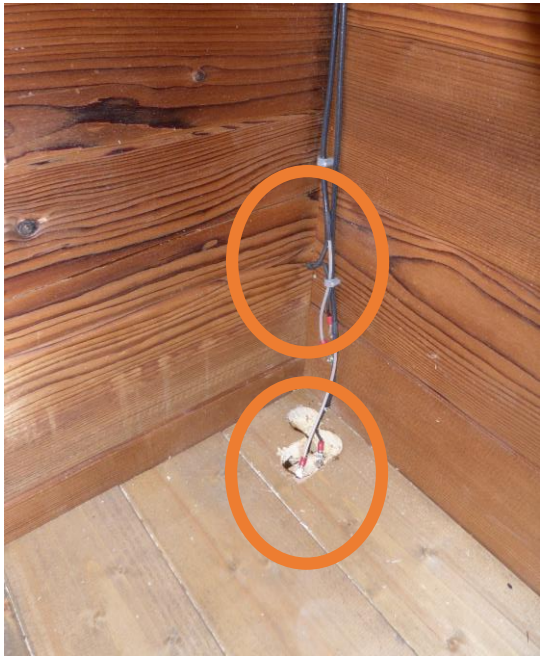
Monitored objects

A. Mozirje

- House located in the park
- Made of TM modified spruce wood (Silvapro, Silvaprodukt)
- Finished in 2009
- Monitoring: March 2015
- 8 MC measurements

Measurements locations

M1	TM spruce	Outside wall, close to the ground.	**3.1**
M2	TM spruce	Rafter, inside.	**1**
M3	TM spruce	Outside wall, 1.5 m above ground.	**2**
M4	Spruce	Lath, close to rafter, inside.	**1**
M5	TM spruce	Rafter, outside.	**2**
M6	TM spruce	Beam inside.	**1**
M7	TM spruce	Beam outside.	**2**
M8	Spruce	Support beam for flooring.	**2**



B. Partisan hospital Franja

- House located in the gorge
- Made of „copper“ treated spruce wood (Silvanolin, Silvaprodukt)
- Finished in 2010
- Monitoring: sept 2014
- 8 MC measurements

Partisan hospital Franja

Catastrophic flood in 2007

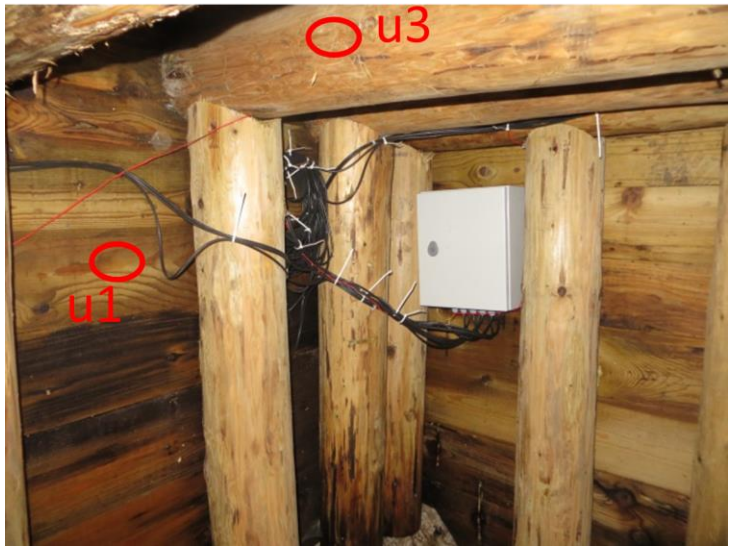
Renovation 2010

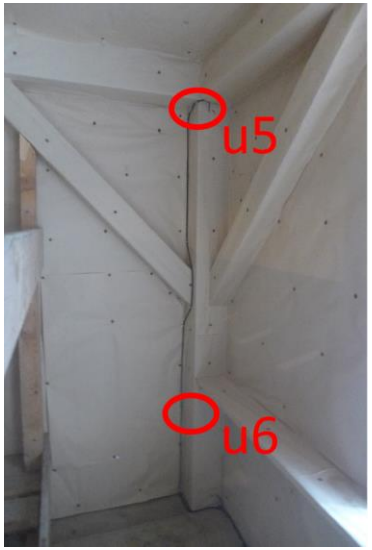
Renovation 2010

Material climate monitoring

F1	Cu-EA spruce	Cellar. Plank is covered with soil from one side.	4
F2	Cu-EA spruce	Cellar. Wood plank; part of the ceiling/floor.	4
F3	Cu-EA spruce	Cellar. Beam; part of the ceiling.	4
F4	Cu-EA spruce	Cellar. Wood plank can be dried from both sides.	4
F5	Cu-EA spruce	Pillar on 1st floor. 1.8 m above the floor. Indoor.	1
F6	Cu-EA spruce	Pillar on 1st floor. 0.5 m above the floor. Indoor.	1
F7	Cu-EA spruce	Façade, corner, 1.8 m above ground.	3.1
F8	Cu-EA spruce	Above the door, part of façade.	3.2

Material climate monitoring





RH measurements

C. Pokljuka - Koprivnik

- Hayrack
- Object located in the Alpine plateau Pokljuka 1000 m
- Made of spruce and larch wood
- Approximately 100 years old
- Monitoring: April 2016
- 8 MC measurements

Material climate monitoring

P1	Larch	Pillar, close to the ground, 2 cm deep.	3.1
P2	Larch	Pillar, close to the ground, 6 cm deep.	3.1
P3	Larch	Pillar, 1.5 m above ground, 2 cm deep.	2
P4	Larch	Pillar, 1.5 m above ground, 6 cm deep.	2
P5	Larch	Pillar, 4 m above ground, 2 cm deep.	2
P6	Larch	Pillar, 4 m above ground, 6 cm deep.	2
P7	Spruce	Rafter.	2
P8	Spruce	Beam.	2

RH measurements

D. Prešeren house in Vrba

- Object located in village
- Construction in house made of spruce wood
- Approximately 500 years old, renovated in 1923
- Monitoring: Nov 2015
- 10 MC measurements
  - Attic (8#)
  - Cellar (2#)

Vrba

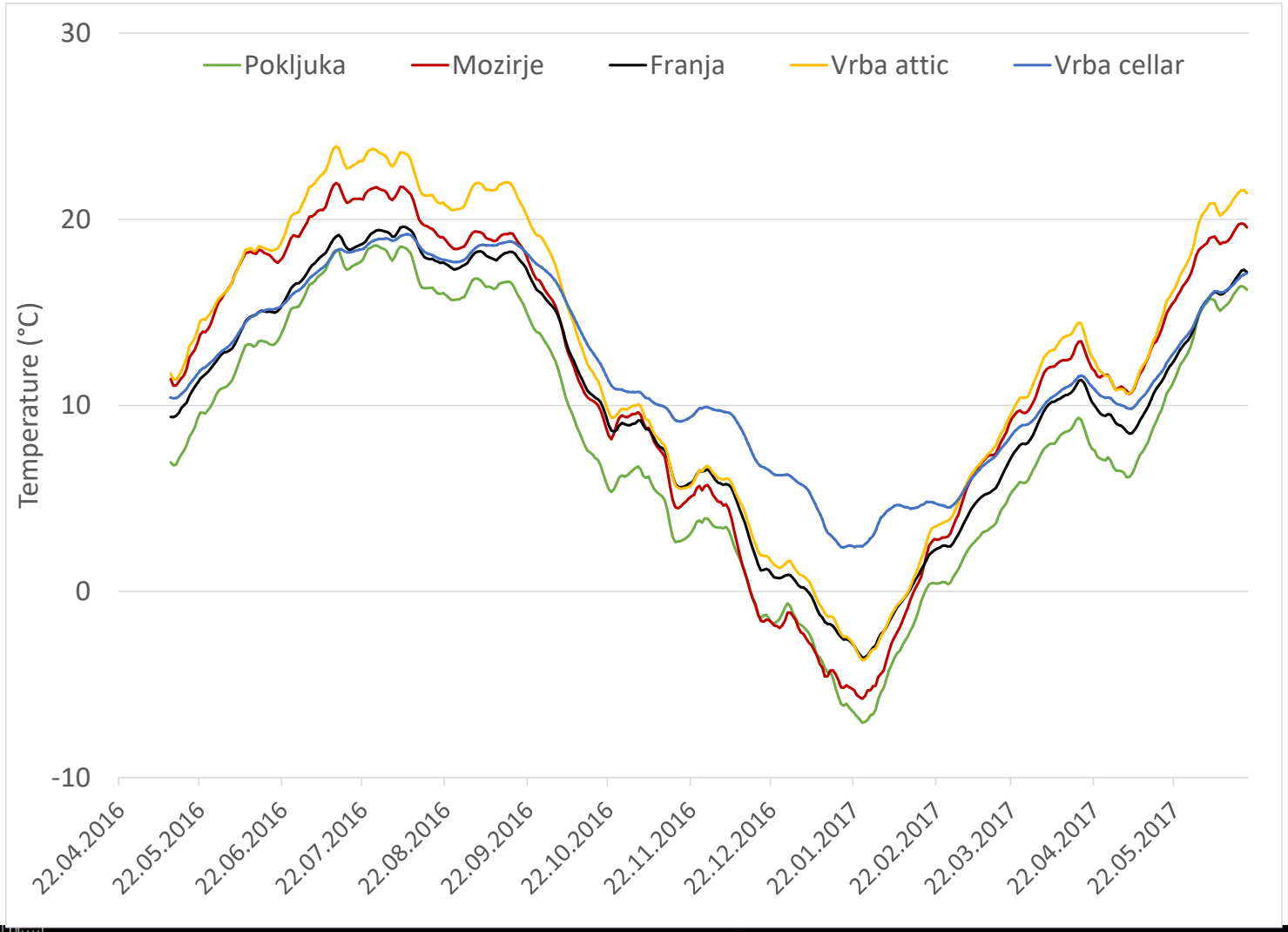
Material climate monitoring

Vrba - attic	V1	Spruce	Plank, vertical part of the façade.	3.1
	V2	Spruce	Plank, above main entrance.	2
	V3	Spruce	Beam above entrance.	1
	V4	Spruce	Rafter 1.	1
	V5	Spruce	Rafter at the end of the house.	1
	V6	Spruce	Rafter 2.	1
	V7	Spruce	Rafter 3.	1
	V8	Spruce	Rafter 4.	1
Vrba - cellar	C1	Spruce	Regal close to the floor.	2
	C2	Spruce	Regal 1.5 m above ground.	1

Results

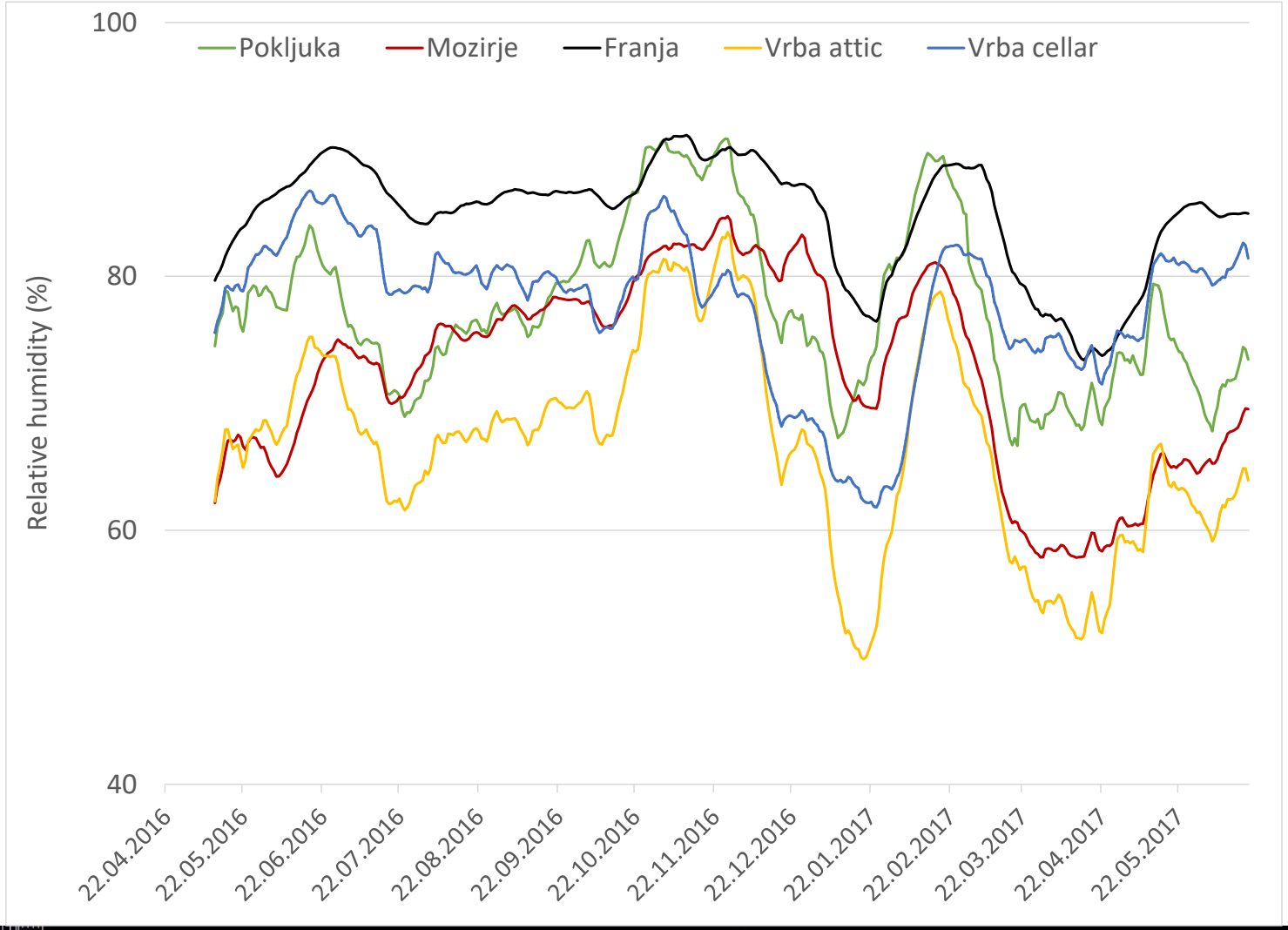
Temperature

(moving average) April 2016 – June 2017

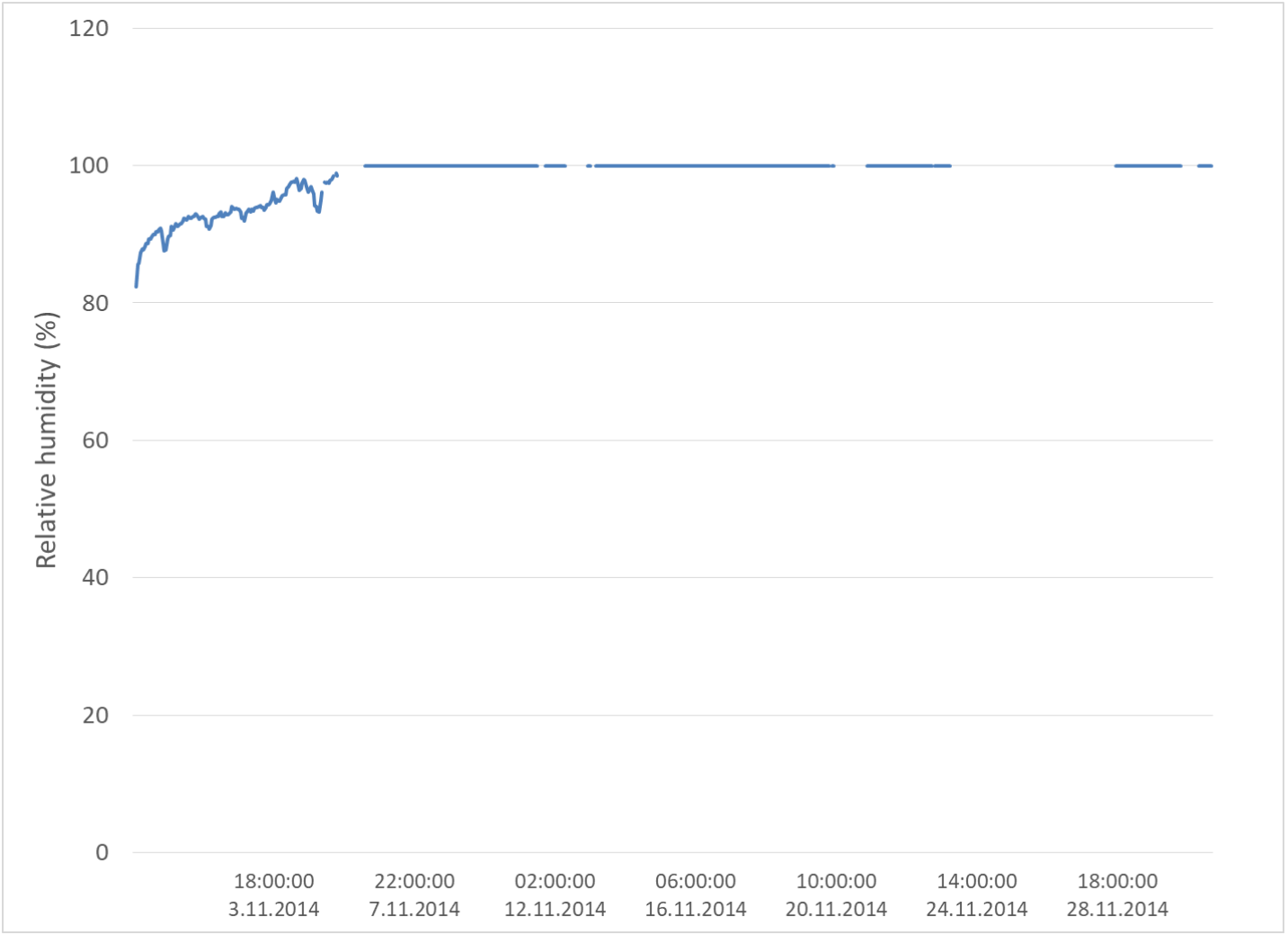


RH

(moving average) April 2016 – June 2017



RH in Franja cellar



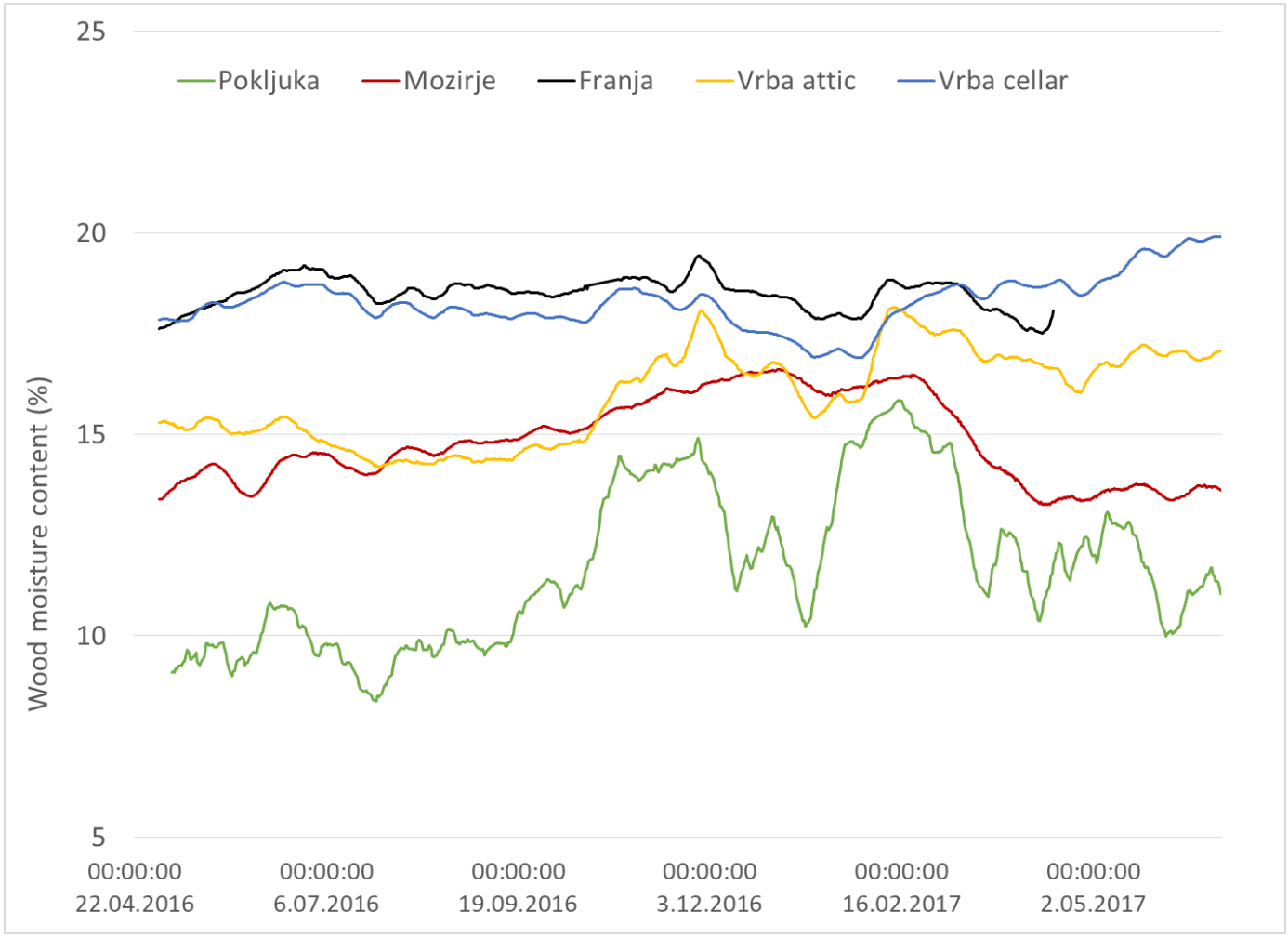
RH and temp - Summary

April 2016 – June 2017

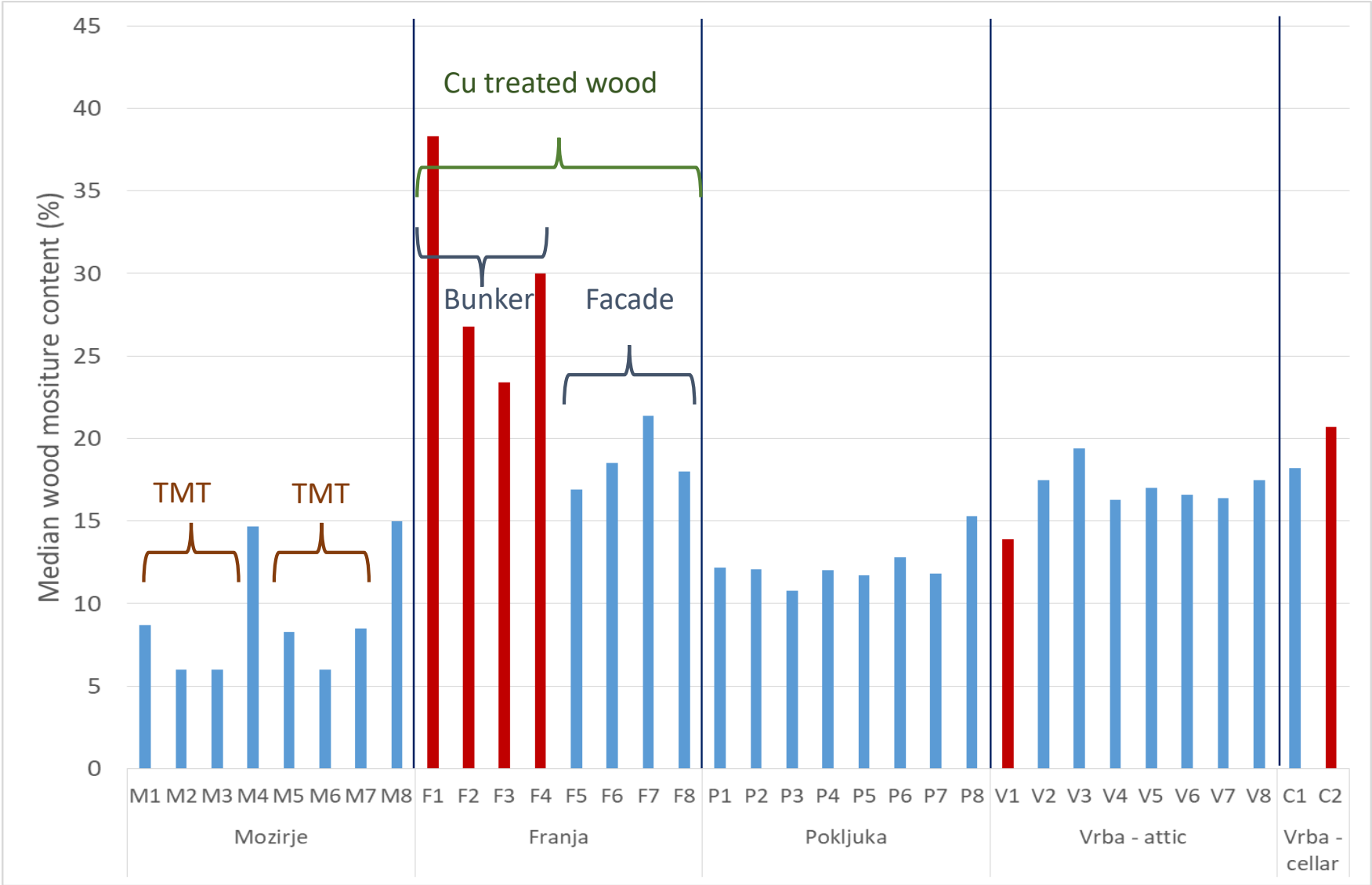
	Mozirje		Franja		Pokljuka		Vrba - attic		Vrba - cellar	
	T (°C)	RH (%)	T (°C)	RH (%)	T (°C)	RH (%)	T (°C)	RH (%)	T (°C)	RH (%)
Average	11.2	72.1	10.2	84.7	8.2	77.4	12.5	66.4	11.8	77.7
Min	-15.5	32.6	-8.9	44.3	-15.4	10.0	-11.9	8.9	-4.7	39.4
Max	34.7	95.7	23.2	96.5	28.5	98.5	34.8	98.5	22.7	96.8
Percentage of meas whit temp. above 20°C	**18%**		**5%**		**8%**		**22%**		**2%**	
Percentage of meas. whit temp. between 20°C and 30°C	**37%**		**30%**		**8%**		**40%**		**33%**	
Percentage of meas. whit the RH above 80%		**24%**		**84%**		**55%**		**16%**		**51%**

MC of wood (UC 1)

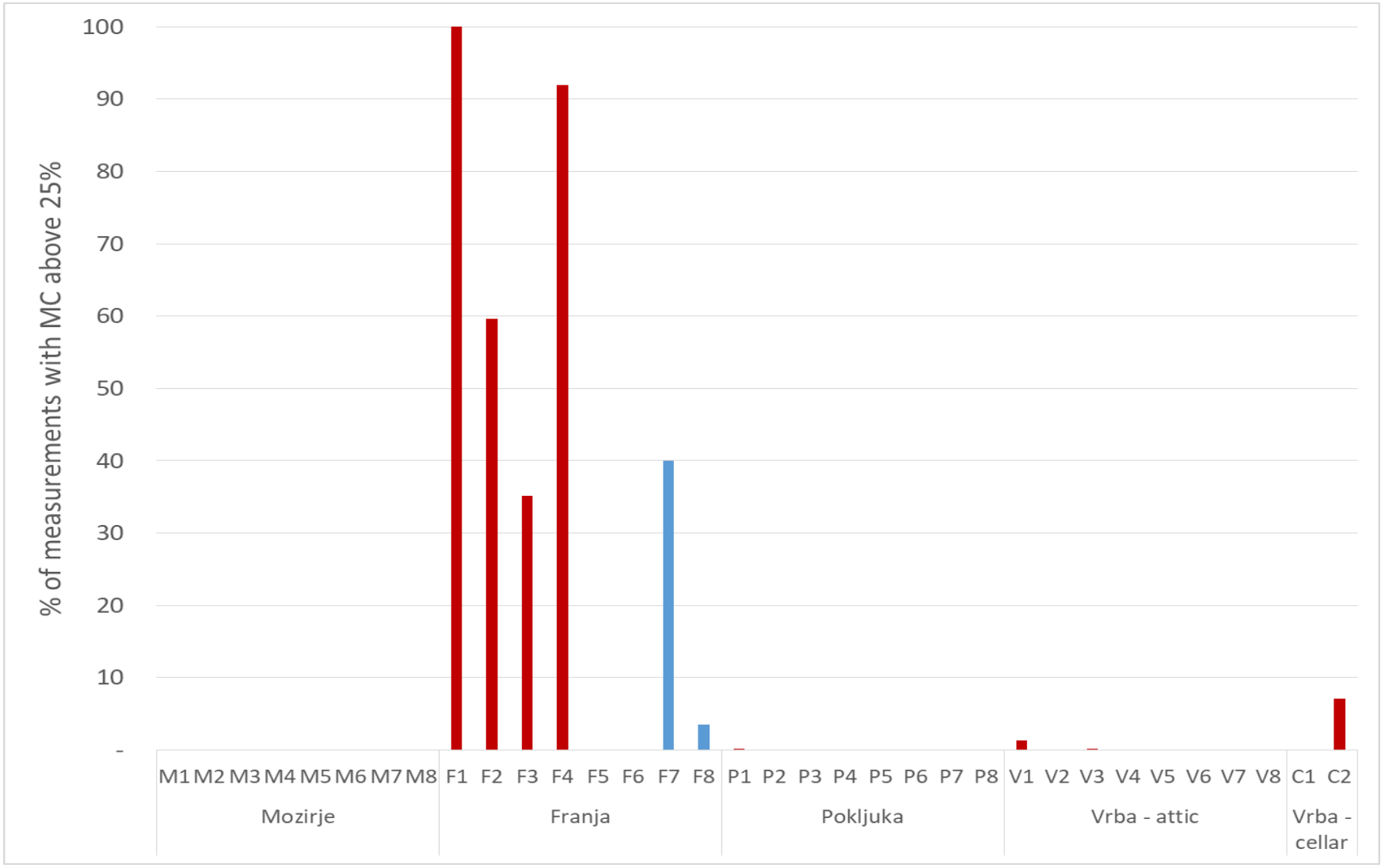
(moving average) April 2016 – June 2017



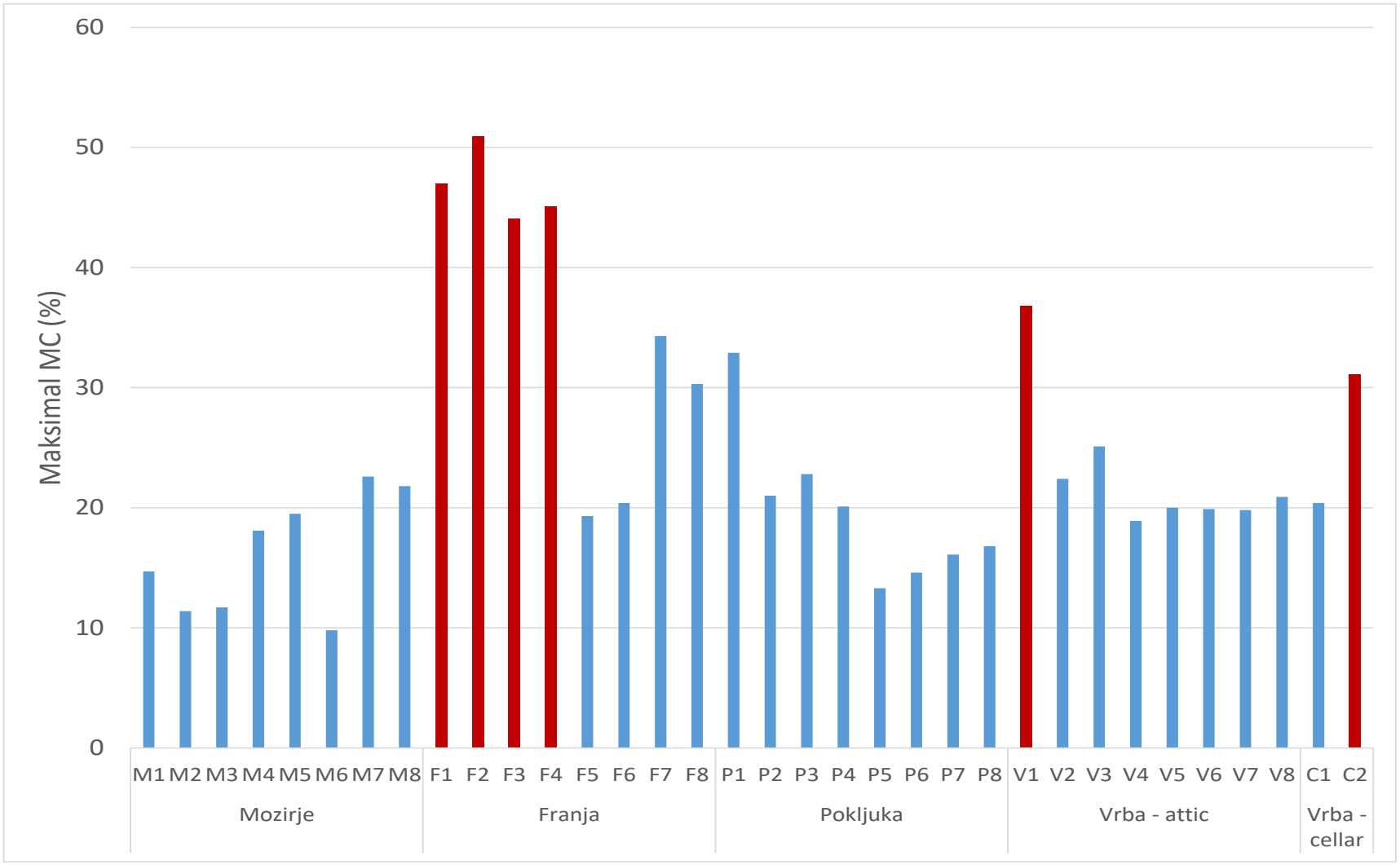
Median MC


Median wood mositure content (%)
45
40
35
30
25
20
15
10
5
0
Cu treated wood
Bunker
Facade
TMT
TMT
M1 M2 M3 M4 M5 M6 M7 M8 F1 F2 F3 F4 F5 F6 F7 F8 P1 P2 P3 P4 P5 P6 P7 P8 V1 V2 V3 V4 V5 V6 V7 V8 C1 C2
Mozirje
Franja
Pokljuka
Vrba - attic
Vrba - cellar

% of days with MC above 25%



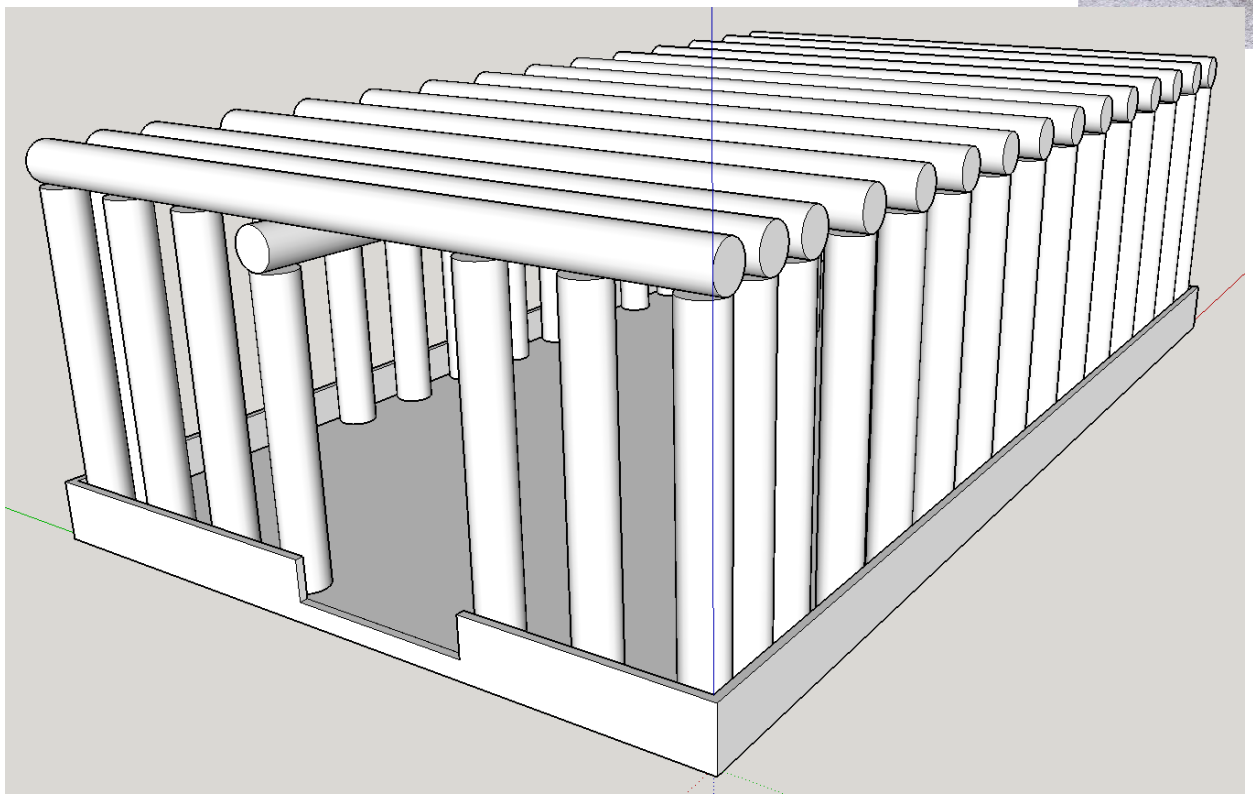
Maximal MC


Maksimal MC (%)
60
50
40
30
20
10
0
M1 M2 M3 M4 M5 M6 M7 M8
F1 F2 F3 F4 F5 F6 F7 F8
P1 P2 P3 P4 P5 P6 P7 P8
V1 V2 V3 V4 V5 V6 V7 V8
C1 C2
Mozirje
Franja
Pokljuka
Vrba - attic
Vrba - cellar

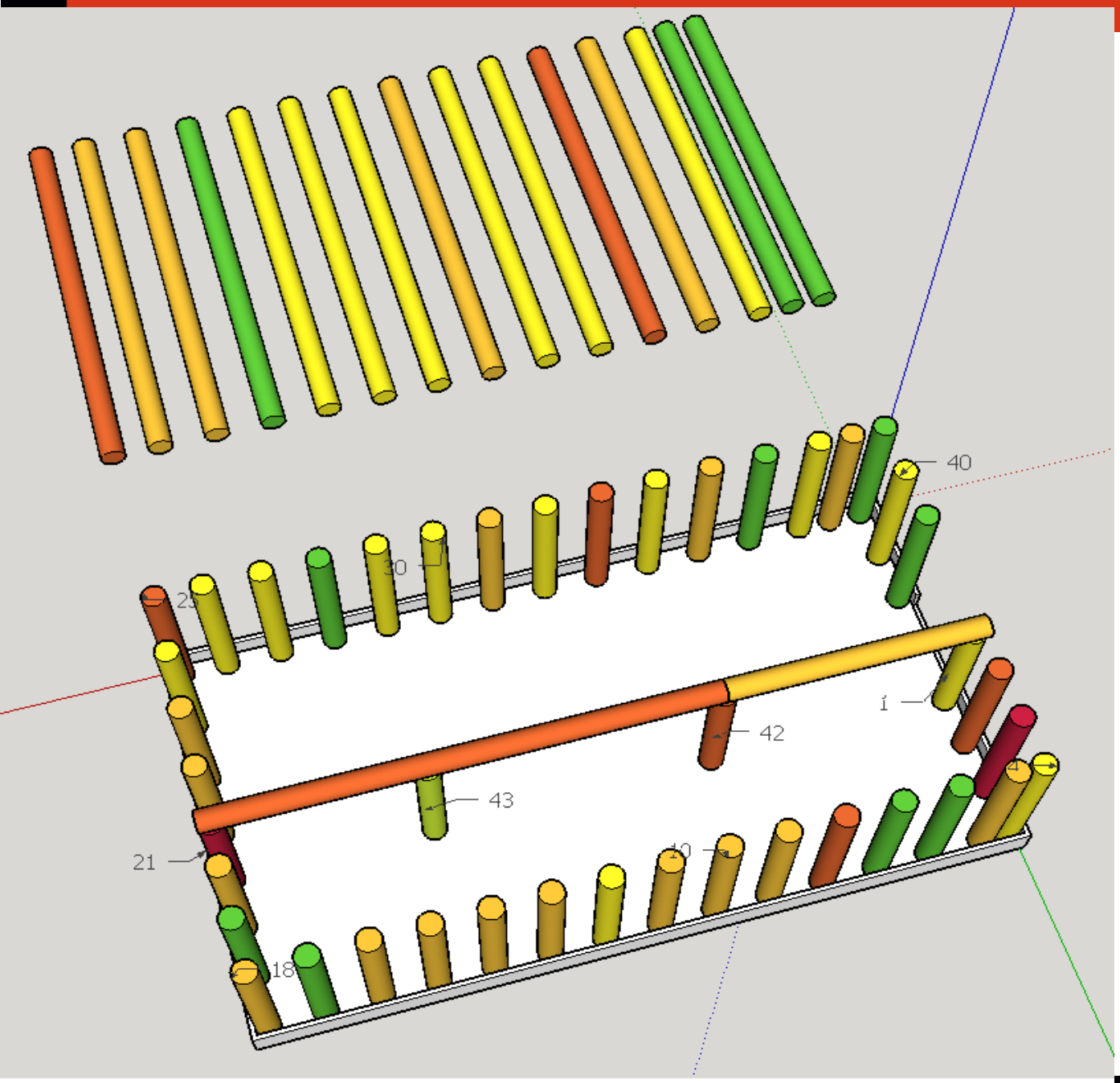
Case study in Franja

Severe decay

Bunker



Resistograph measuremnts



% of the degraded crossection

1	0 - 10 %
2	11 - 30 %
3	31 - 60 %
4	61 - 80 %
5	81 - 100 %

Conclusions

- Moisture monitoring is a very useful method which enables evaluation of micro-climate conditions in monitored buildings.
- There were quite significant variations between different micro-climates and material climates determined in rather short distance.
- It should be considered, that only one location of moisture monitoring is not sufficient for overall assessment of the building.
- In order to obtain even more reliable data, monitoring at the respective objects will be continued.

Other monitored objects

Acknowledgment

- Slovenian Research Agency (P4-0015, L4-5517, L4-7547)

- Tigr4SMART

TIGR4smart

- IQ DOM