

# VALJALA PÜHA MARTINI KIRIK

## Seinte niiskusemõõtmised aastatel 2012-2019, kiriku sisekliima ja seinte sooldumine



Põhiline ehitusmaterjal: Kaarma dolokivi ja kohalik lubjakivi (Valjala dolokivi).

### Kiriku probleemid

Seinad märjad, ebasobiv sisekliima, ulatuslikud biokahjustused, külmakahjustused, ehitise konstruktsiooni deformatsioonid:



vetikad, külmakahjustus, majavamm



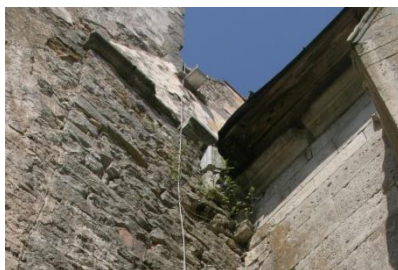
vetikad kondensvee niredel



vetikas horisontaalsetel pindadel  
(toitained tolmust?)



Vee-, jää- ja lumekahjustused



ebaõnnestunud vihmaveesüsteem,  
taimed kasvavad seinapragudes



sõnajalad ja sammal



„kunstilised kahjustused“ – põhjus külmumine ja sooldumine



võlvide vajumine, seinad ülevalt  
väljapoole kaldu



allakukkunud võlviroided



kondensvesi (7.07.2012)



seinamaalingute hävimine



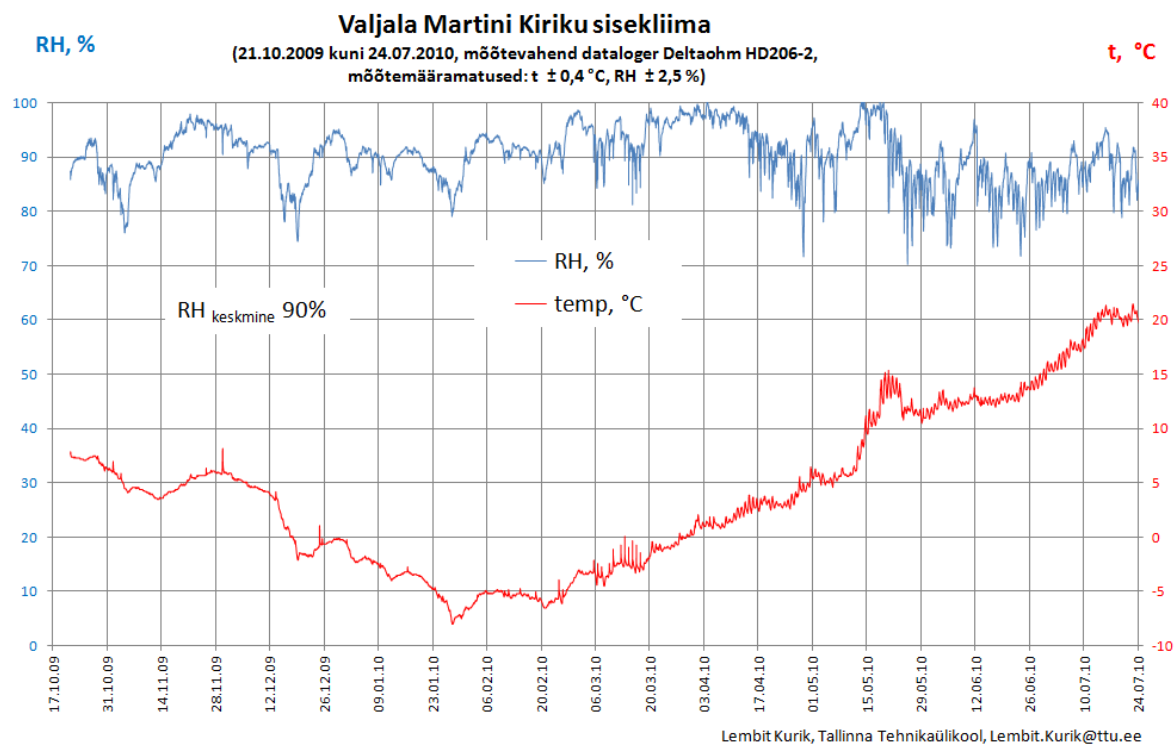
lagunenud krohv ja vuugid -väga  
lühike räästas, vihmaveesüsteemi  
puudumine



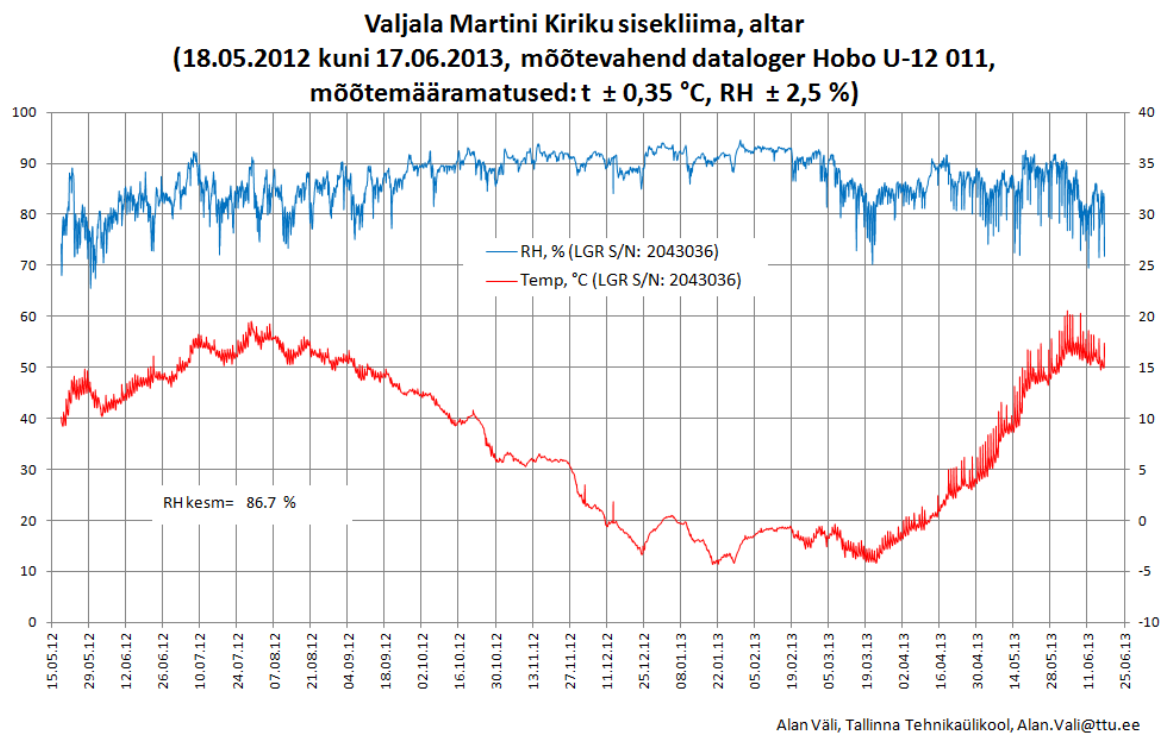
seina lagunemine suure veekoormuse  
tõttu

Töenäoliselt üks Eesti vanimaid ehitisi on väga halvas olukorras ja vajaks investeeringuid vältimaks kiriku aeglast kuid pidevat hävimist.

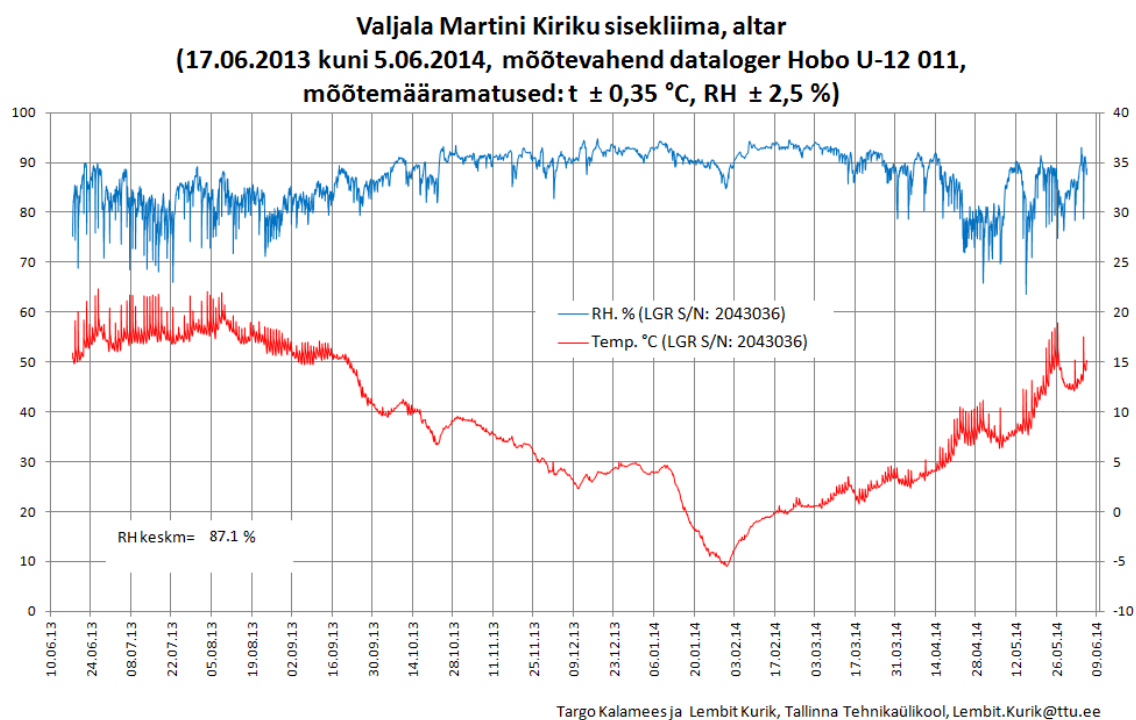
## Kiriku sisekliima



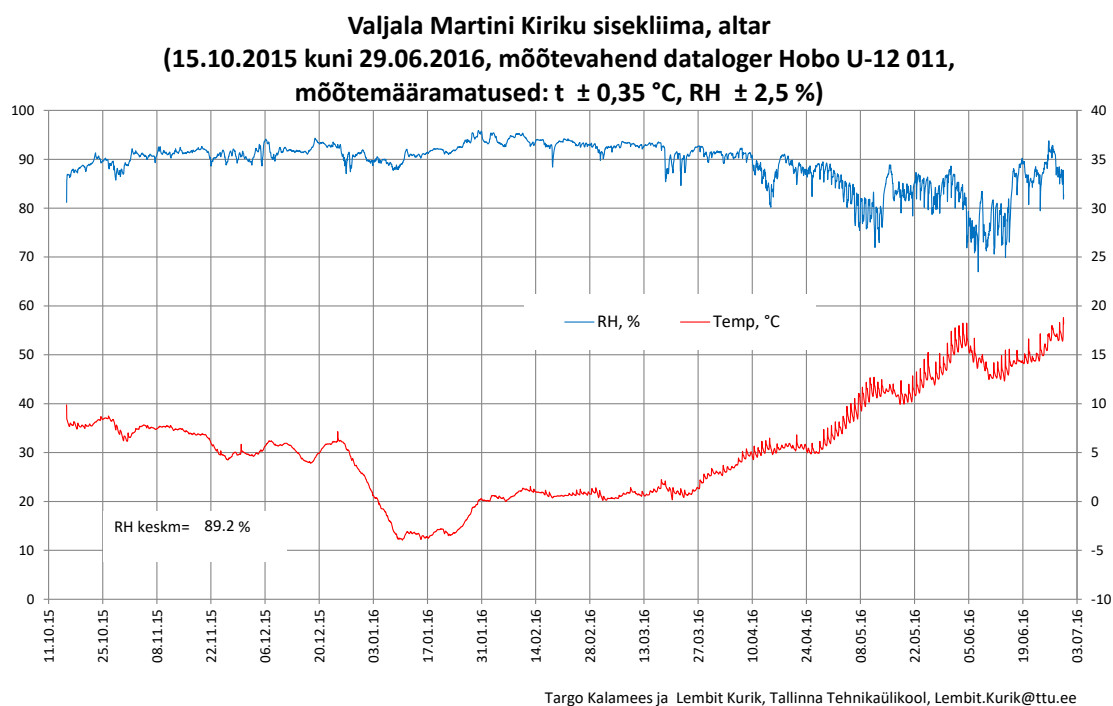
Sisekliima mõõtetulemused 2009/2010 (Pühakodade projekt, Rändmeister)



## Sisekliima mõõtetulemused 2012-2013 (SMC projekt)

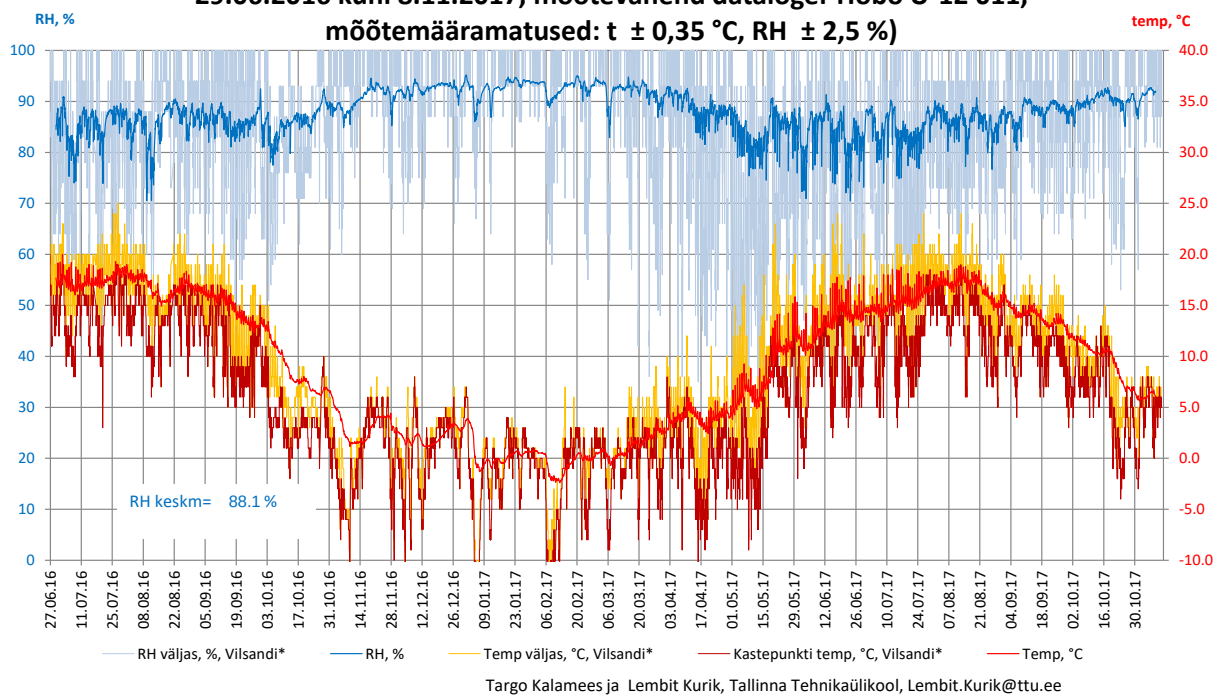


## Sisekliima mõõtmistulemused 2013-2014



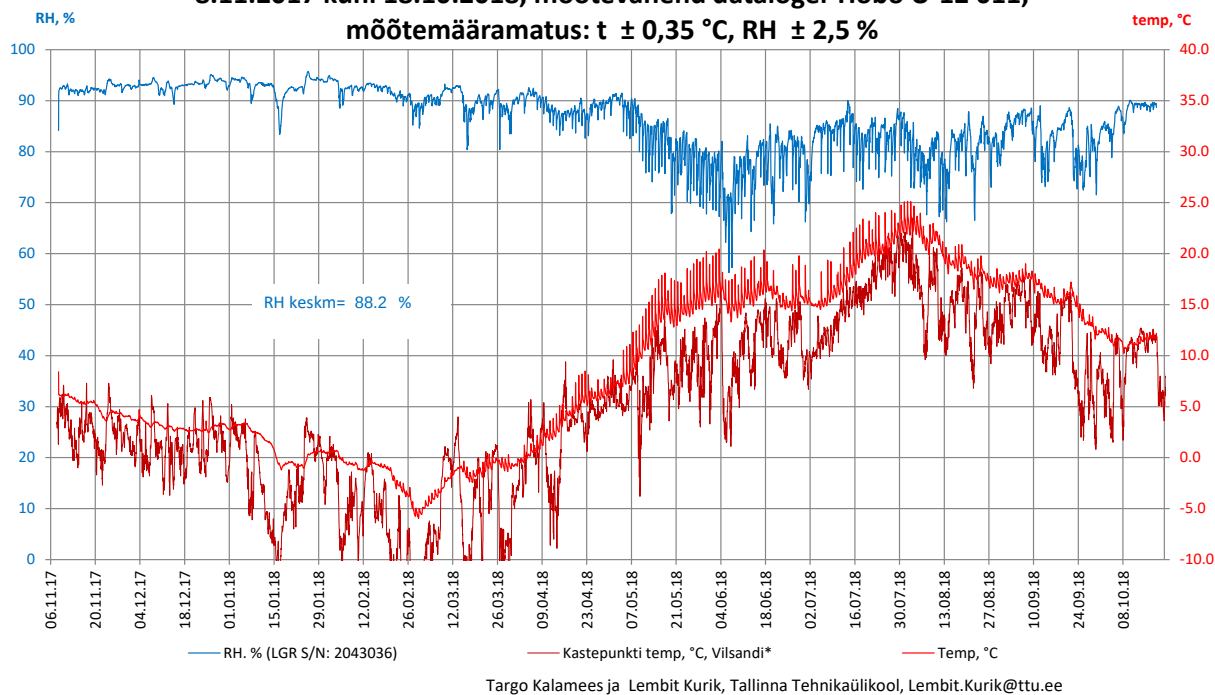
## Sisekliima mõõtmistulemused 2015-2016

**Valjala Martini Kiriku sisekliima, altar,  
29.06.2016 kuni 8.11.2017, mõõtevahend dataloger Hobo U-12 011,  
mõõtemääramatused:  $t \pm 0,35\text{ }^{\circ}\text{C}$ ,  $\text{RH} \pm 2,5\text{ }\%$**



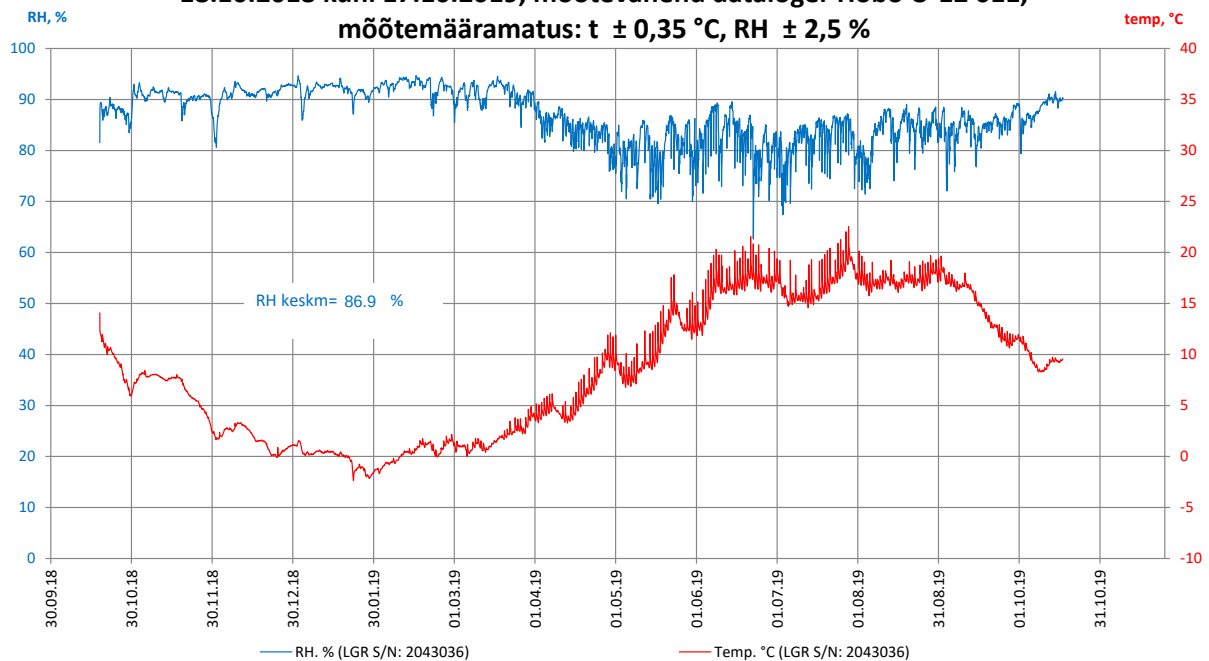
**Sisekliima mõõtmistulemused 2016-2017**

**Valjala Martini Kiriku sisekliima, altar,  
8.11.2017 kuni 18.10.2018, mõõtevahend dataloger Hobo U-12 011,  
mõõtemääramatus:  $t \pm 0,35\text{ }^{\circ}\text{C}$ ,  $\text{RH} \pm 2,5\text{ }\%$**



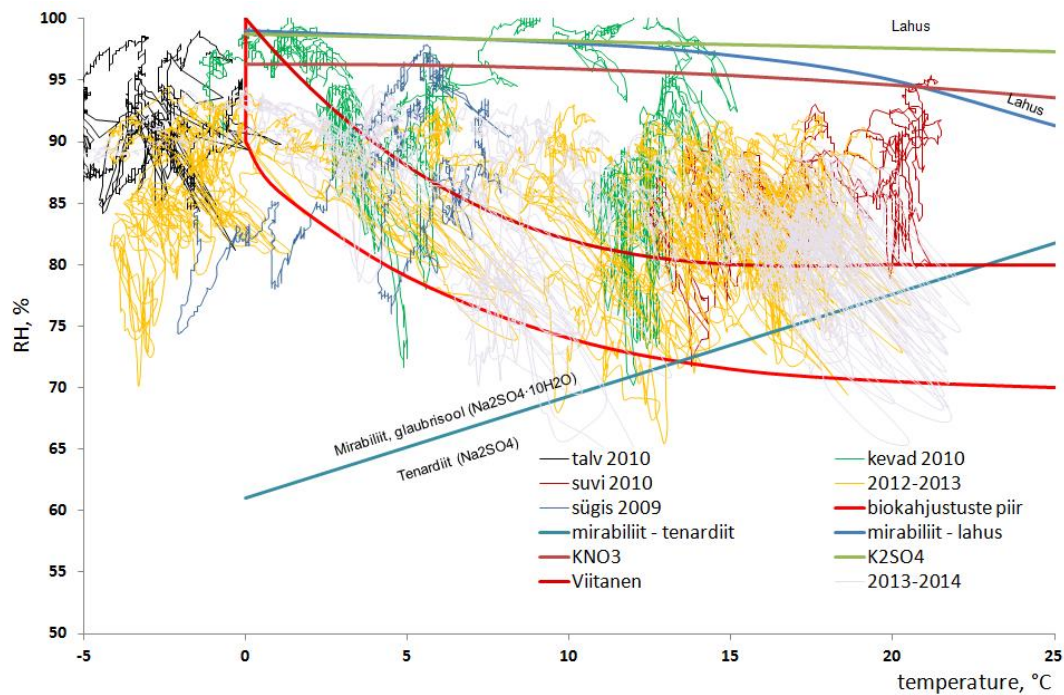
**Sisekliima mõõtmistulemused 2017-2018**

**Valjala Martini Kiriku sisekliima, altar,  
18.10.2018 kuni 17.10.2019, mõõtevahend dataloger Hobo U-12 011,  
mõõtemääramatus:  $t \pm 0,35\text{ }^{\circ}\text{C}$ ,  $\text{RH} \pm 2,5\text{ } \%$**



Targo Kalamees ja Lembit Kurik, Tallinna Tehnikaülikool, Lembit.Kurik@ttu.ee

**Sisekliima mõõtmistulemused 2018-2019**



**Sisekliima mõõtmistulemused esitatud temperatuur – suhteline õhuniiskus teljestikus.**

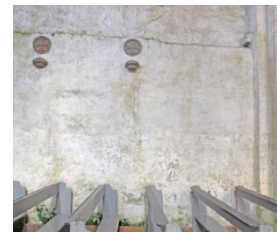
Tüüpiliselt kõigile Saaremaa kütmata kirikutele on suhteline õhuniiskus kirikus läbi terve aasta väga kõrge (ligi 90 %), mis loob soodsad tingimused vetikate, hallituse, seente ja bakterite arenguks. Talvel langeb sisetemperatuur pikaks ajaks nullist allapoole, mille tulemusel väga niisketes seintes tekivad külmakahjustused.

## Seinte niiskustumõõtmised

Mõõtmiste teostamise ajad: 07.07.2012, 12.06.2013 (SMC project 2012-2013), 08.08.2014, 29.06.2016, 3.07.2017, 13.09.2017, 8.11.2017, 6.04.2018, 10.07.2018, 18.10.2018, 10.08.2019 ja 17.10.2019..

sensor: Moist P mõõtesügavusega kuni 30 cm.

Pikihoone põhjasein keskmises ja läänepoolses löövis:



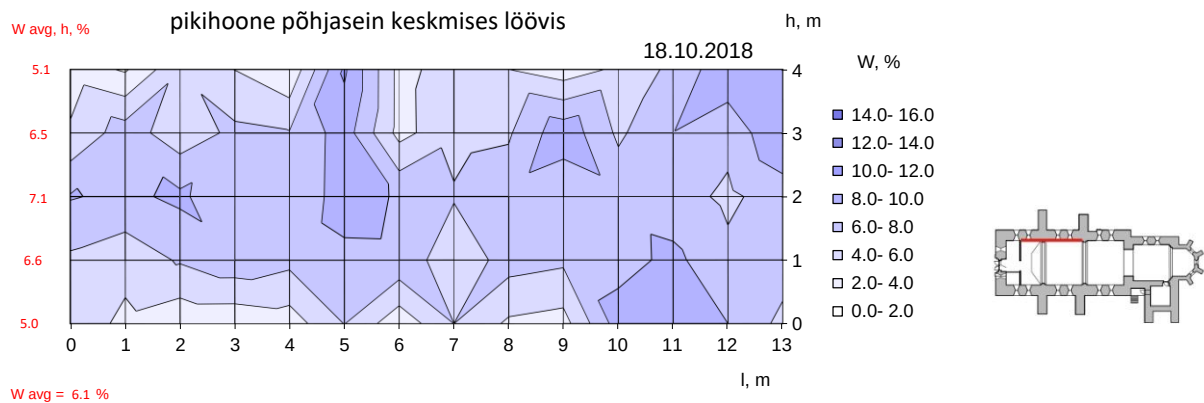
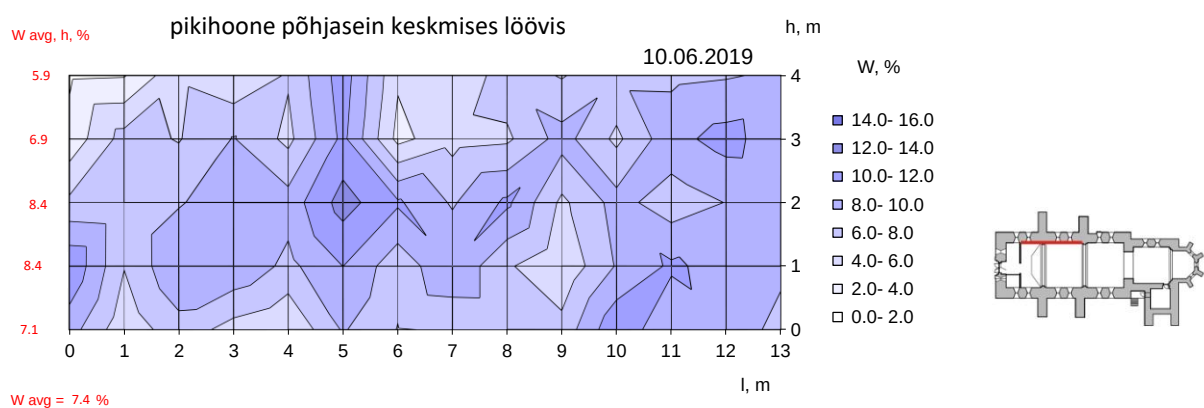
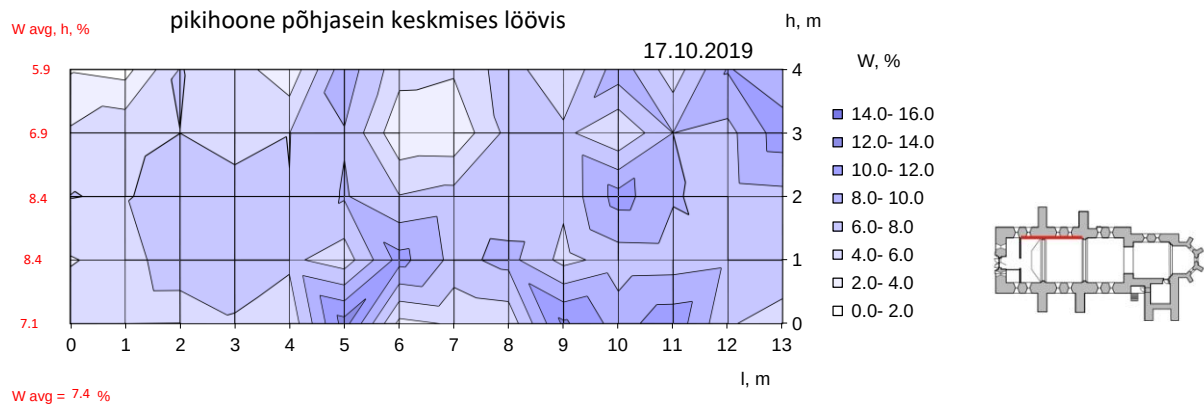
Fotod seina siseküljest

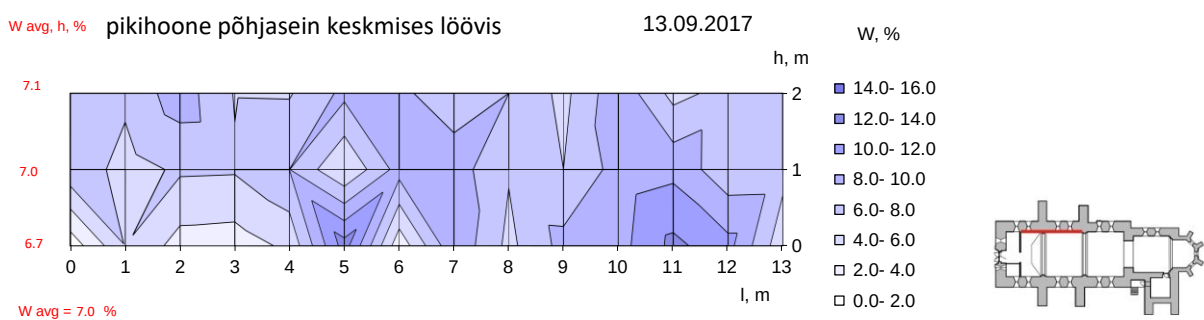
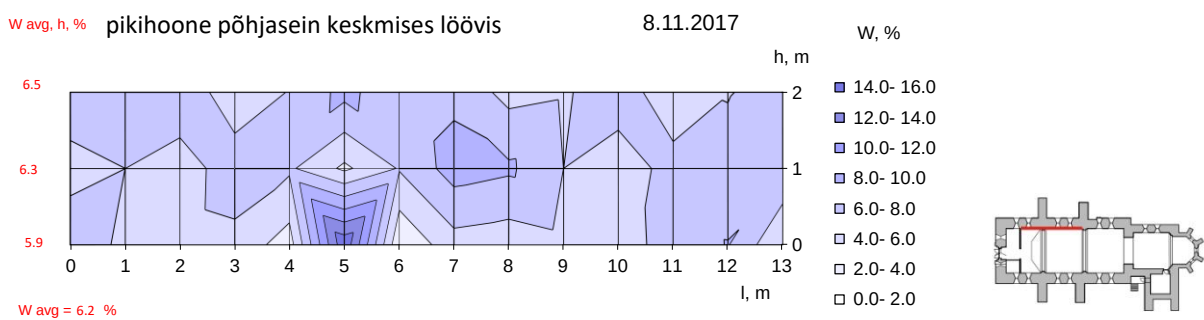
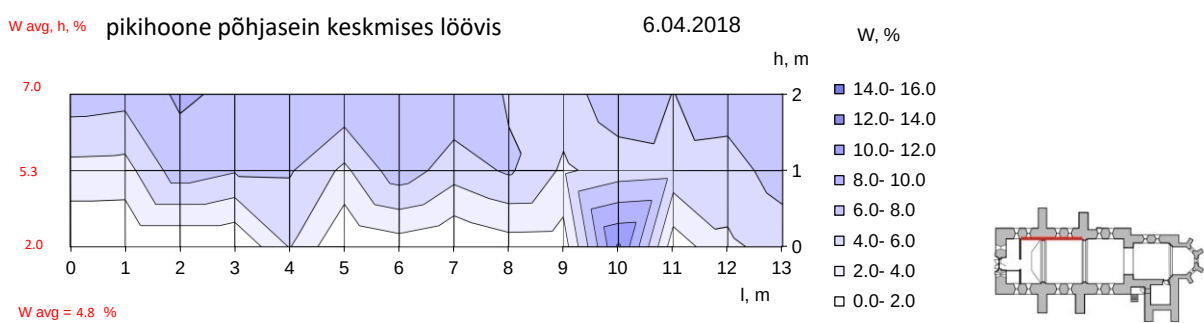
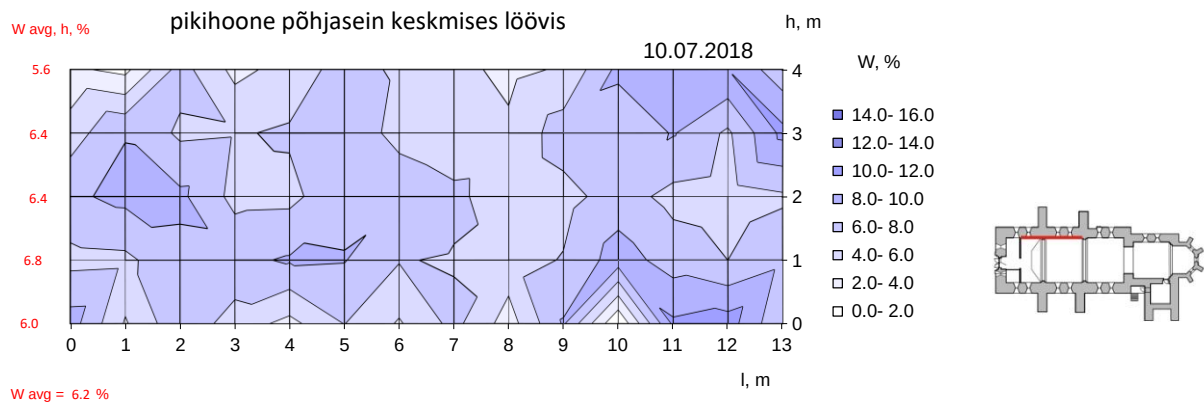


Rohelise vetika punktikujulised kolooniad



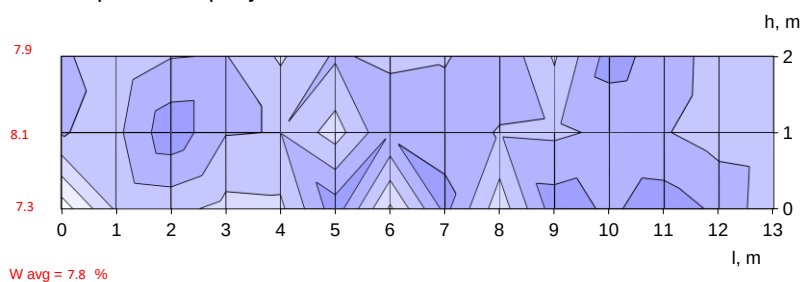
Seina välisvaade



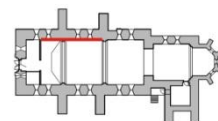
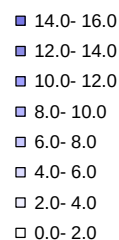


W avg, h, % pikihoone põhjasein keskmises lõõvis

3.07.2017

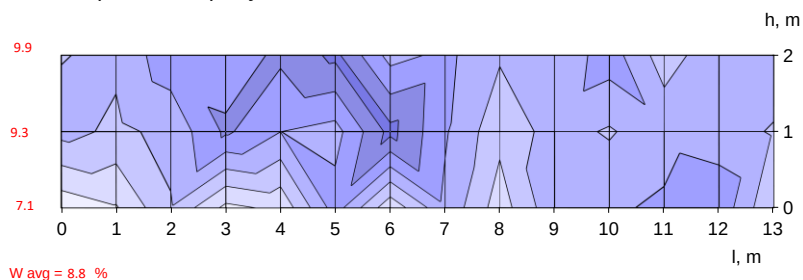


W, %

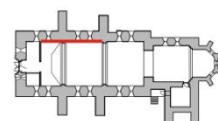
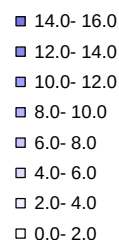


W avg, h, % pikihoone põhjasein keskmises lõõvis

29.06.2016

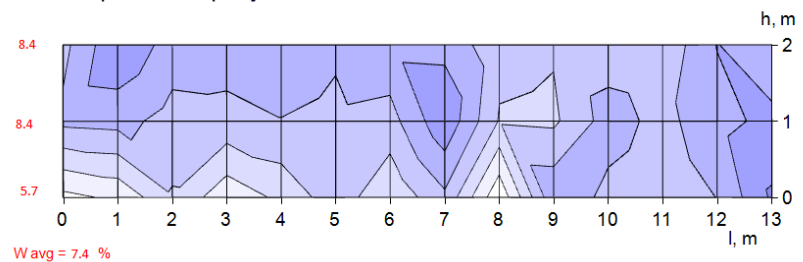


W, %

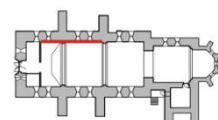
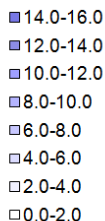


W avg, h, % pikihoone põhjasein keskmises lõõvis

8.08.2014

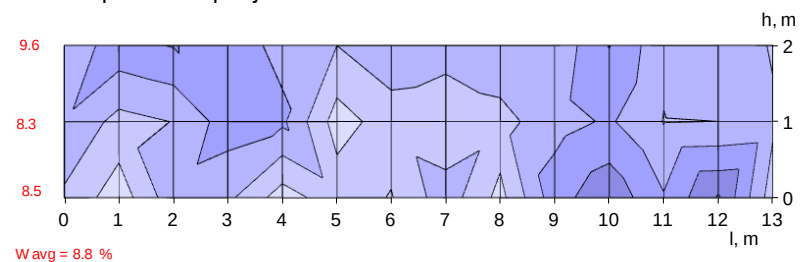


W, %

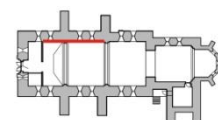
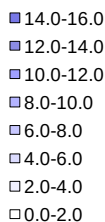


W avg, h, % pikihoone põhjasein keskmises lõõvis

12.06.2013

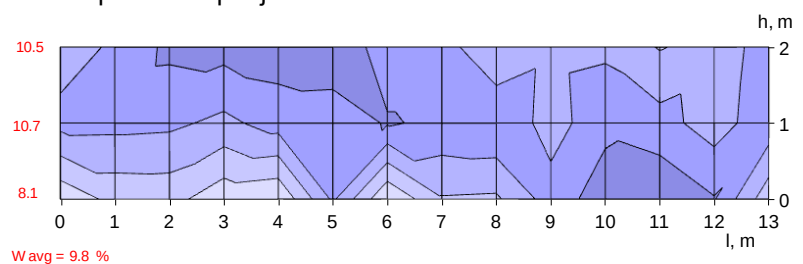


W, %

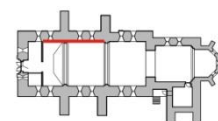
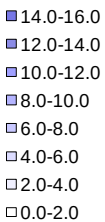


W avg, h, % pikihoone põhjasein keskmises lõõvis

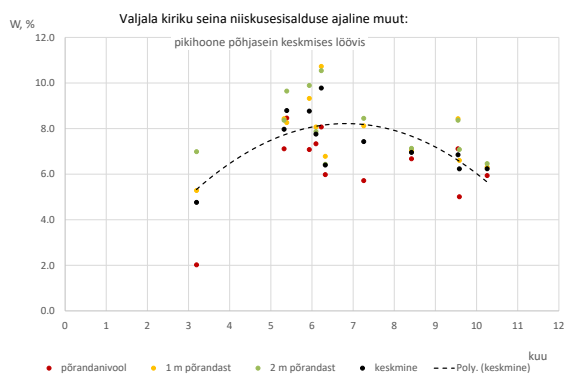
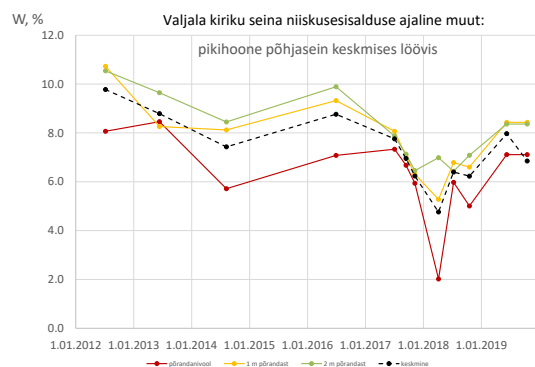
7.07.2012



W, %



Seina niiskusesisalduse kaardid 2012 kuni 2019

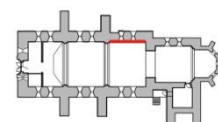
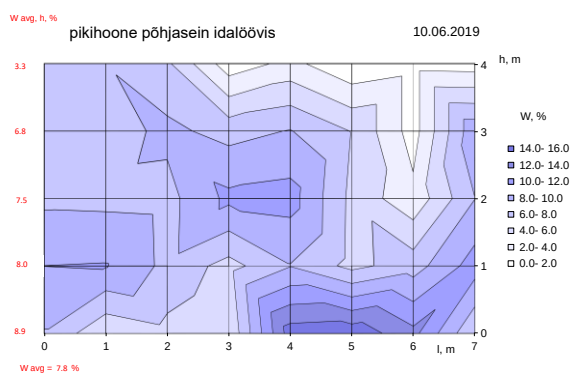
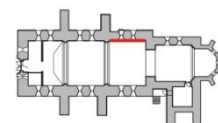
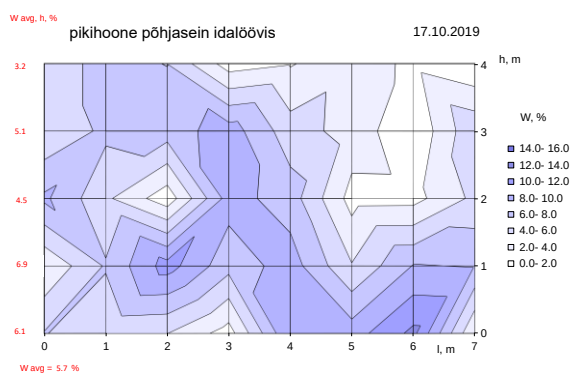


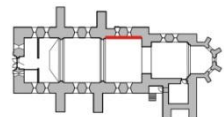
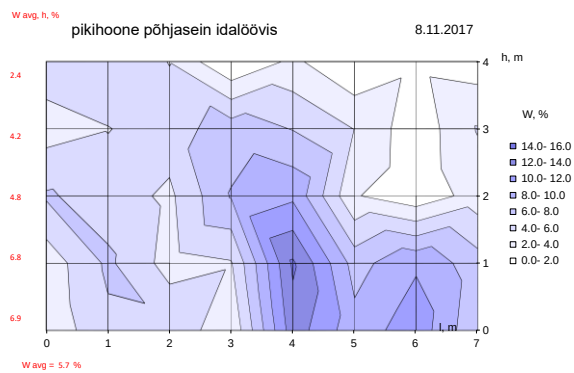
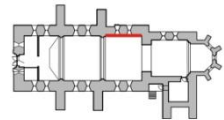
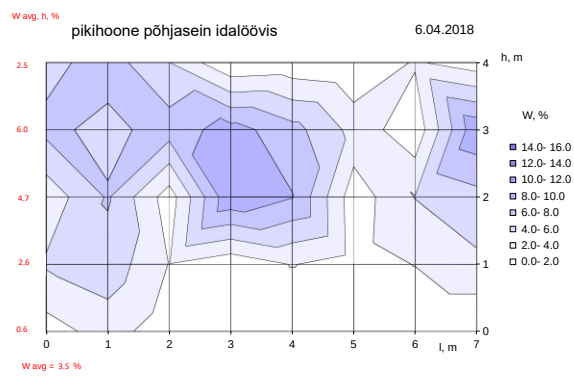
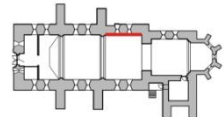
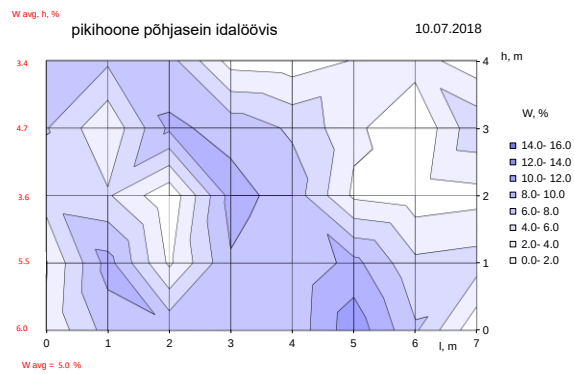
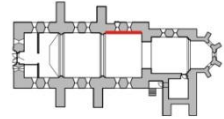
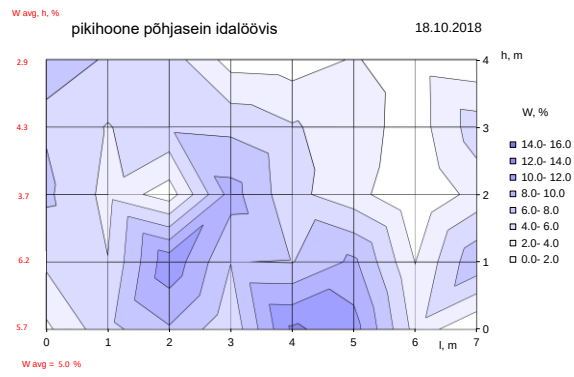
2012 kuni aprill 2018 mõõdeti seina niiskust kõrguseni kuni 2 meetrit, edaspidi kuni kõrguseni 4 m. Sein on väga niiske läbi aasta pea kogu ulatuses, niiskusesisaldus on maksimaalne suve alul, vähenedes sügise poole. Varakevadel 2018 olid pöranda nivool niiskusesisalduse näidud madalad. Seda on võimalik seletada selliselt, et talvel/kevadel uut niiskust lisandub vähe, seina alumise osa vuugid on osaliselt tühjad ja sein hoiab vett halvemini kinni.

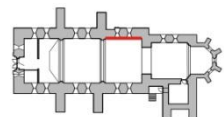
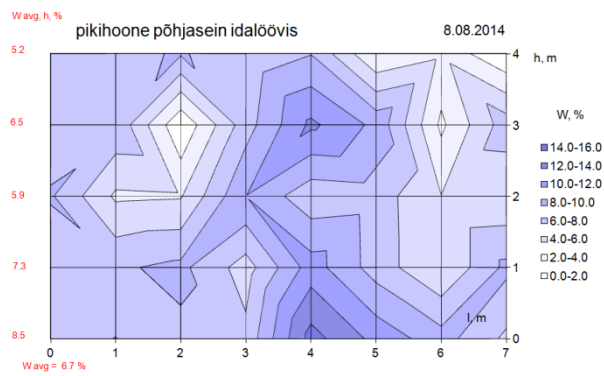
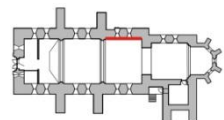
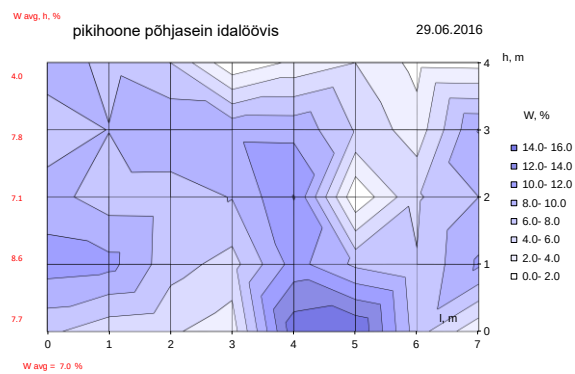
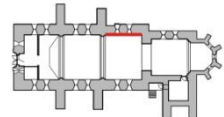
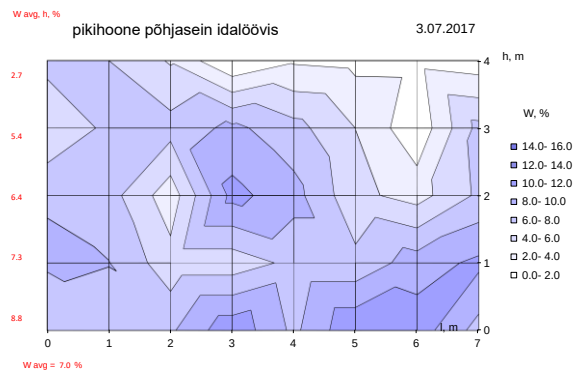
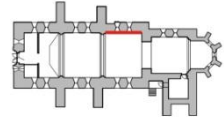
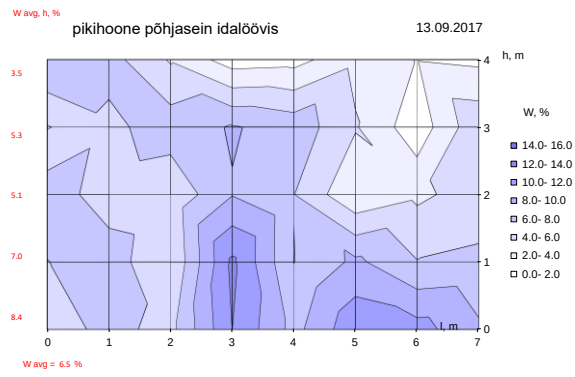
## Põhjasein pikihoone idalöövis:

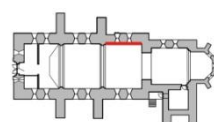
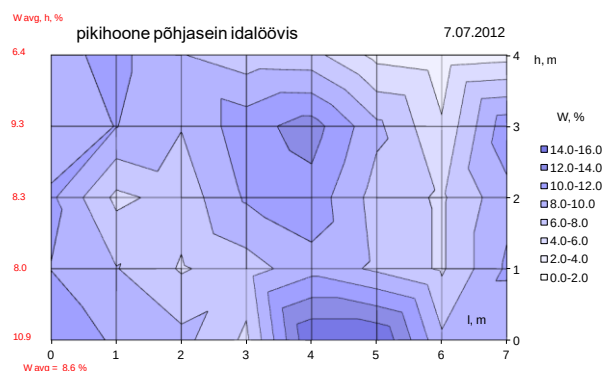
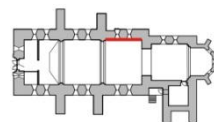
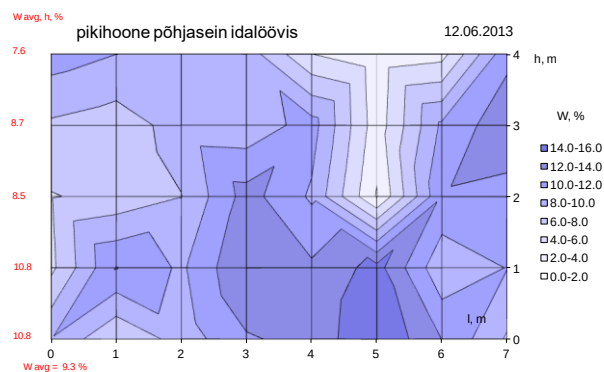


### Seina sise- ja väliskülg

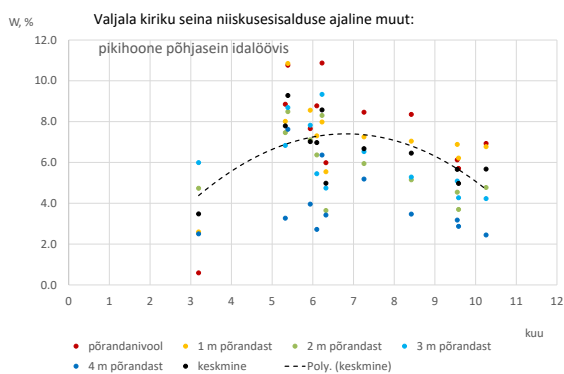
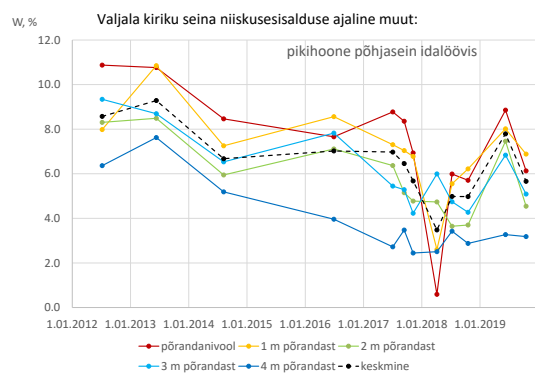








## Seina niiskusjaotus 2012 kuni 2019



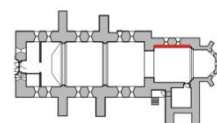
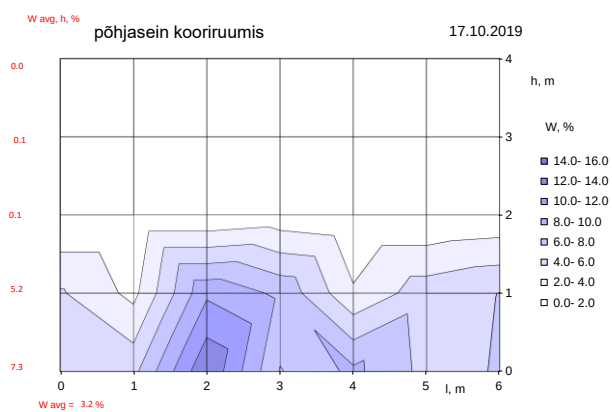
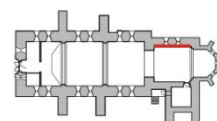
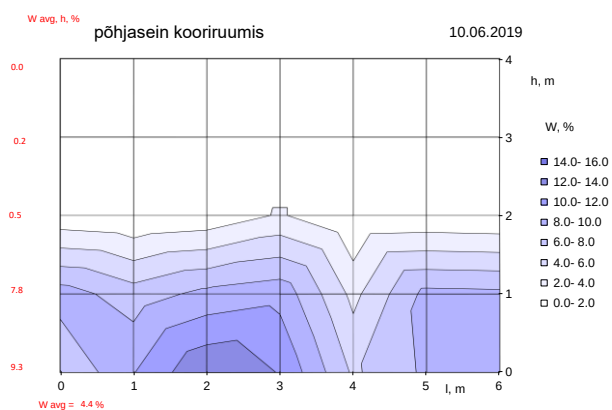
Sein on niiske läbi aasta, niiskusesisaldus on maksimaalne suve alul, vähenedes sügise poole ja talvel.

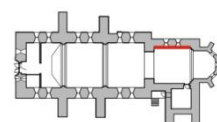
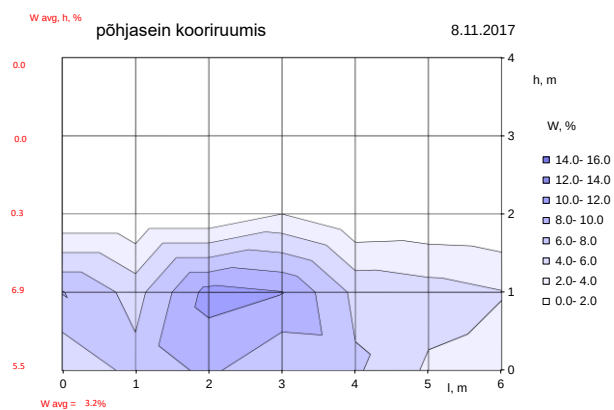
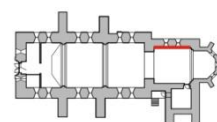
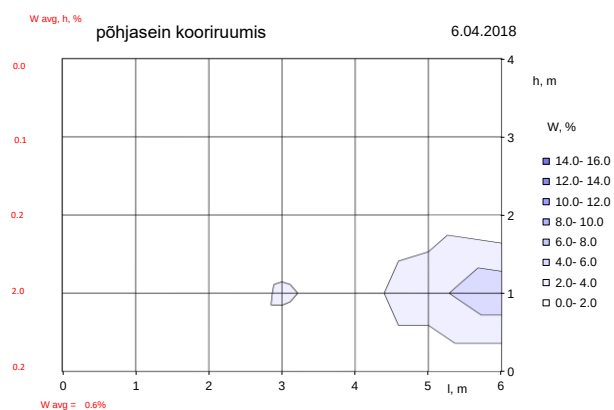
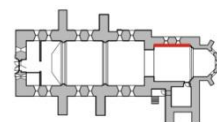
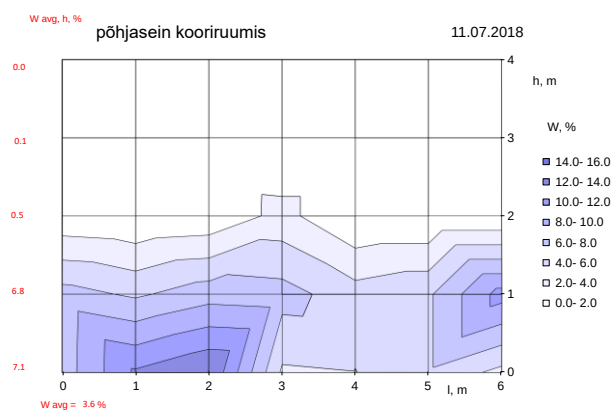
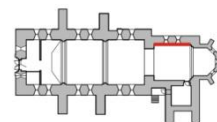
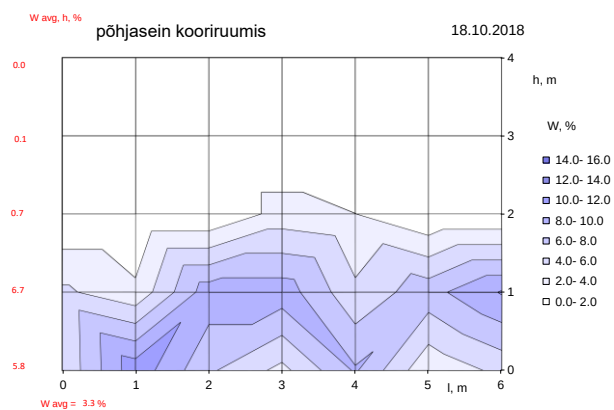
## Kooriruumi põhjasein:

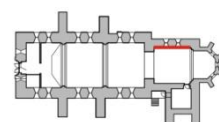
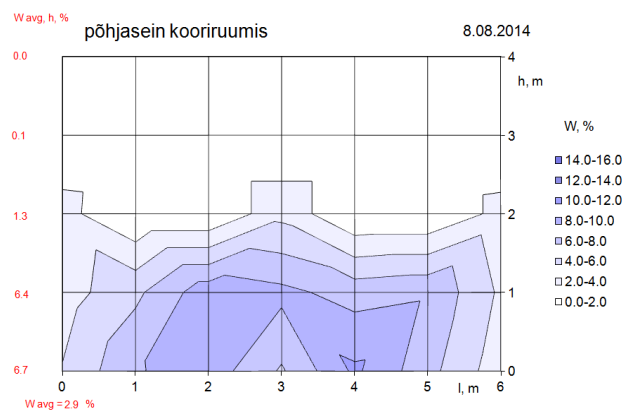
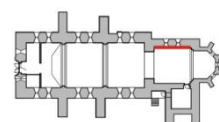
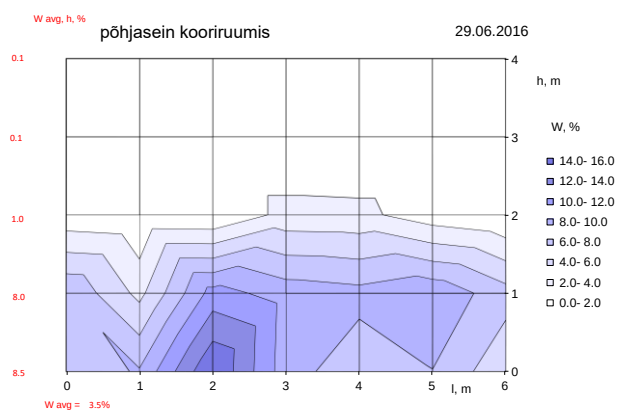
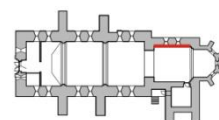
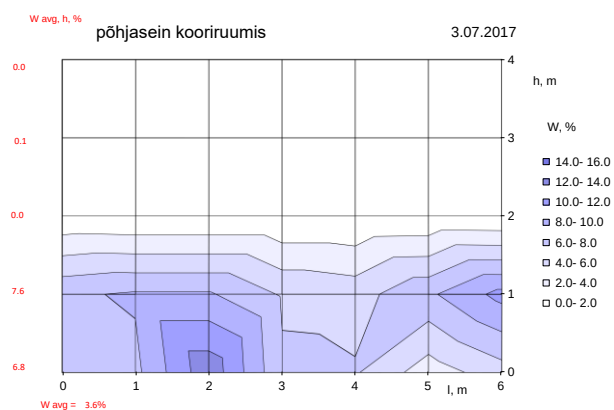
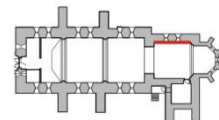
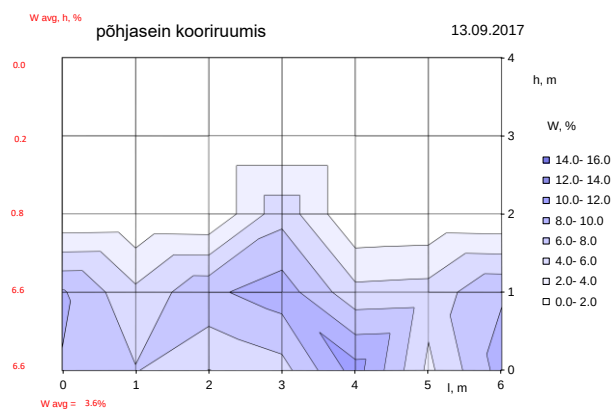


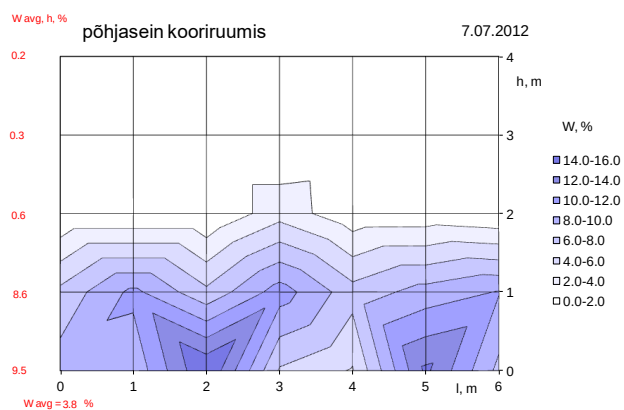
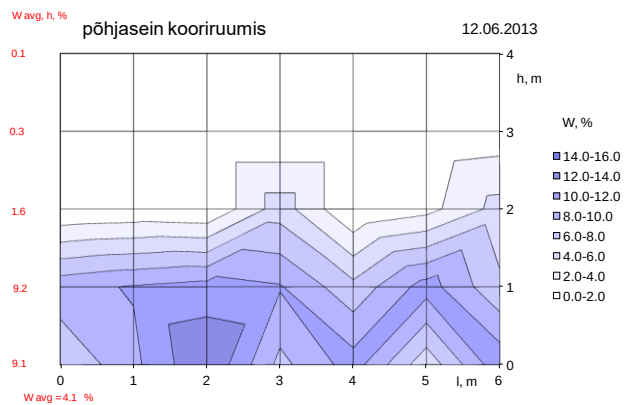
Seina sisekülj kahjustunud seinamaalingutega

Vaade väljast

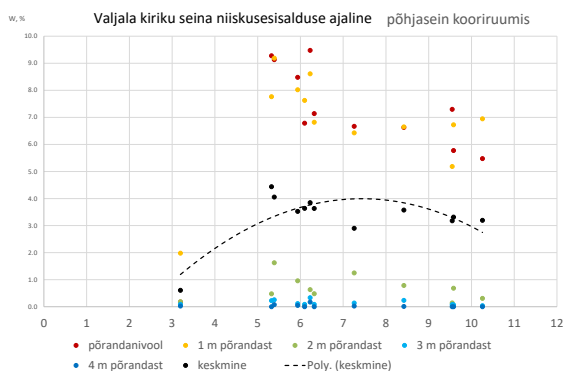
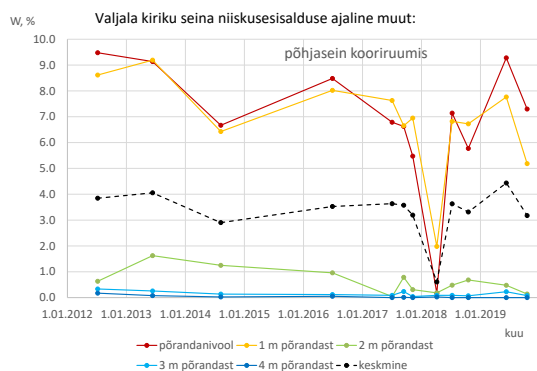






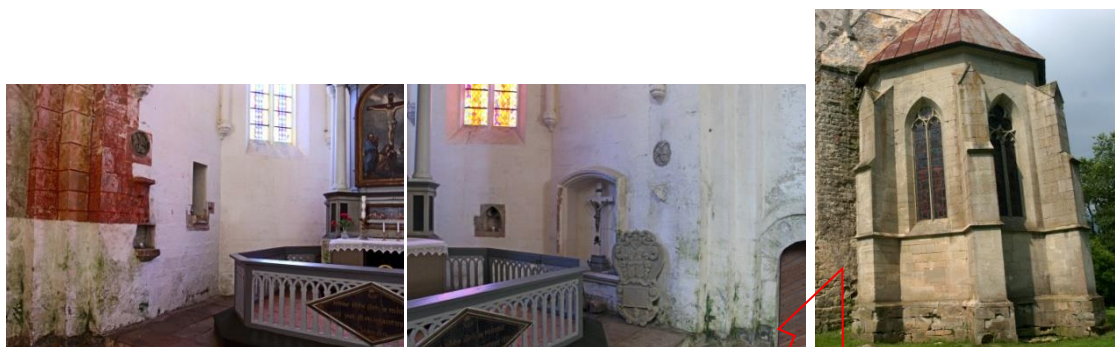


## Seina niiskusjaotus 2012 kuni 2019



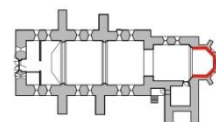
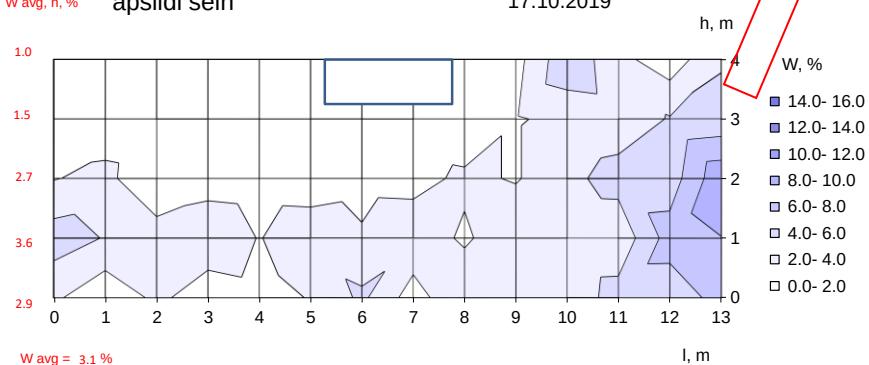
Seina alumine osa on olnud ühtlaselt niiske kogu mõõtmiste aja jooksul, välja arvatud 2018 –nda aasta aprillis, kõrgemal kui 2 meetrit on sein kuiv.

## Apsiidi sein:



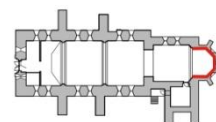
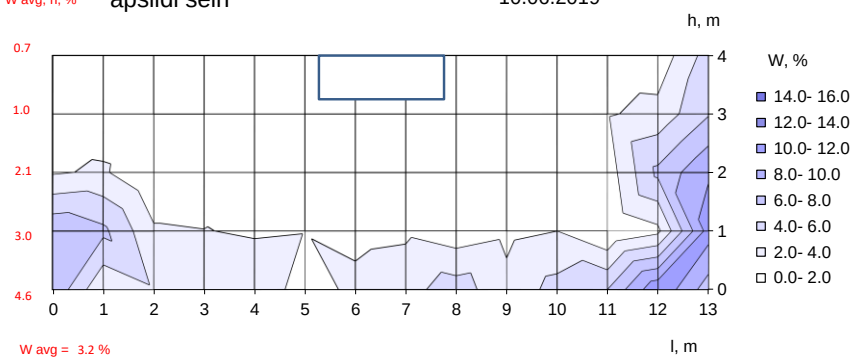
W avg, h, % apsiidi sein

17.10.2019



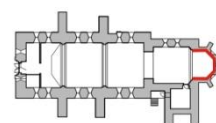
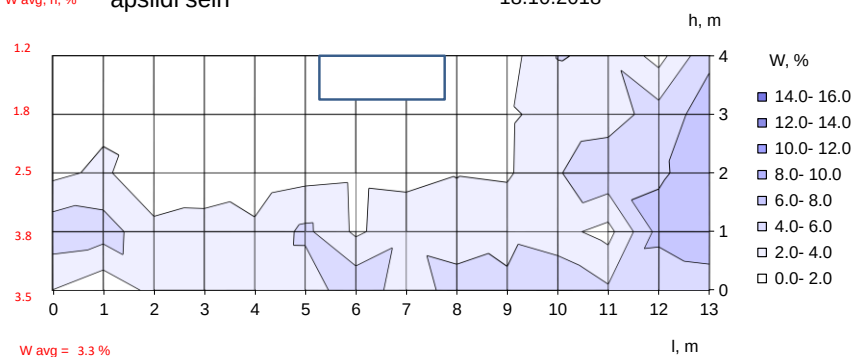
W avg, h, % apsiidi sein

10.06.2019



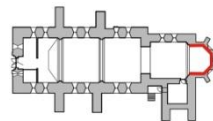
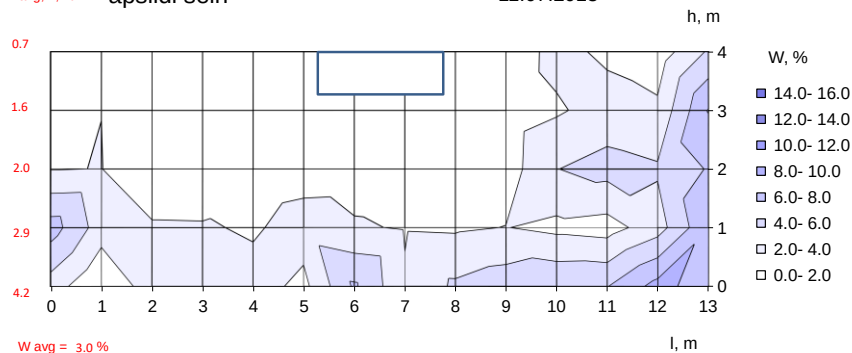
W avg, h, % apsiidi sein

18.10.2018



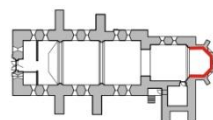
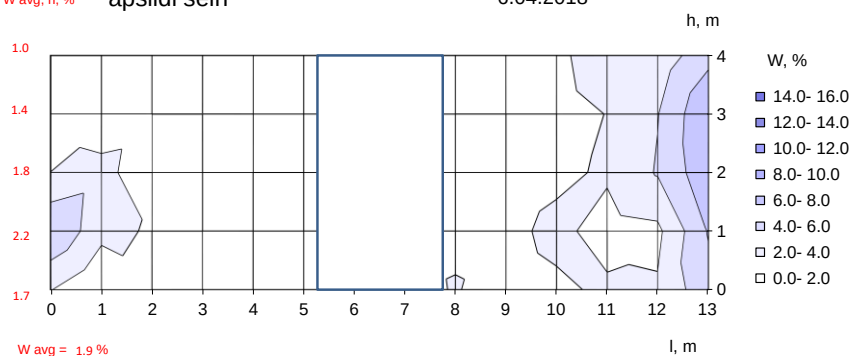
W avg, h, % apsiidi sein

11.07.2018



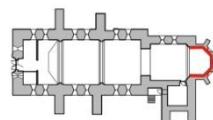
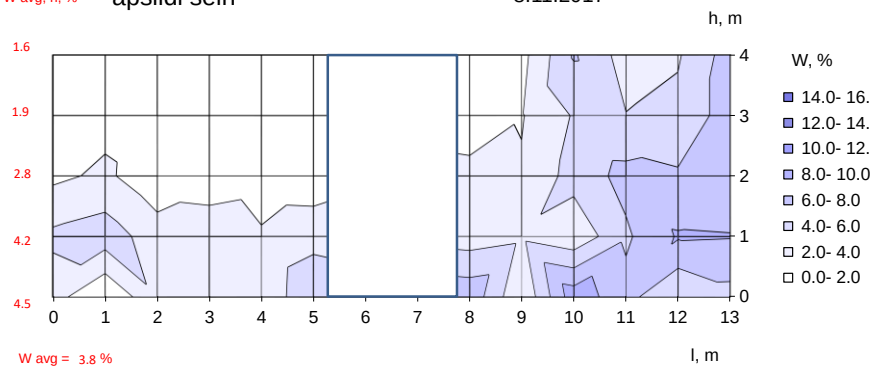
W avg, h, % apsiidi sein

6.04.2018



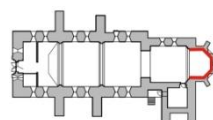
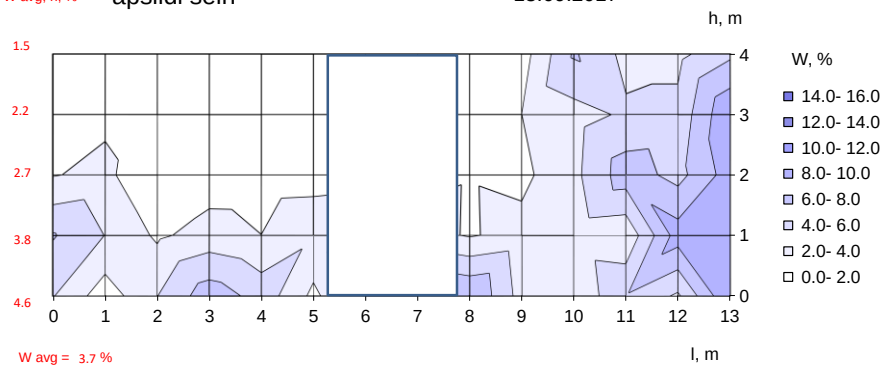
W avg, h, % apsiidi sein

8.11.2017



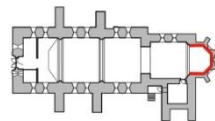
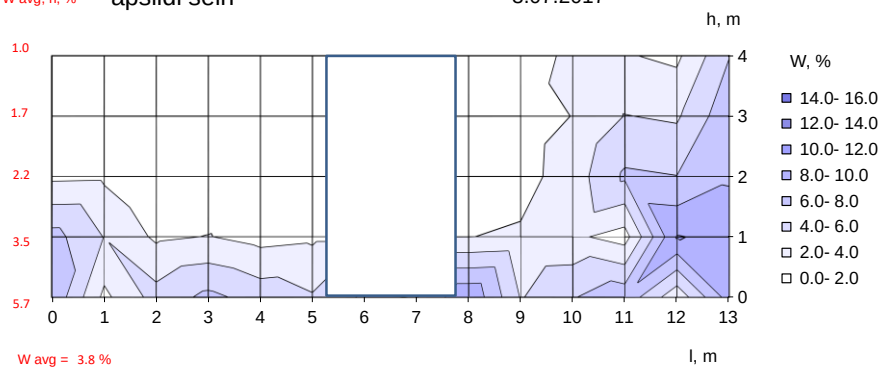
W avg, h, % apsiidi sein

13.09.2017



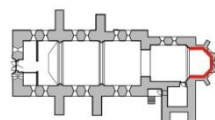
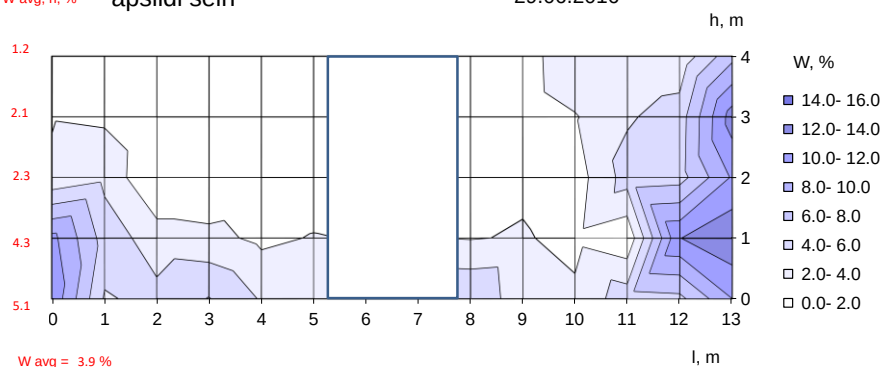
W avg, h, % apsiidi sein

3.07.2017



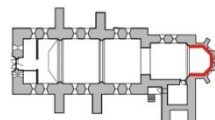
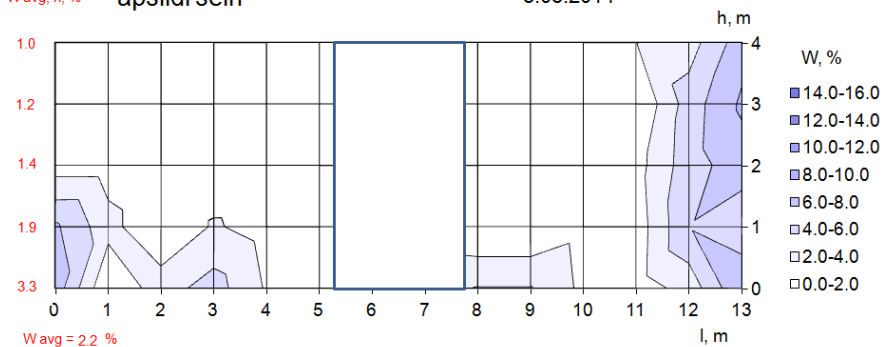
W avg, h, % apsiidi sein

29.06.2016



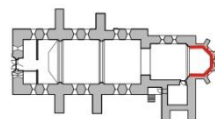
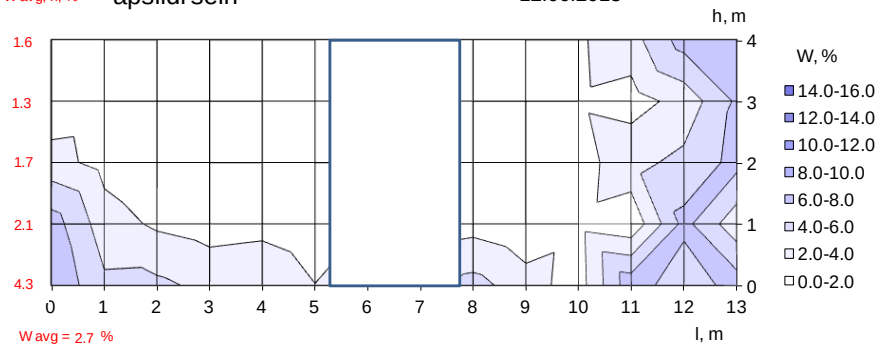
W avg, h, % apsiidi sein

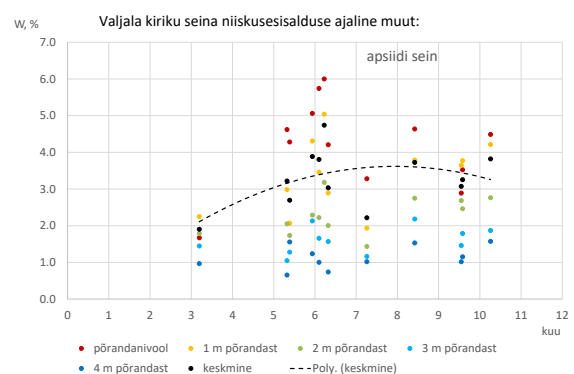
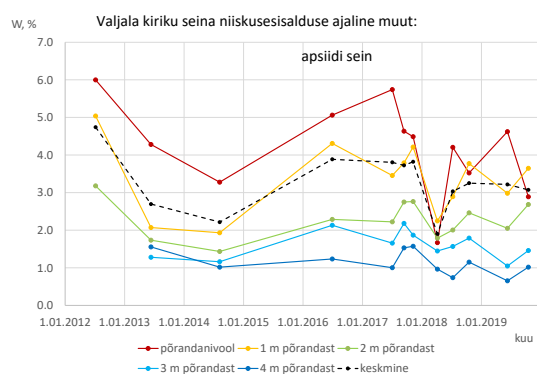
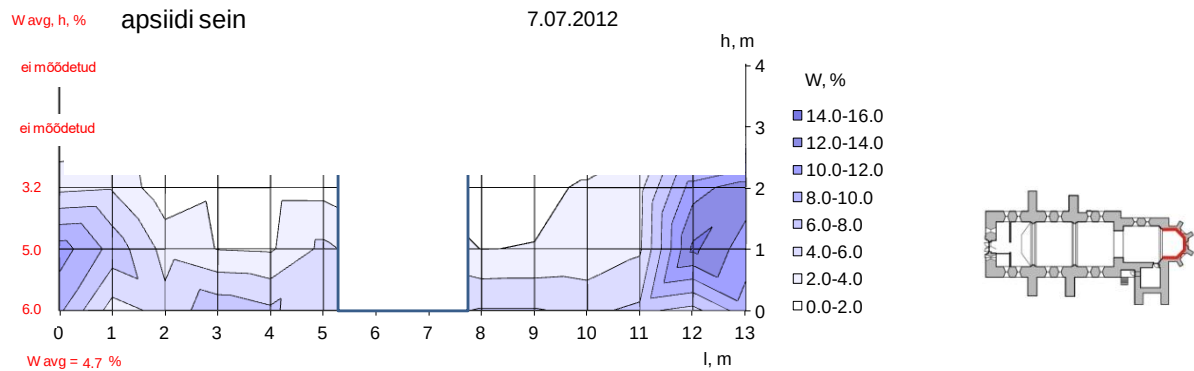
8.08.2014



W avg, h, % apsiidi sein

12.06.2013





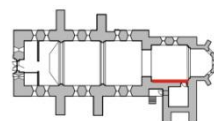
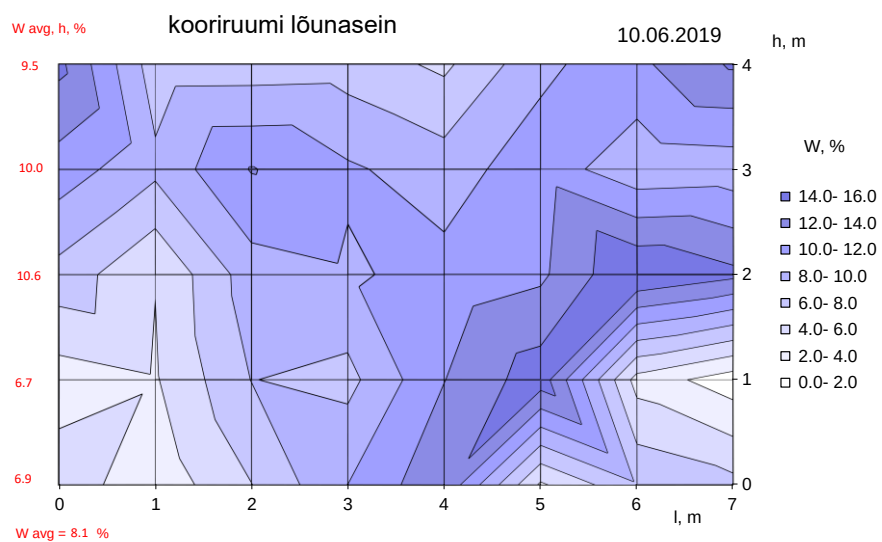
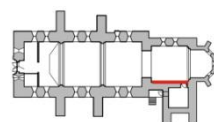
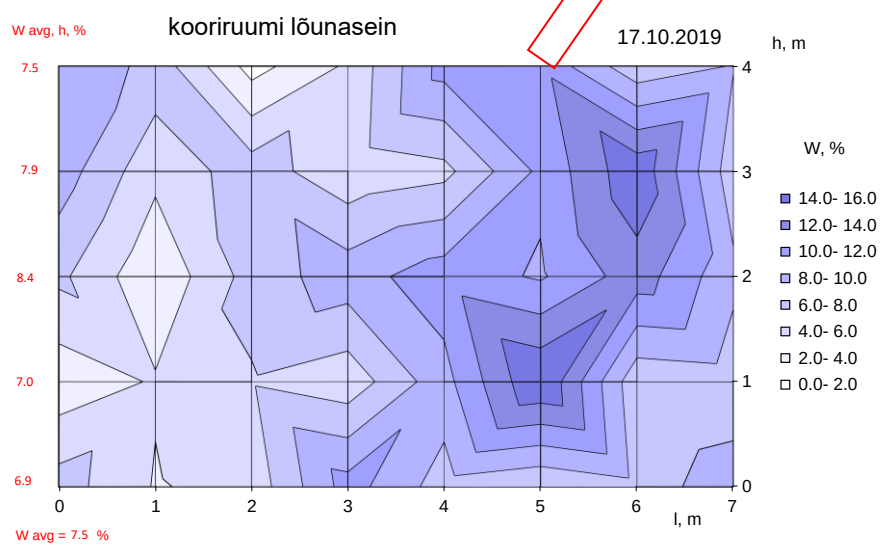
Seina niiskusjaotus 2012 kuni 2019

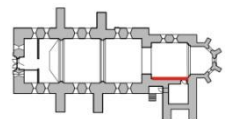
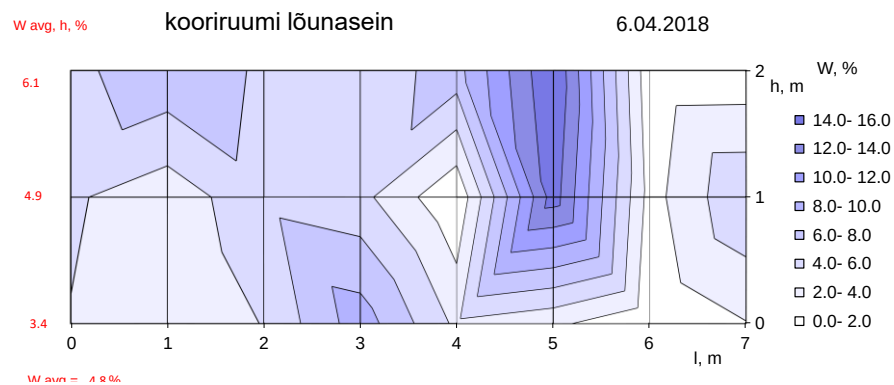
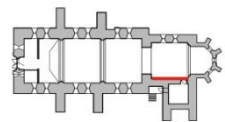
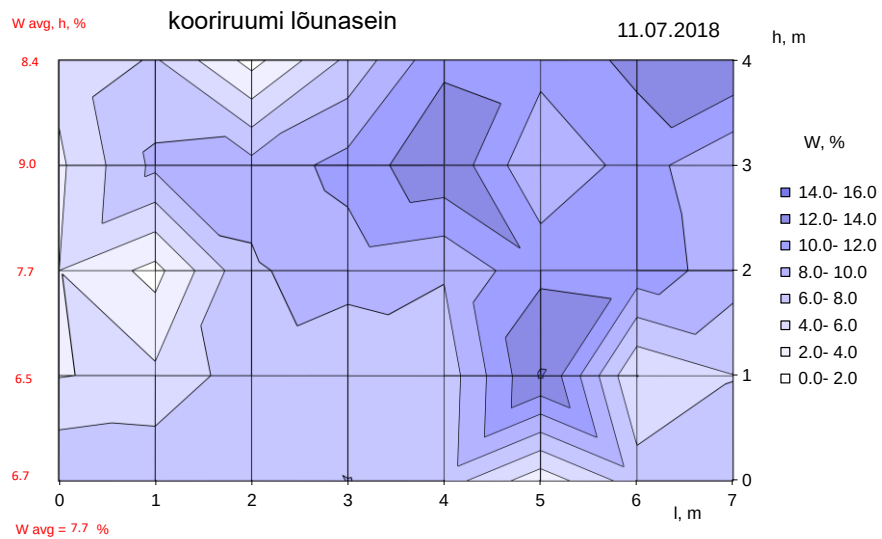
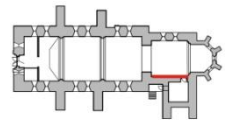
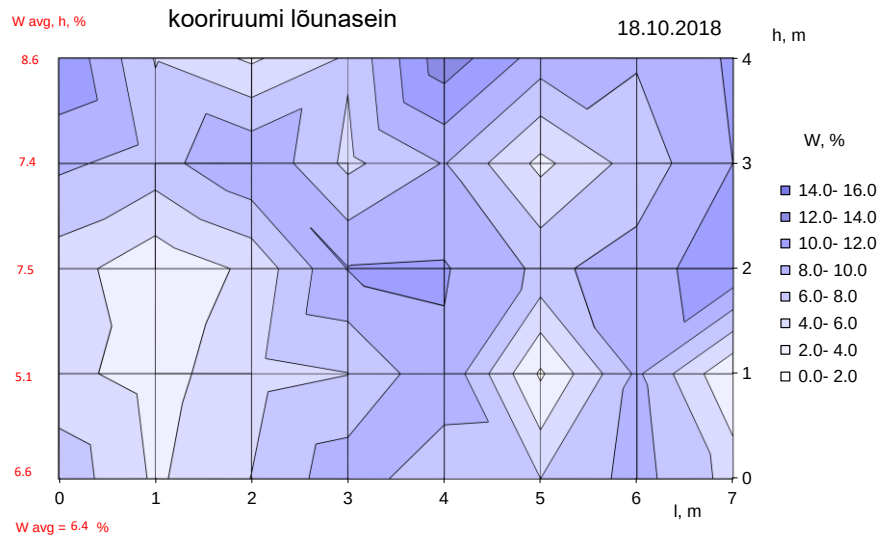
2015 ja 2017-ndal aastal on apsiidi katust ja selle ümbrust remonditud kuid kahjuks selle positiivne mõju seina niiskusesisundile pole kuigi suur. Seina olukorda mõjutab ka veel kestev vundamendi remont ja selle teostamiseks ehitatud varikatus.



Apsiidi katus ja sein 29.06.2016 ning 8.11.2017

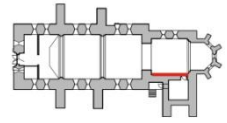
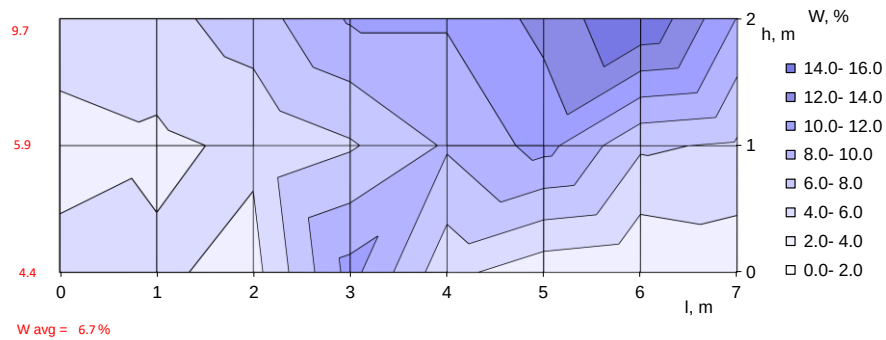
## Kooriruumi lõunasein.





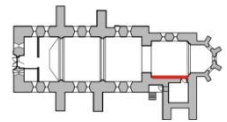
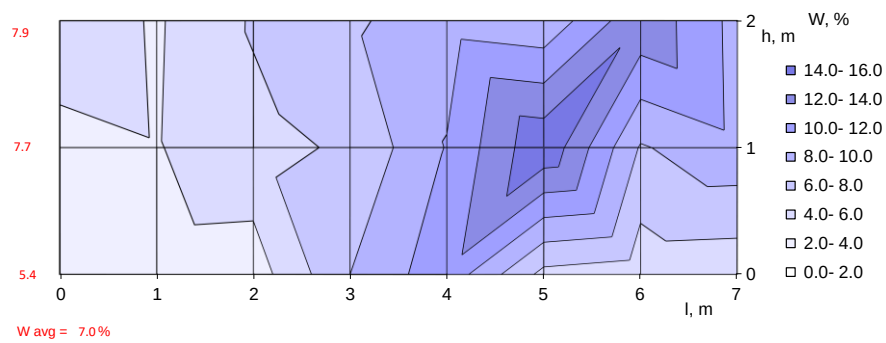
W avg, h, % kooriruumi lõunasein

8.11.2017



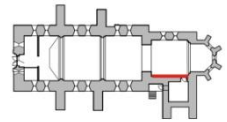
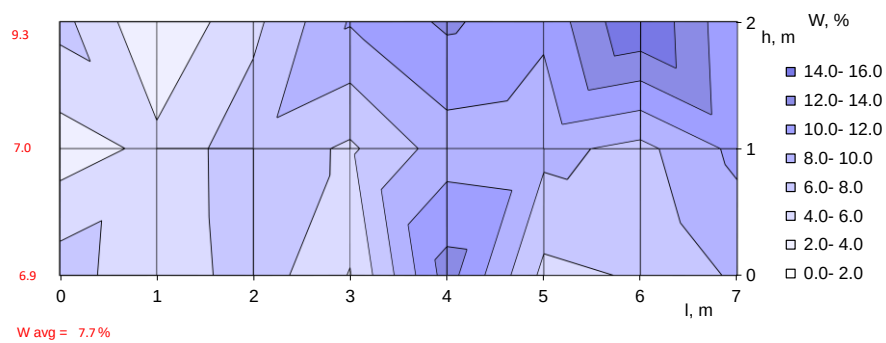
W avg, h, % kooriruumi lõunasein

13.09.2017



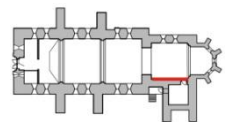
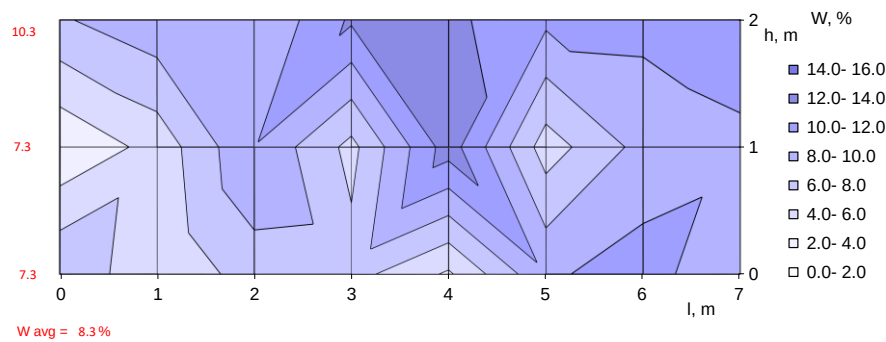
W avg, h, % kooriruumi lõunasein

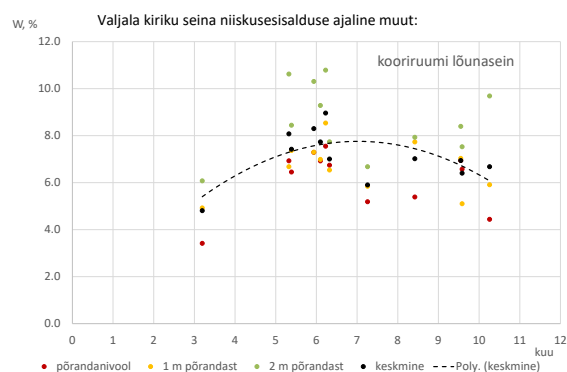
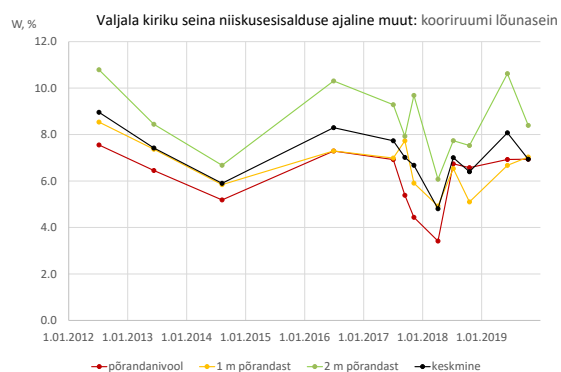
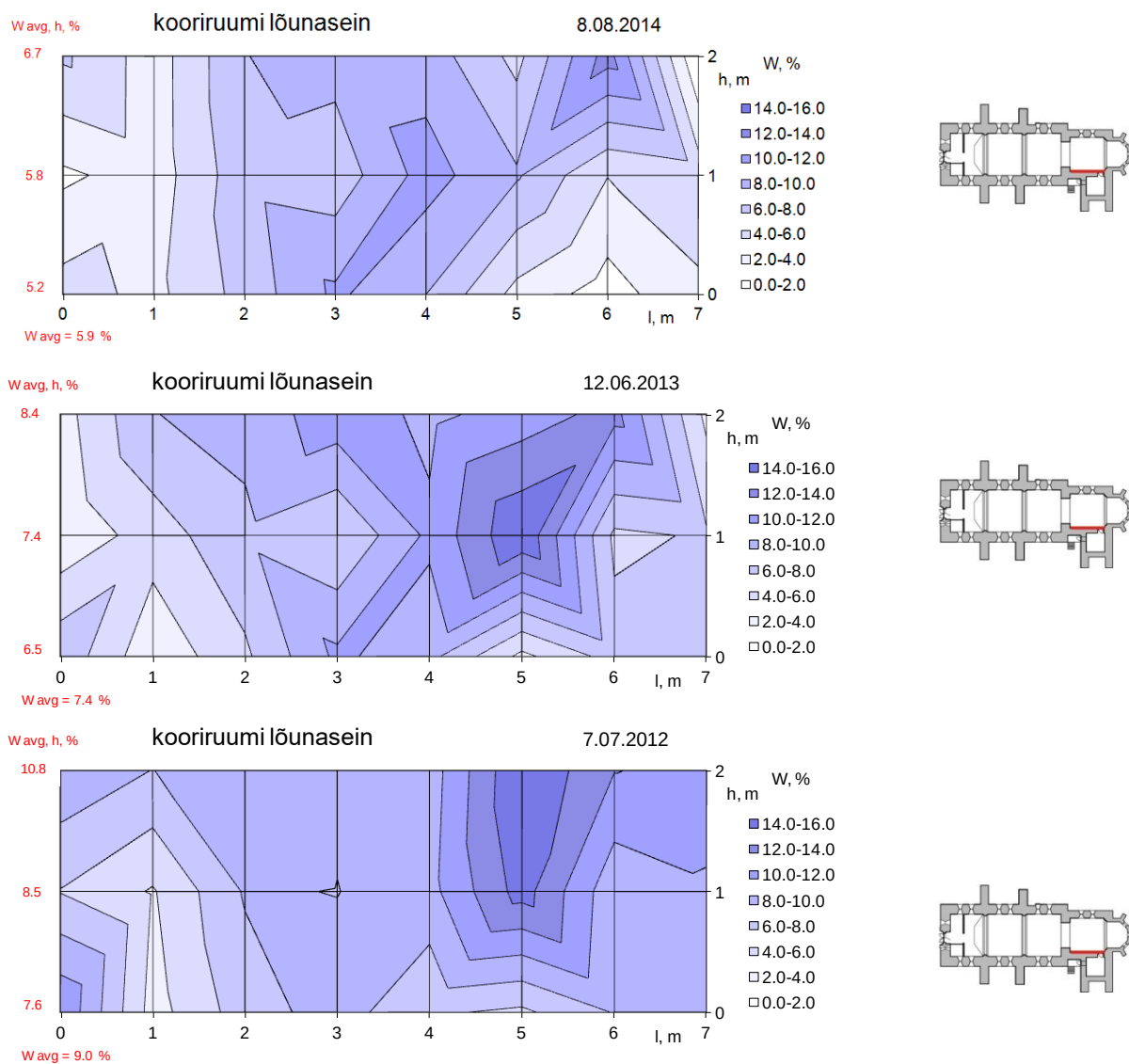
3.07.2017



W avg, h, % kooriruumi lõunasein

29.06.2016

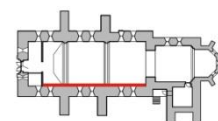
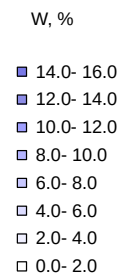
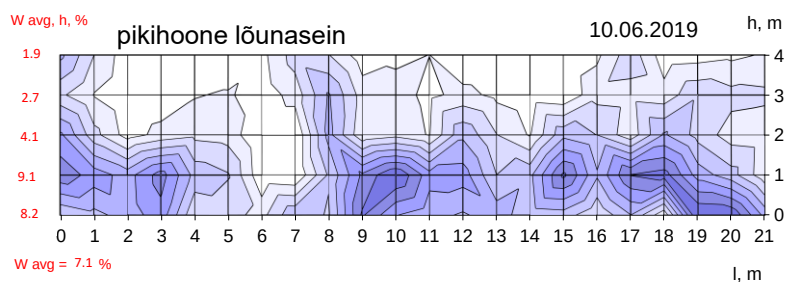
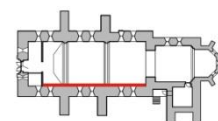
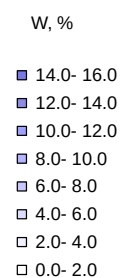
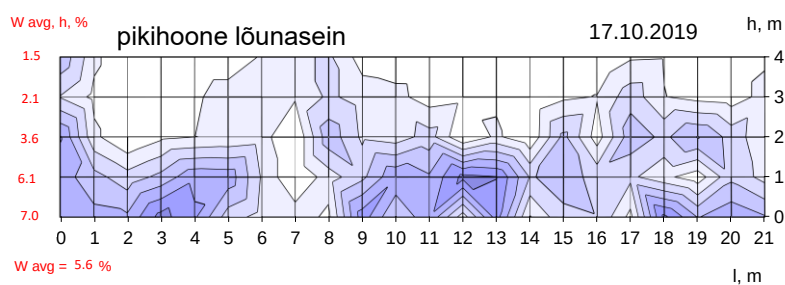
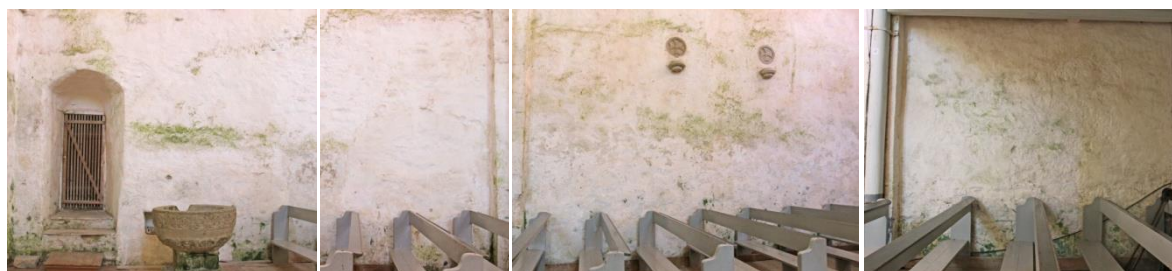


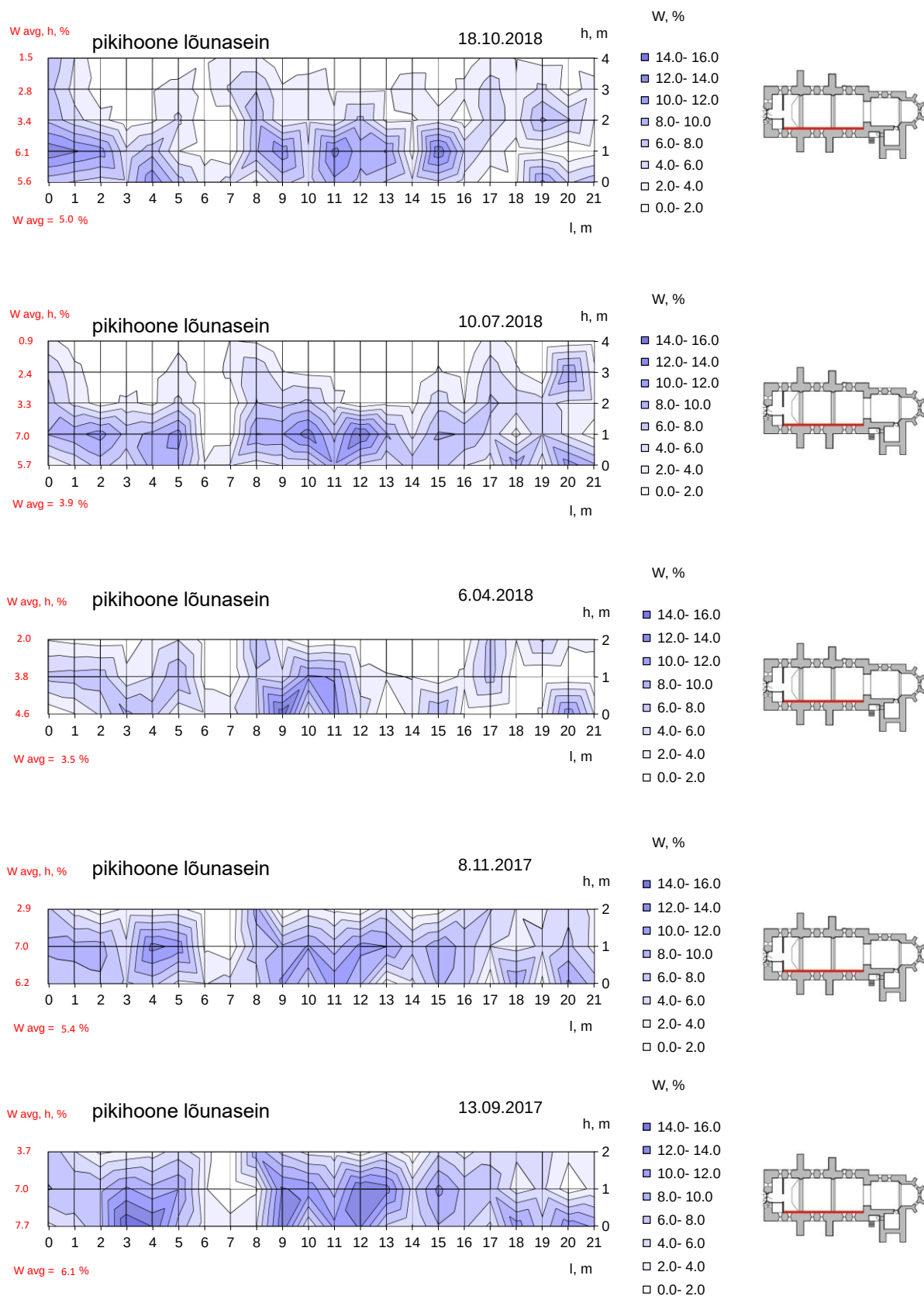


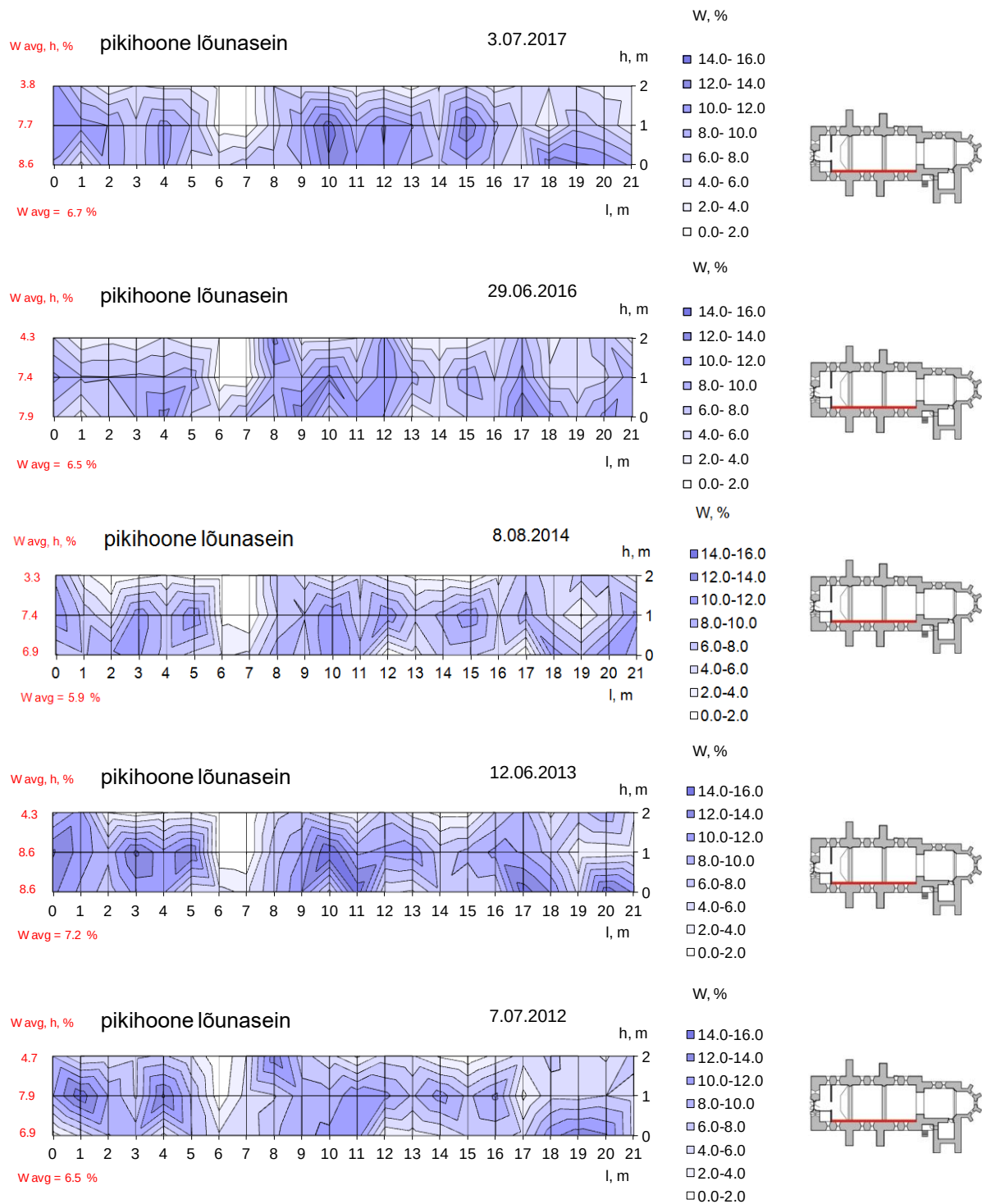
**Seina niiskusjaotus 2012 kuni 2019**

Sein on ühtlaselt märg kogu mõõdetud ulatuses. Probleemne koht on katuse ja torni kokkupuute koht, kus katuselt voolaval veel pole head teed kiiresti maapinnani jõuda.

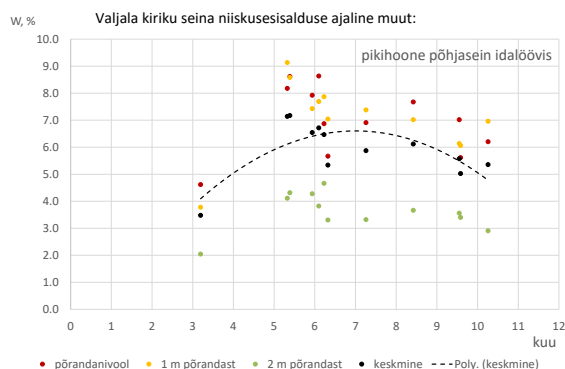
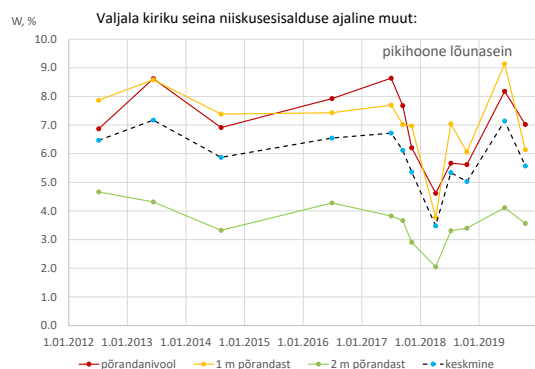
## Pikihoone lõunasein



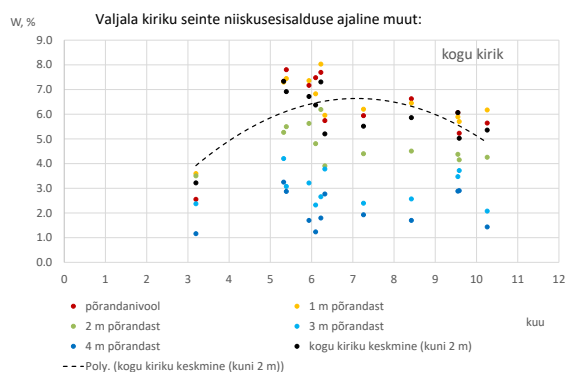
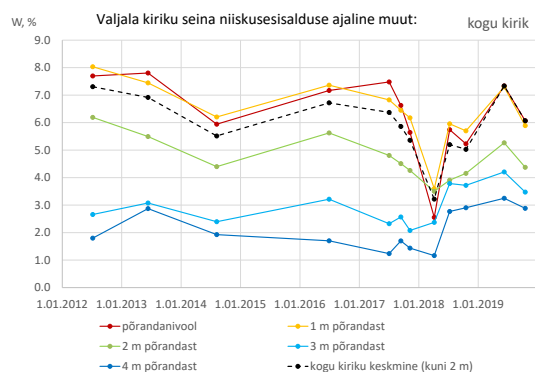




Seina niiskusjaotus 2012 kuni 2019



Seina niiskusesisaldus ajas muutub vähe, väikesed muutused on sesoonset laadi, sein on niiskem suve alguses, sügiseks niiskusesisaldus veidi väheneb.

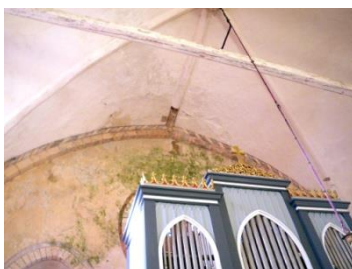
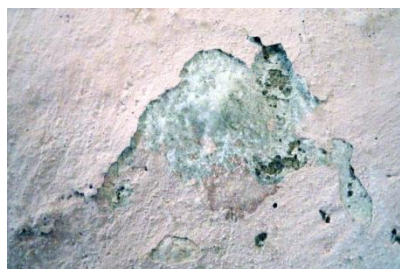


Niiskusesisalduse muutused keskmistatud kogu kirikule.

Kiriku seinad väga niisked (peaaegu veega küllastanud) – põhjus vihmavee ärajuhtimise süsteemi puudumine, väline krohv lagunenud, suur õhuniiskus kiriku siseõhus (osaliselt eelnevate põhjuste tagajärg). Kiriku seinte niiskus on muutlik just seinte alumises osas, kuni 1m (niiskuse oluline langus aprill 2018), kõrgemal on seinte niiskusolukord vähe sõltuv aastaajast.

## Soolad kirikus

Kirikus esineb efloresents – seinas olevas vees lahustunud soolade kristalliseerumine seina pinnal ja ka seina sisemistes poorides ning pragudes. Selline nähtus toimub, kui seinas olev vesi aurustub, kas siis suhtelise õhuniiskuse langemise või temperatuuri muutumise tõttu. Paljud soolad võivad oma struktuuris sisaldada kristallvett. Sõltuvalt tingimustest võib see kogus erineda, mis tähendab seda, et keskkonnatingimuste muutumisel kristalliseerunud soola ruumala muutub ja lõhub seinamaterjali. Väljakristalliseerunud soolad võivad sobivates tingimustes lahustuda (protsessi kiirus sõltub väga palju konkreetse soola lahustuvusest) ja uuesti kristalliseeruda. Seinte välispindadel aitab lahustumisele kaasa muidugi ka vihm.



Eflorestsents kiriku lääneseinal oreli taga ja selle põhjustaja – vihmavee leke tõenäoliselt katuse otsaviilu või ka seina eendite kaudu. Sool on välja lahustunud seinamaterjalist, sest eflorestsentsi piirkond asub lääneportaali kohal ja kapillaarvesi pinnasest sinna ei jõua.

Soolade koostis määrati röntgenfluorestsentsi meetodil (R. Traksmäa):

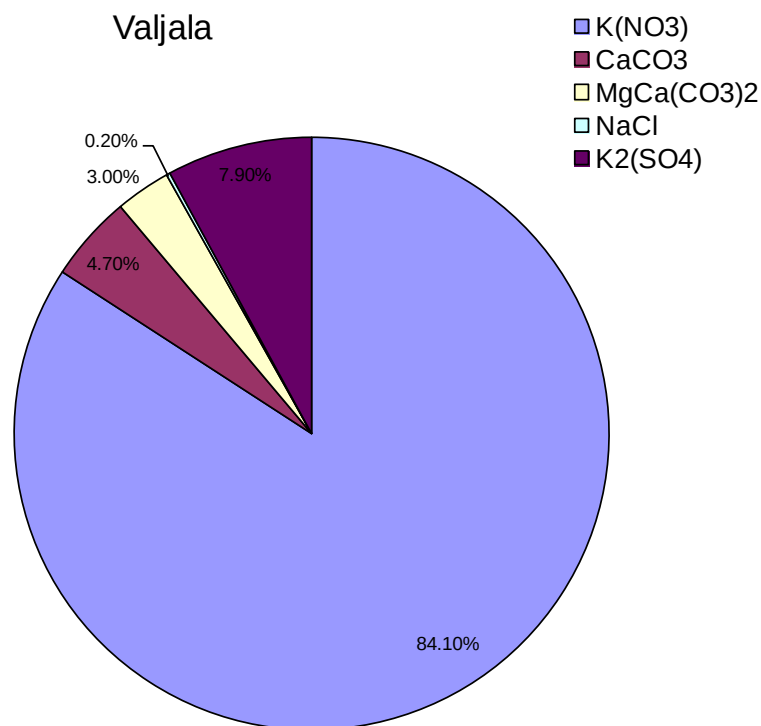
File name: Valjala kiriku oreli tagune sein (Saaremaa 22102009).raw

Concentrations:

-----

|             |       |            |               |
|-------------|-------|------------|---------------|
| 04-009-3532 | 84.1% | K(NO3)     | Niter         |
| 00-005-0586 | 4.7%  | CaCO3      | Calcite; syn  |
| 01-083-1766 | 3.0%  | MgCa(CO3)2 | Dolomite      |
| 00-005-0628 | 0.2%  | NaCl       | Halite; syn   |
| 04-006-6196 | 7.9%  | K2(SO4)    | Arcanite; syn |

|    |       |        |        |
|----|-------|--------|--------|
| C  | 1.0%  | CO2    | 3.5%   |
| N  | 11.7% |        |        |
| O  | 46.7% | Excess | +33.3% |
| Na | 0.1%  | Na2O   | 0.1%   |
| Mg | 0.4%  | MgO    | 0.7%   |
| S  | 1.5%  | SO3    | 3.6%   |
| Cl | 0.1%  |        |        |
| K  | 36.1% | K2O    | 43.5%  |
| Ca | 2.6%  | CaO    | 3.6%   |



Soolade koostis Valjala kiriku lääneseinal (R. Traksmaa)

K<sub>2</sub>SO<sub>4</sub> korral on kristalse soola tekkimiseks vajalik, et RH oleks <97..98 % (sõltuvalt temperatuurist). KNO<sub>3</sub> eflorestsents algab aga õhuniiskuse korral, mis on väiksem kui 95..96 %. NaCl-di (tasakaaluline RH 75%) on proovis väga vähe, kas siis lahustunud Na ja Cl ionide vähesuse tõttu või oli õhuniiskuse liiga suur. Ülejäänud soolad CaCO<sub>3</sub> ja CaMg(CO<sub>3</sub>)<sub>2</sub> on ilmselt proovi sattunud seinamaterjali (dolokivi, mört) osakesed. Soolaproovi võtmise ajal oli RH 89% ja t 7,4 °C.

Proovist leitud ionidest oleks võimalik kombineerida sobivate tingimuste korral veel mitmeid sooli: näiteks Mg(NO<sub>3</sub>)<sub>2</sub>·6H<sub>2</sub>O (RH<sub>tasakaaluline;20°C</sub> = 54%), Ca(NO<sub>3</sub>)<sub>2</sub>·4H<sub>2</sub>O (RH<sub>tasakaaluline;20°C</sub> = 53%), NaNO<sub>3</sub> (RH<sub>tasakaaluline;20°C</sub> = 74%) [Camuffo, 2013], Na<sub>2</sub>SO<sub>4</sub>·10H<sub>2</sub>O (RH<sub>tasakaaluline;20°C</sub> = 95%) (allikas: <http://193.175.110.91/saltwiki/index.php/Thenardite>). Kui õnnestub tulevikus kirikus suhtelist õhuniiskust vähendada, siis tekib oht sooldumise probleemi laienemiseks.

Na soolade väga väike osakaal tuleneb ilmselt sellest, et lubjakivi sisaldab oluliselt vähem Na kui K (vaata tabel 1). Kirjanduse andmetel sisaldab ka atmosfääri tolm rohkem K kui Na.

Tabel 1. N ja K sisaldus lubjakivis ja Kaarma dolokivis (Trikkel)

|                 | K <sub>2</sub> O, % | Na <sub>2</sub> O, % |
|-----------------|---------------------|----------------------|
| lubjakivi       | 0,55...0,75;        | 0,02...0,12          |
| Kaarma dolokivi | 0,2                 | 0,2...0,4            |

NO<sub>3</sub><sup>-</sup> ionide allikas on suure tõenäosusega organilist päritolu – linnu/nahkhiire sõnnik, bakterite poolt õhust seotud lämmastik, ... . Õhusaaste mõju tõenäosus on väiksem, sest ümbruses puudub suurtööstus. Konkreetse proovi korral on pinnasest pärinev nitraat peaaegu välistatud, sest proovivõtu koht on suure ukseava kohal.

Nitraadid lahustuvad hästi ja on võimelised niiskes seinas liikuma kaugele. Sulfaadid lahustuvad halvemini ja neid on ka analüüsitud proovis vähem. Kuna soolad on orgaanilist päritolu hapete poolt seinamaterjalist välja lahustatud, siis selline protsess muudab seina hõredamaks ja nõrgemaks.

2017. aastal analüüsiti 4 soolaproovi:

1. kiriku lõunasein ~2 meetri kõrgusel (13.09.17): peamine sool  $\text{KNO}_3$ , leidis ka  $\text{SiO}_2$ ,  $\text{CaO}$ ,  $\text{SnO}_2$ .

2. krohvituukk soolaga kiriku lõunaseinast, millest analüüsiti eraldi 3 fraktsiooni:

- peamine kiht: peamine  $\text{CaCO}_3$  (kaltsiit), oluliselt ka  $\text{KNO}_3$  ja  $\text{SiO}_2$ , vähesel määral  $\text{MgCO}_3 \cdot 3(\text{H}_2\text{O})$ -d ja  $\text{FeO} \cdot \text{Fe}_2\text{O}_3$
- järgmine kiht: peamine  $\text{SiO}_2$ , olulisel määral  $\text{CaCO}_3$ , veidi ka  $\text{KNO}_3$  – e.
- kolmas kiht: peamine  $\text{SiO}_2$ , olulisel määral  $\text{CaCO}_3$ , veidi ka  $\text{MgCO}_3 \cdot 3(\text{H}_2\text{O})$ ,  $\text{FeO} \cdot \text{Fe}_2\text{O}_3$ ,  $\text{SiO}_2$ ,

3. koori põhjasein 1,5 m kõrgusel seinamaalingute all: peamine komponent  $\text{SiO}_2$ , oluline ka  $\text{CaCO}_3$ , vähesel määral  $\text{CaMg}(\text{CO}_3)_2$  ja  $\text{Ca}_2\text{Al}_2\text{SiO}_7$ .

4. nišš ja auk kooriruumis, mille sein kaetud vetikate kihiga: peamine  $\text{CaCO}_3$  (kaltsiit), leidub veel  $\text{Al}_2(\text{SO}_4)_3$ ,  $\text{FeO} \cdot \text{Fe}_2\text{O}_3$ ,  $\text{SiO}_2$  ja  $\text{CaCO}_3$  (aragoniit).

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Kirjandus:

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