ČESKÉ VYSOKÉ UČENÍ TECHNICKÉ V PRAZE

FAKULTA STAVEBNÍ

KATEDRA KONSTRUKCÍ POZEMNÍCH STAVEB

STUDIJNÍ OBOR BUDOVY A PROSTŘEDÍ

Design of the Kashitu high school

Návrh střední školy v Kashitu

Annexes

Přílohy

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Annex 1 - Cost of building materials

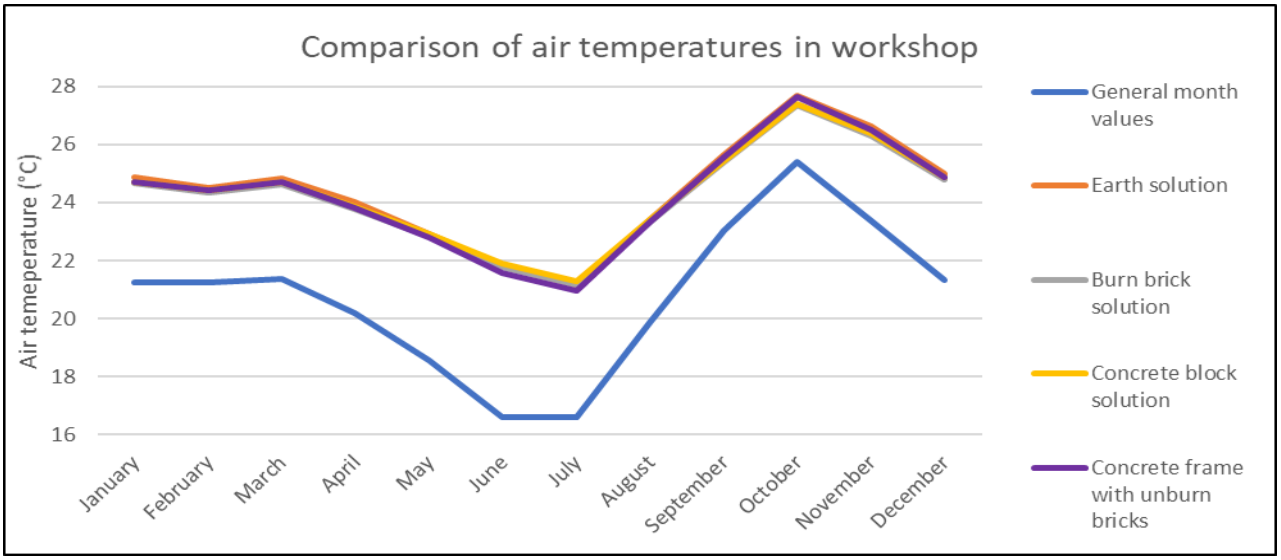
Building materials/stavební materiály				
Name in English	Name in Czech	Price in Lusaka	Price in Kapiri Mposhi	Note
Bricks/Cihly				
cement	cementové	-	4	4" 90x190x390
		-	5	6" 140 x 190 x 390mm
burn	pálené	-	1,5	280x130x110
Metal sheet/Střešní plech - wander type				
normal		-	85	3,6x0,8
galvanized		-	85	3,5x0,8
finishing	zakončení	-	45	2m
normal		170	-	0,3mm;4,2x1m
galvanized		160	-	0,3mm;3x1m
Timber/Řezivo				
2x6		-	100	6m
2x4		-	65	6m
2x2		-	27	6m
Cement				
Zambezi		-	70	32,5kg
Dangod		-	72	32,5kg
building up	zdi	72,5	-	50kg
Floor	podlaha	77	-	50kg
Glass/Sklo				
plate	deska	-	300	2,2x1,2m
plate	deska	-	250	1,83x1,22m
Window steel frame/Kovový rám okna				
		-	400	1,2x1m
		-	650	1,8x0,9m
Reinforced steel rod/Vyztuž do betonu				
Ordinary	Běžná	-	155	15m, 3,771 kg
Floor	Podlaha	-	700	50mx1,5m
Fence	Plot	-	1200	30mx2m
Wire	Drát	-	20	kg
Steel beam/Ocelový nosník				
			90	30x30mm;6m
Ceiling board	stropní deska	120	-	sadrokarton;0,9x3,6m
Plywood	překližka	260	-	4mm;2,4m
screws	sroubí	100/150	-	500ks/7kg
Termite poison	Ochrana před termity	-	65	1l

Annex 2 – DesignBuilder materiál comparison

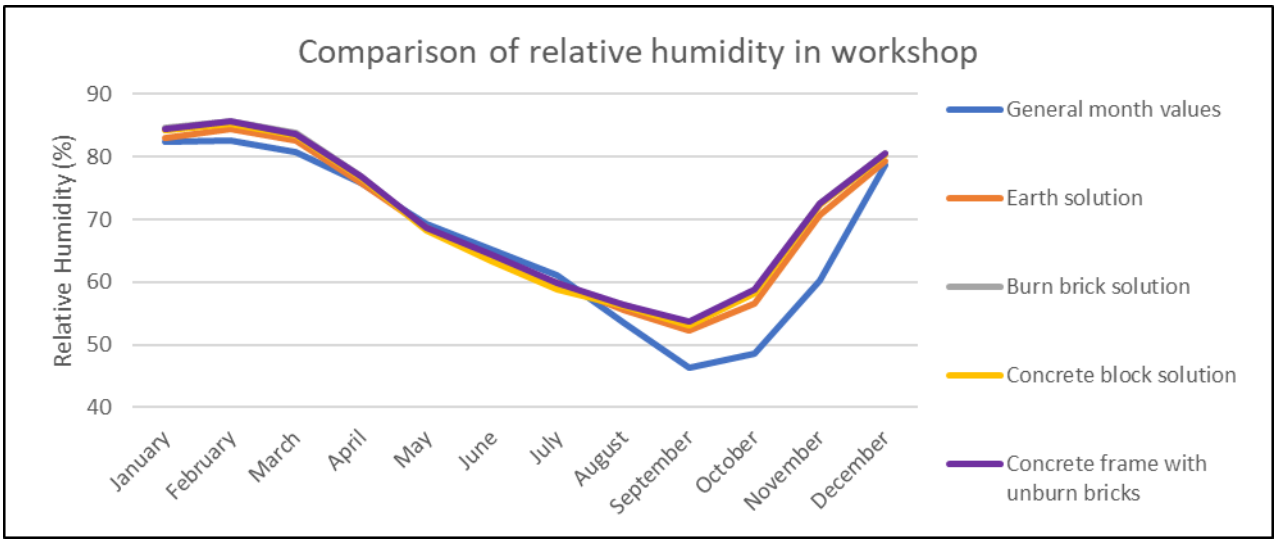
Earth solution	Air Temperature (°C)	Radiant Temperature (°C)	Operative Temperature (°C)	Relative Humidity (%)
January	24,87	24,86	24,87	83,05
February	24,52	24,49	24,5	84,45
March	24,85	24,83	24,84	82,5
April	24,01	24,04	24,03	75,85
May	22,92	22,9	22,91	68,58
June	21,8	21,83	21,82	63,84
July	21,17	21,15	21,16	59,95
August	23,41	23,31	23,36	55,49
September	25,64	25,52	25,58	52,34
October	27,7	27,61	27,65	56,6
November	26,61	26,58	26,59	70,71
December	24,98	25	24,99	79,39
Burn brick solution	Air Temperature (°C)	Radiant Temperature (°C)	Operative Temperature (°C)	Relative Humidity (%)
January	24,65	24,62	24,63	84,58
February	24,34	24,29	24,32	85,63
March	24,62	24,58	24,6	83,78
April	23,76	23,77	23,76	76,93
May	22,85	22,82	22,84	68,5
June	21,78	21,79	21,79	63,59
July	21,17	21,13	21,15	59,09
August	23,33	23,21	23,27	56,31
September	25,41	25,26	25,34	53,36
October	27,37	27,24	27,3	58,58
November	26,32	26,25	26,29	72,61
December	24,79	24,79	24,79	80,61
Concrete block solution	Air Temperature (°C)	Radiant Temperature (°C)	Operative Temperature (°C)	Relative Humidity (%)
January	24,73	24,72	24,72	84,26
February	24,42	24,38	24,4	85,28
March	24,7	24,67	24,69	83,4
April	23,85	23,86	23,85	76,68
May	22,93	22,92	22,92	68,22
June	21,91	21,95	21,93	63,28
July	21,29	21,27	21,28	58,79
August	23,4	23,29	23,35	56,18
September	25,46	25,32	25,39	53,05
October	27,39	27,26	27,32	58,3
November	26,38	26,32	26,35	72,39
December	24,86	24,88	24,87	80,26

Concrete frame with unburn bricks	Air Temperature (°C)	Radiant Temperature (°C)	Operative Temperature (°C)	Relative Humidity (%)
January	24,71	24,67	24,69	84,41
February	24,42	24,34	24,38	85,67
March	24,71	24,65	24,68	83,57
April	23,83	23,82	23,83	76,82
May	22,78	22,73	22,76	68,58
June	21,57	21,55	21,56	64,37
July	20,98	20,91	20,94	59,8
August	23,34	23,19	23,26	56,35
September	25,55	25,39	25,47	53,68
October	27,64	27,49	27,57	58,76
November	26,51	26,42	26,46	72,46
December	24,87	24,86	24,86	80,45

Tab. 1: Workshop situation data



Pic. 1: Comparison of air temperatures in workshop

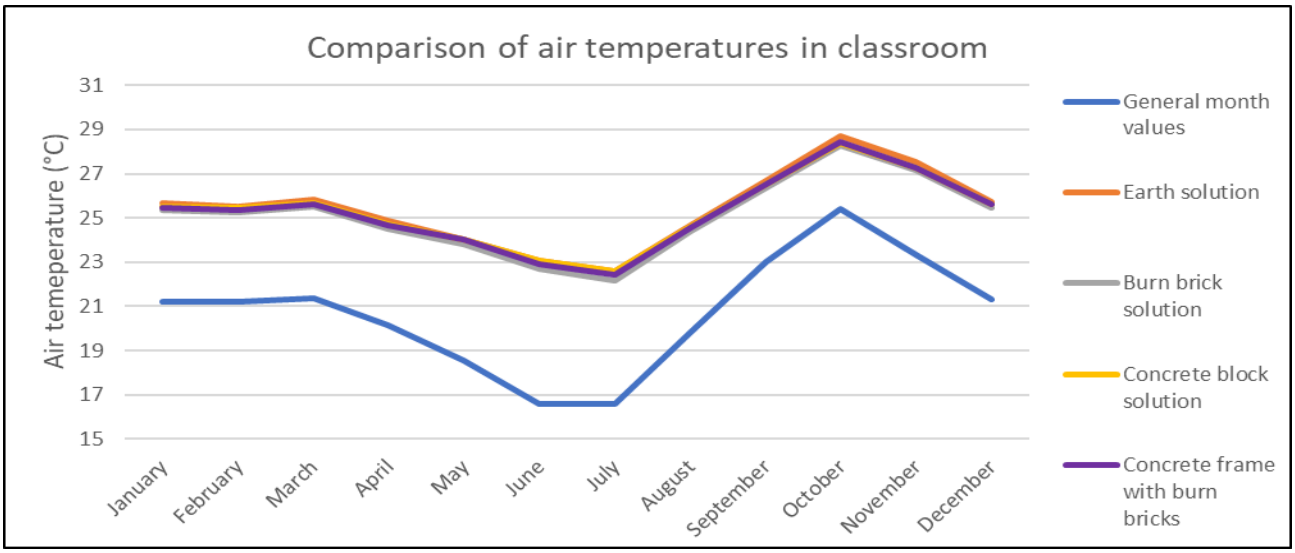


Pic. 2: Comparison of relative humidity in workshop

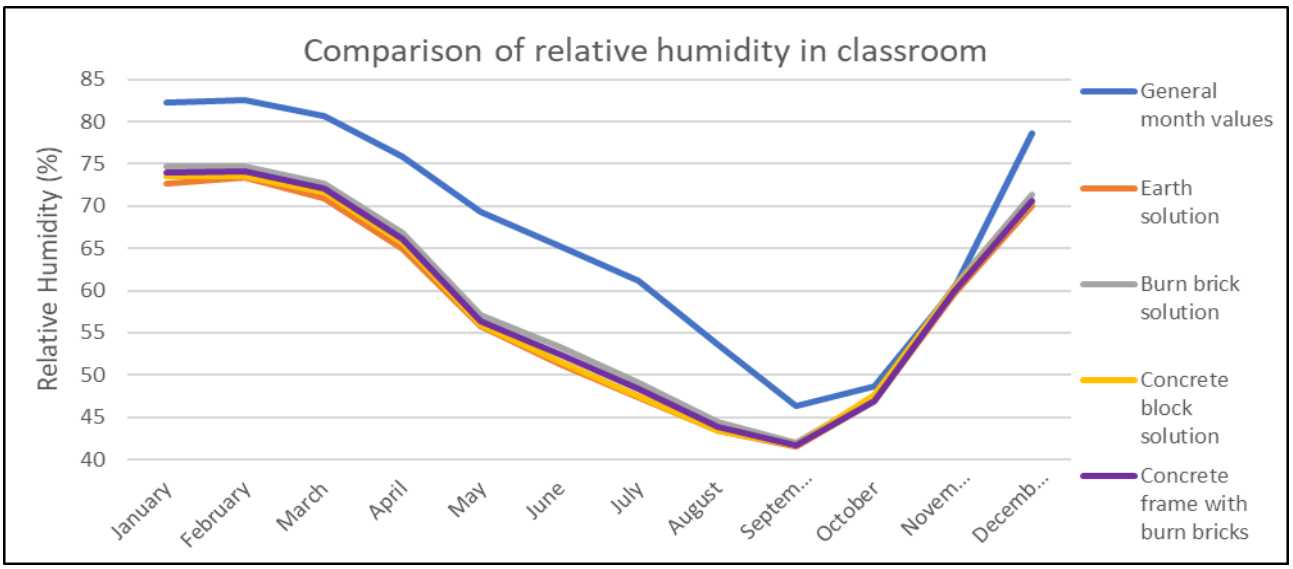
Earth solution	Air Temperature (°C)	Radiant Temperature (°C)	Operative Temperature (°C)	Relative Humidity (%)
January	25,69	25,89	25,79	72,63
February	25,53	25,66	25,59	73,39
March	25,82	26,01	25,91	70,98
April	24,9	25,14	25,02	64,91
May	24,05	24,2	24,13	55,73
June	23,08	23,22	23,15	51,28
July	22,6	22,59	22,6	47,39
August	24,66	24,66	24,66	43,39
September	26,69	26,73	26,71	41,52
October	28,71	28,76	28,73	46,91
November	27,54	27,72	27,63	59,62
December	25,74	26,01	25,87	69,99
Burn brick solution	Air Temperature (°C)	Radiant Temperature (°C)	Operative Temperature (°C)	Relative Humidity (%)
January	25,35	25,38	25,36	74,64
February	25,27	25,23	25,25	74,67
March	25,5	25,5	25,5	72,68
April	24,53	24,58	24,55	66,79
May	23,82	23,79	23,8	57,16
June	22,71	22,72	22,71	53,25
July	22,19	22,09	22,14	49,11
August	24,4	24,23	24,32	44,4
September	26,39	26,23	26,31	42
October	28,26	28,13	28,19	47,39
November	27,14	27,13	27,13	60,37
December	25,47	25,55	25,51	71,38
Concrete block solution	Air Temperature (°C)	Radiant Temperature (°C)	Operative Temperature (°C)	Relative Humidity (%)
January	25,5	25,64	25,57	73,52
February	25,45	25,53	25,49	73,57
March	25,69	25,8	25,75	71,62
April	24,73	24,89	24,81	65,73
May	24,05	24,13	24,09	55,94
June	23,08	23,19	23,14	51,64
July	22,6	22,59	22,59	47,51
August	24,62	24,55	24,58	43,46
September	26,54	26,49	26,51	41,64
October	28,4	28,35	28,38	47,64
November	27,28	27,38	27,33	60,21
December	25,61	25,8	25,7	70,47

Concrete frame with burn bricks	Air Temperature (°C)	Radiant Temperature (°C)	Operative Temperature (°C)	Relative Humidity (%)
January	25,48	25,55	25,52	74,02
February	25,37	25,37	25,37	74,13
March	25,62	25,66	25,64	72,07
April	24,68	24,78	24,73	66,09
May	24,01	24,05	24,03	56,42
June	22,93	23	22,97	52,43
July	22,41	22,36	22,38	48,38
August	24,58	24,47	24,52	43,91
September	26,54	26,42	26,48	41,64
October	28,42	28,34	28,38	46,95
November	27,28	27,33	27,3	59,9
December	25,61	25,75	25,68	70,61

Tab. 2: Classroom situation data



Pic. 3: Comparison of air temperatures in classroom

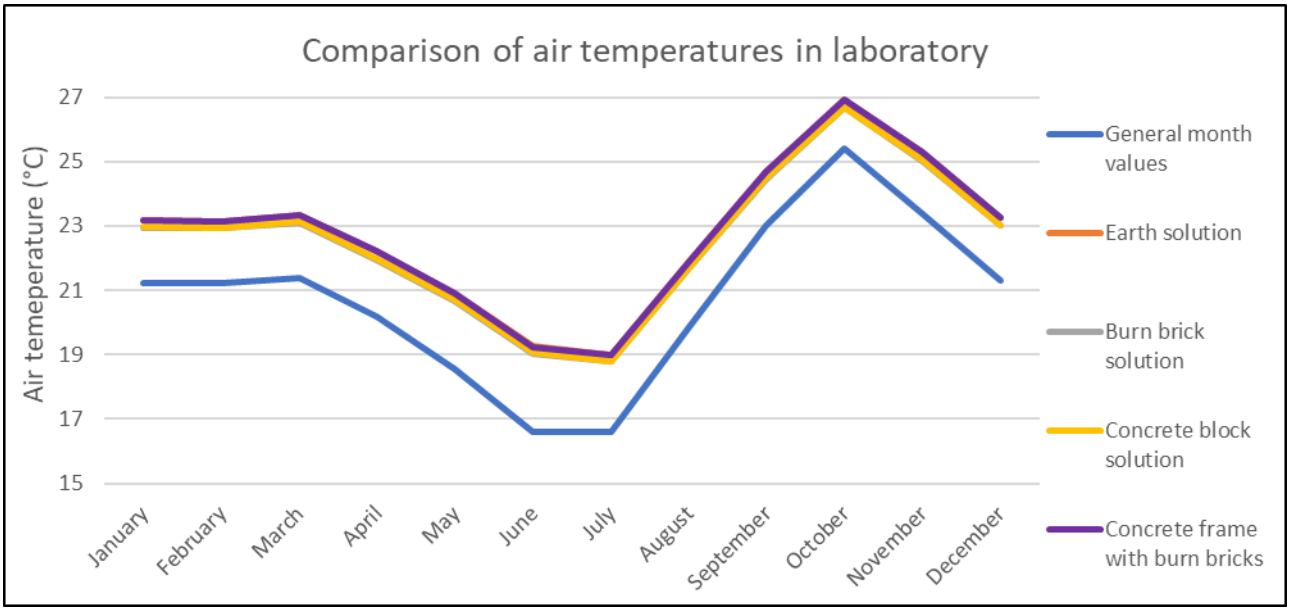


Pic. 4: Comparison of relative humidity in classroom

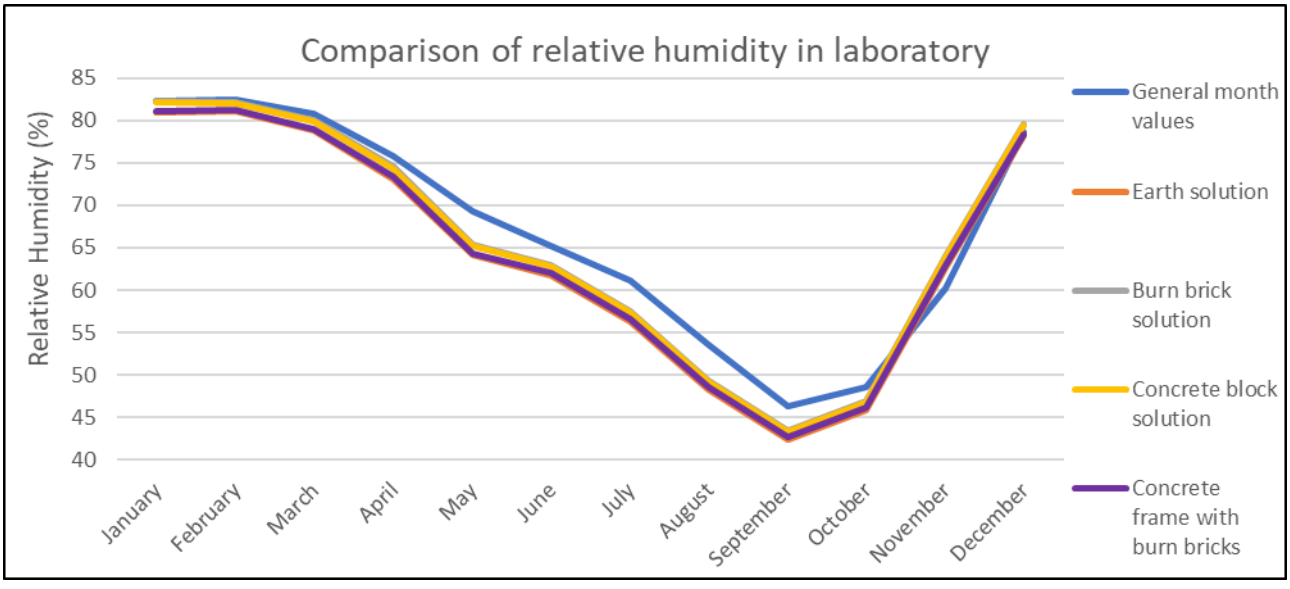
Earth solution	Air Temperature (°C)	Radiant Temperature (°C)	Operative Temperature (°C)	Relative Humidity (%)
January	23,19	24,4	23,8	80,97
February	23,13	24,23	23,68	81,04
March	23,35	24,53	23,94	78,75
April	22,23	23,53	22,88	73,07
May	20,91	22,26	21,58	64,1
June	19,26	20,87	20,06	61,72
July	18,99	20,36	19,67	56,31
August	21,92	22,97	22,45	48,25
September	24,7	25,51	25,1	42,44
October	26,93	27,68	27,31	45,85
November	25,3	26,35	25,83	62,66
December	23,25	24,46	23,86	78,18
Burn brick solution	Air Temperature (°C)	Radiant Temperature (°C)	Operative Temperature (°C)	Relative Humidity (%)
January	22,95	24	23,47	82,31
February	22,92	23,89	23,41	82,2
March	23,11	24,14	23,63	80,05
April	21,95	23,08	22,52	74,52
May	20,68	21,93	21,3	65,36
June	19,03	20,53	19,78	63,02
July	18,77	20,06	19,42	57,51
August	21,7	22,64	22,17	49,34
September	24,46	25,11	24,78	43,41
October	26,67	27,22	26,94	46,89
November	25,02	25,88	25,45	64,01
December	23,01	24,07	23,54	79,53
Concrete block solution	Air Temperature (°C)	Radiant Temperature (°C)	Operative Temperature (°C)	Relative Humidity (%)
January	22,97	24,04	23,5	82,14
February	22,95	23,93	23,44	82,03
March	23,14	24,19	23,66	79,87
April	21,98	23,12	22,55	74,32
May	20,7	21,94	21,32	65,19
June	19,05	20,55	19,8	62,82
July	18,8	20,08	19,44	57,3
August	21,72	22,67	22,19	49,15
September	24,49	25,15	24,82	43,24
October	26,7	27,26	26,98	46,73
November	25,05	25,93	25,49	63,81
December	23,02	24,09	23,55	79,39
Concrete frame with burn bricks	Air Temperature (°C)	Radiant Temperature (°C)	Operative Temperature (°C)	Relative Humidity (%)

January	23,18	24,42	23,8	81,15
February	23,12	24,25	23,68	81,21
March	23,34	24,55	23,95	78,93
April	22,21	23,54	22,87	73,32
May	20,9	22,3	21,6	64,38
June	19,24	20,88	20,06	62,07
July	18,97	20,38	19,67	56,67
August	21,91	23,02	22,47	48,55
September	24,69	25,53	25,11	42,71
October	26,93	27,71	27,32	46,1
November	25,29	26,38	25,84	62,94
December	23,26	24,51	23,89	78,3

Tab. 3: Laboratory situation data



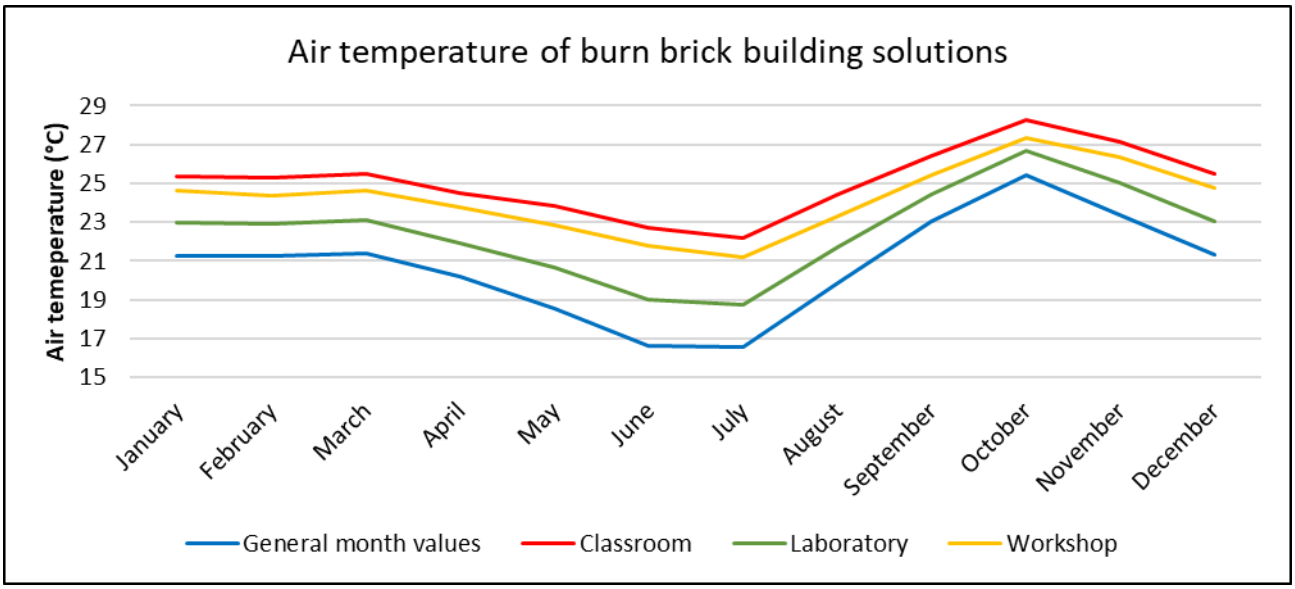
Pic. 5: Comparison of air temperatures in laboratory



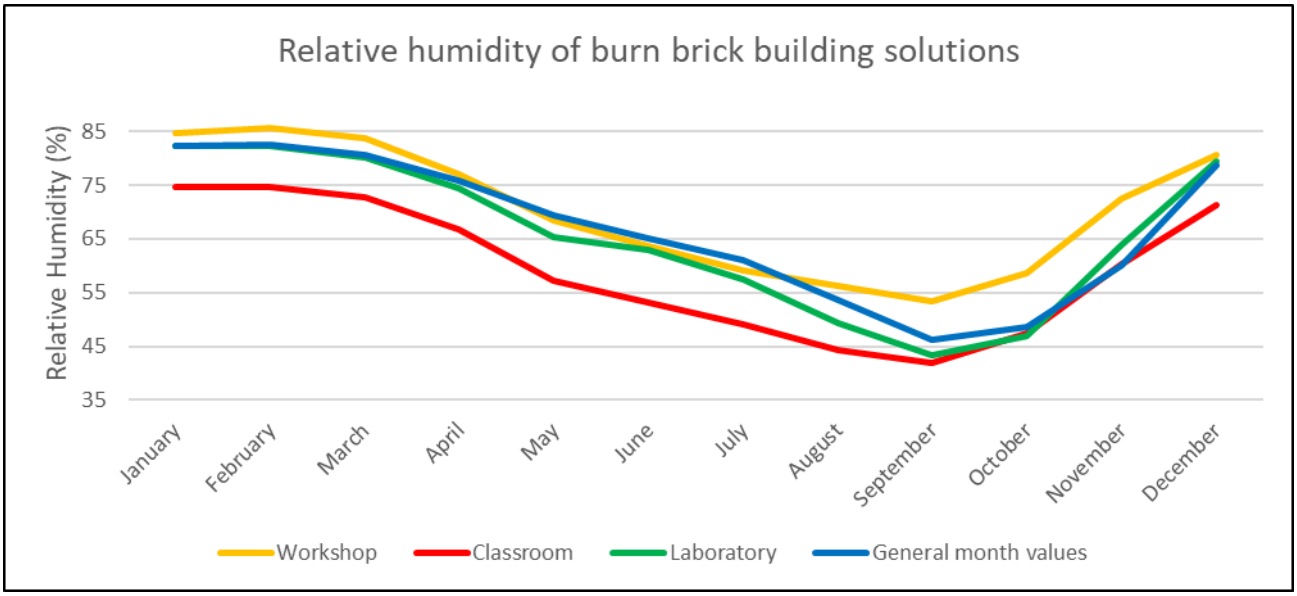
Pic. 6: Comparison of relative humidity in laboratory

Note:

On the following graphs is shown, how the temperature and the relative humidity is changing for the different use of the building in the case of Burn bricks building. This graph is shown only for presenting the differences between different uses of the building.



Pic. 7: Comparison of air temperature in different use of the building in case of burn brick wall solution



Pic. 8: Comparison of relative humidity in different use of the building in case of burn brick wall solution

Annex 3 – Sustainability assessment tool

Environmental parameters						
Material	GWP [kg CO_2-eq]	AP [kg SO_2-eq]	POCP [kg ethylene eq]	EP [kg PO4-eq]	ODP [kg CFC-11 eq]	Embodied energy [MJ]
Rammed earth	0,00E+00	8,80E-04	7,10E-05	2,20E-04	3,80E-07	2,00E+00
CEB	9,60E-02	3,00E-04	2,20E-05	3,70E-05	3,00E-07	7,00E-01
Burn bricks	5,70E-01	4,90E-02	2,20E-04	3,40E-04	4,20E-07	6,30E+00
Concrete blocks	2,90E-01	1,20E-02	6,10E-05	1,20E-04	2,50E-06	2,70E+00
Concrete	1,10E-01	2,70E-03	1,90E-04	3,40E-04	2,80E-06	8,70E-01
Reinforcement steel	2,60E+00	1,10E-02	6,10E-04	6,50E-04	1,50E-05	3,00E+01

Summary	Volume density [kg/m2]	GWP [kg CO_2-eq]	AP [kg SO_2-eq]	POCP [kg ethylene eq]	EP [kg PO4-eq]	ODP [kg CFC-11 eq]	Embodied energy [MJ]
Rammed earth	570	0,00E+00	5,02E-01	4,05E-02	1,25E-01	2,17E-04	1,14E+03
CEB	560	5,38E+01	1,68E-01	1,23E-02	2,07E-02	1,68E-04	3,92E+02
Burn bricks	194	1,10E+02	9,49E+00	4,26E-02	6,58E-02	8,13E-05	1,22E+03
Concrete blocks	196	5,68E+01	2,35E+00	1,20E-02	2,35E-02	4,90E-04	5,29E+02
Concrete frame + CEB	308	6,78E+00	1,66E-01	1,17E-02	2,09E-02	1,72E-04	5,36E+01

Tab. 1: Basic environmental values

Amount of the material used in the locality				
Solution	Quantity of material (%)		Transportation (km)	Transportation (Kg*km)
Rammed earth	Soil	100	0	0
CEB	Soil	90	0	5040
	Cement	10	90	
Burn bricks	Soil	100	0	0
Concrete blocks	Sand	60	10	8232
	Cement	40	90	
Concrete frame + CEB	Soil	87	0	3599
	Cement	13	90	

Tab. 2: Amount of the material used in the locality

Use and degradation of the land			
Solution	Amount of material (kg)		Use of area m2
Rammed earth	Soil	513	0,17
CEB	Soil	560	0,19
Burn bricks	Soil to burn	174	34,16
Concrete blocks	Transported materials		0,00
Concrete frame + CEB	Soil	448	0,15

Tab. 3: Use and degradation of the land

Environmental Performance									
Solution	**GWP**	**AP**	**POCP**	**EP**	**ODP**	**FFDP**	**Transportation**	**Use**	**IA(Normalization)**
Rammed earth	1,00	0,96	0,07	0,00	0,67	0,07	1,00	0,99	0,83
CEB	0,51	1,00	0,98	1,00	0,79	0,71	1,00	0,99	0,89
Burn bricks	0,00	0,00	0,00	0,57	1,00	0,00	1,00	0,00	0,28
Concrete blocks	0,48	0,77	0,99	0,97	0,00	0,59	0,00	1,00	0,63
Concrete frame + CEB	0,94	1,00	1,00	1,00	0,78	1,00	0,56	1,00	0,89

Tab. 4: Normalized environmental performance (red = worst solution, green = best solution)

Economic performance:

Rammed earth				
Unit	Description	Amount (ZMW)	Unit price (ZMW)	Summary (ZMW)
m²	Average cost of m2 of rammed earth	1,000	1192,00	1192,00
h	placing the soil to the framework	0,330	-	-
h	ramming	0,116	-	-
h	Working hours framework (attach and disable)	1,686	-	-
%	Complementary direct costs	2,000	1192,00	23,84
Summary	Hours	2,13	Total cost:	1215,84

CEB wall				
Unit	Description	Amount (ZMW)	Unit price (ZMW)	Summary (ZMW)
Ud	CEB blocks, 2x90x140x280	71,000	2,12	150,29
kg	Grey cement in bags	14,780	1,97	29,12
h	Working hours masonry	3,570	-	-
kg	Indoor cement mortar for cement plaster th. 15 mm	12,500	1,45	18,13
h	Working hours interior plastering	0,712	-	-
kg	Indoor cement mortar for cement plaster th. 20 mm	32,000	1,45	46,40
h	Working hours interior plastering	0,943	-	-
%	Complementary direct costs	2,000	243,94	4,88
Summary	Hours	5,23	Total:	248,82

Burn brick wall				
Unit	Description	Amount (ZMW)	Unit price (ZMW)	Summary (ZMW)
Ud	Burn bricks, 110x130x280	28,750	1,50	43,13
kg	Grey cement in bags	7,715	1,97	15,20
h	Working hours masonry	1,700	-	-
kg	Indoor cement mortar for cement plaster th. 15 mm	12,500	1,45	18,13
h	Working hours interior plastering	0,712	-	-
kg	Indoor cement mortar for cement plaster th. 20 mm	32,000	1,45	46,40
h	Working hours interior plastering	0,943	-	-
%	Complementary direct costs	2,000	122,85	2,46
Summary	Hours	3,36	Total:	125,31

Concrete block wall				
Unit	Description	Amount (ZMW)	Unit price (ZMW)	Summary (ZMW)
Ud	Concrete blocks, 140x190x390	12,500	5,00	62,50
kg	Grey cement in bags	4,950	1,97	9,75
h	Working hours masonry	1,296	-	-
kg	Indoor cement mortar for cement plaster th. 15 mm	12,500	1,45	18,13
h	Working hours interior plastering	0,712	-	-
kg	Indoor cement mortar for cement plaster th. 20 mm	32,000	1,45	46,40
h	Working hours interior plastering	0,943	-	-
%	Complementary direct costs	2,000	136,78	2,74
Summary	Hours	2,95	Total:	139,52
Concrete frame + CEB wall				
Unit	Description	Amount (ZMW)	Unit price (ZMW)	Summary (ZMW)
m	Wood for formwork, 26 mm thick.	4,000	4,50	18,00
kg	Stainless steel nails.	0,168	21,50	3,61
h	Working hours formwork	1,033	-	-
m	Steel reinforcement	2,339	25,83	60,42
kg	Steel wire	0,611	20,00	12,22
kg	Grey cement in bags	24,500	14,10	345,45
h	Working hours concrete pillar	2,990	-	-
Ud	CEB blocks, 90x140x280	28,400	2,12	60,12
kg	Grey cement in bags	5,912	1,97	11,65
h	Working hours masonry	1,428	-	-
kg	Indoor cement mortar for cement plaster th. 15 mm	12,500	1,45	18,13
h	Working hours interior plastering	0,712	-	-
kg	Indoor cement mortar for cement plaster th. 20 mm	32,000	1,45	46,40
h	Working hours interior plastering	0,943	-	-
%	Complementary direct costs	2,000	136,29	2,73
Summary	Hours	7,11	Total:	578,72

Tab. 5: Construction cost and working hours for every solution of construction systems

Summary:

Solution	**Construction cost (ZMW)**	**Working hours (h)**
Rammed earth	1 216	2,13
CEB	249	5,23
Burn bricks	125	3,36
Concrete blocks	140	2,95
Concrete frame + CEB	579	7,11

Tab. 6: Summary of construction cost and working hours for every solution of construction system

Economic performance			
Solution	**Construction cost**	**Working hours (**	**IF (Normalization)**
Rammed earth	0,00	0,00	0,00
CEB	0,89	0,62	0,78
Burn bricks	1,00	0,25	0,70
Concrete blocks	0,99	0,16	0,66
Concrete frame + CEB	0,58	1,00	0,75

Tab. 7: Normalized economic performance (red = worst solution, green = best solution)

Functional performance:

Solution	**Dn,w (dB)**	**c ([J/K].C)**	**Moisture resistance (kg/m2h0,5)**	**Lifespan (years)**	**Experience by local people (-)**
Rammed earth	57,00	501 600	2,70	49,00	0,00
CEB	57,00	470 400	2,70	70,00	0,80
Burn bricks	45,00	162 624	25,10	70,00	1,00
Concrete blocks	47,00	196 000	1,80	75,00	1,00
Concrete frame + CEB	45,00	271 740	2,80	70,00	0,70

Tab. 8: Functional parameters for every solution of construction system

Functional performance						
Solution	**Dn, w**	**c**	**Moisture resistance**	**Lifespan**	**Experience by local people**	**IA(Normalization)**
Rammed earth	1,00	1,00	0,96	0,00	0,00	0,49
CEB	1,00	0,91	0,96	0,81	0,80	0,88
Burn bricks	0,00	0,00	0,00	0,81	1,00	0,45
Concrete blocks	0,17	0,10	1,00	1,00	1,00	0,74
Concrete frame + CEB	0,00	0,32	0,96	0,81	0,70	0,60

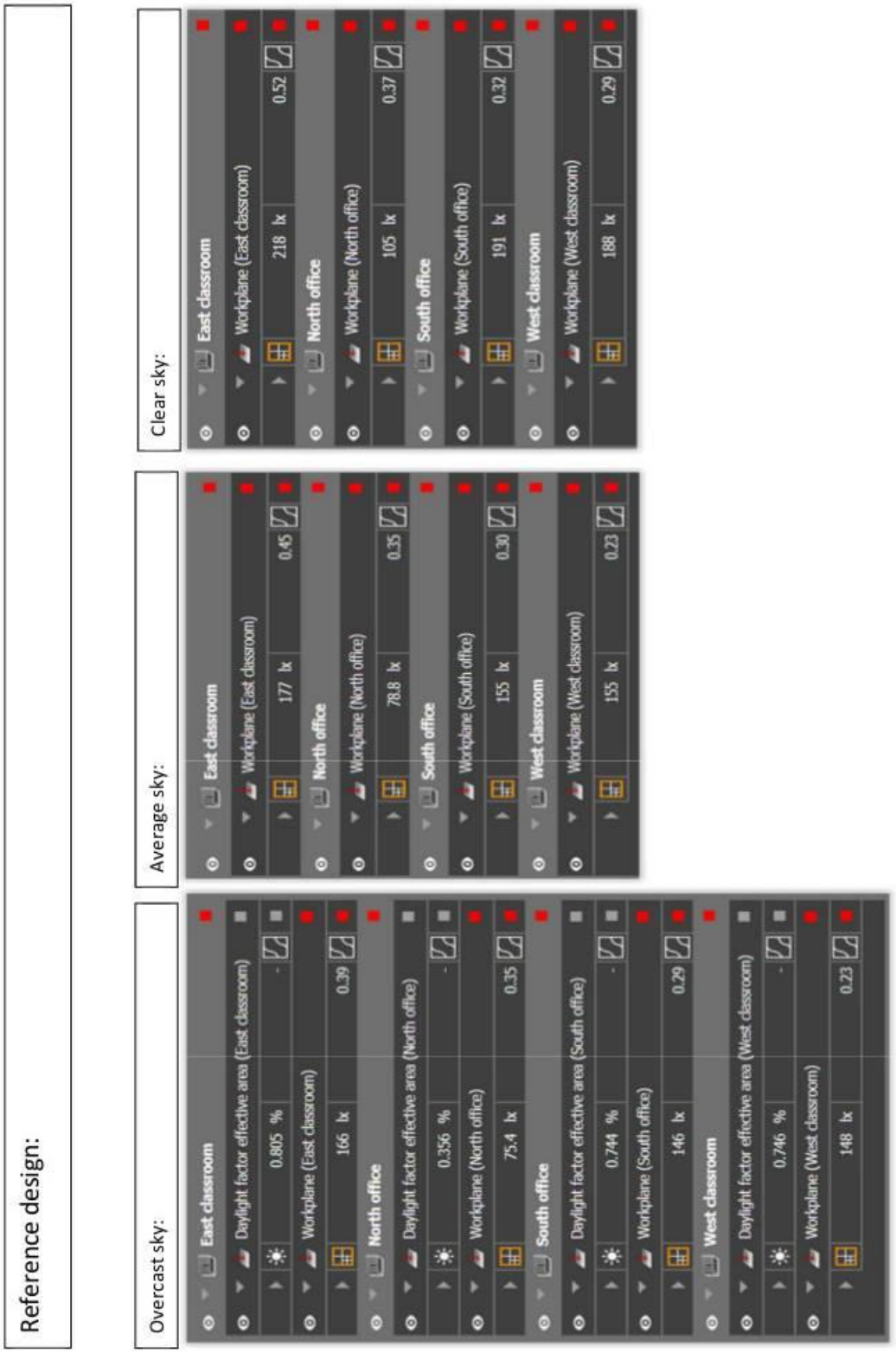
Tab. 9: Normalized functional performance (red = worst solution, green = best solution)

Total environmental score:

Sustainable score	**Functional**	**Environmental**	**Economic**	**NS**
Weights (%)	50	20	30	100
Rammed earth	0,49	0,83	0,00	0,41
CEB	0,88	0,89	0,78	0,86
Burn bricks	0,45	0,28	0,70	0,49
Concrete blocks	0,74	0,63	0,66	0,70
Concrete frame + CEB	0,60	0,89	0,75	0,70

Tab. 10: Total environmental score (red = worst solution, green = best solution)

Annex 4 – DIALux evo calculation for classroom building



Improved geometry:

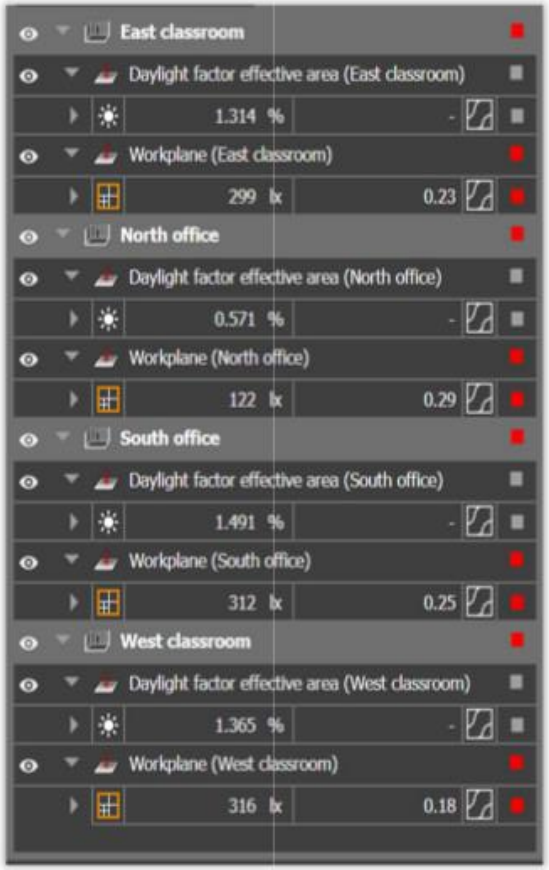
Overcast sky:

Average sky:

Clear sky:

Vertical roof windows:

Overcast sky:



Average sky:

Clear sky:

Transparent roof sheet:

Overcast sky:

Average sky:

Clear sky:

Annex 5 – Acoustic calculation of the classroom

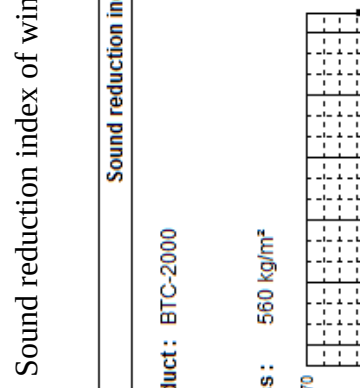
Airbourne sound insulation:

Sound reduction index of windows

Sound reduction index

Product : BTC-2000

Mass : 560 kg/m²



Freq.	R
Hz	dB
100	41.0
125	42.4
160	43.9
200	45.0
250	46.4
315	47.8
400	49.0
500	50.4
630	51.9
800	53.1
1000	54.4
1250	54.3
1600	53.1
2000	51.8
2500	50.6
3150	55.8
4000	60.9
5000	63.7

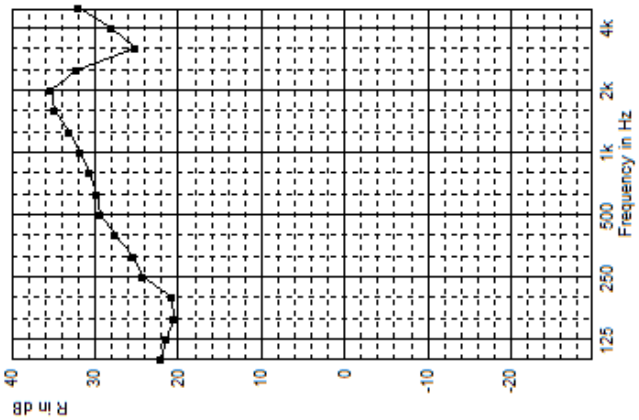
R_w (C_i;C_{tr}) = 53 (-1;-3) dB
R_{nose} = 53 dB(A)
R_{route} = 50 dB(A)

Values estimated from laboratory measurements.
Data supplied by user

Sound reduction index of solid wall

Sound reduction index

Product : vidrio 4 mm

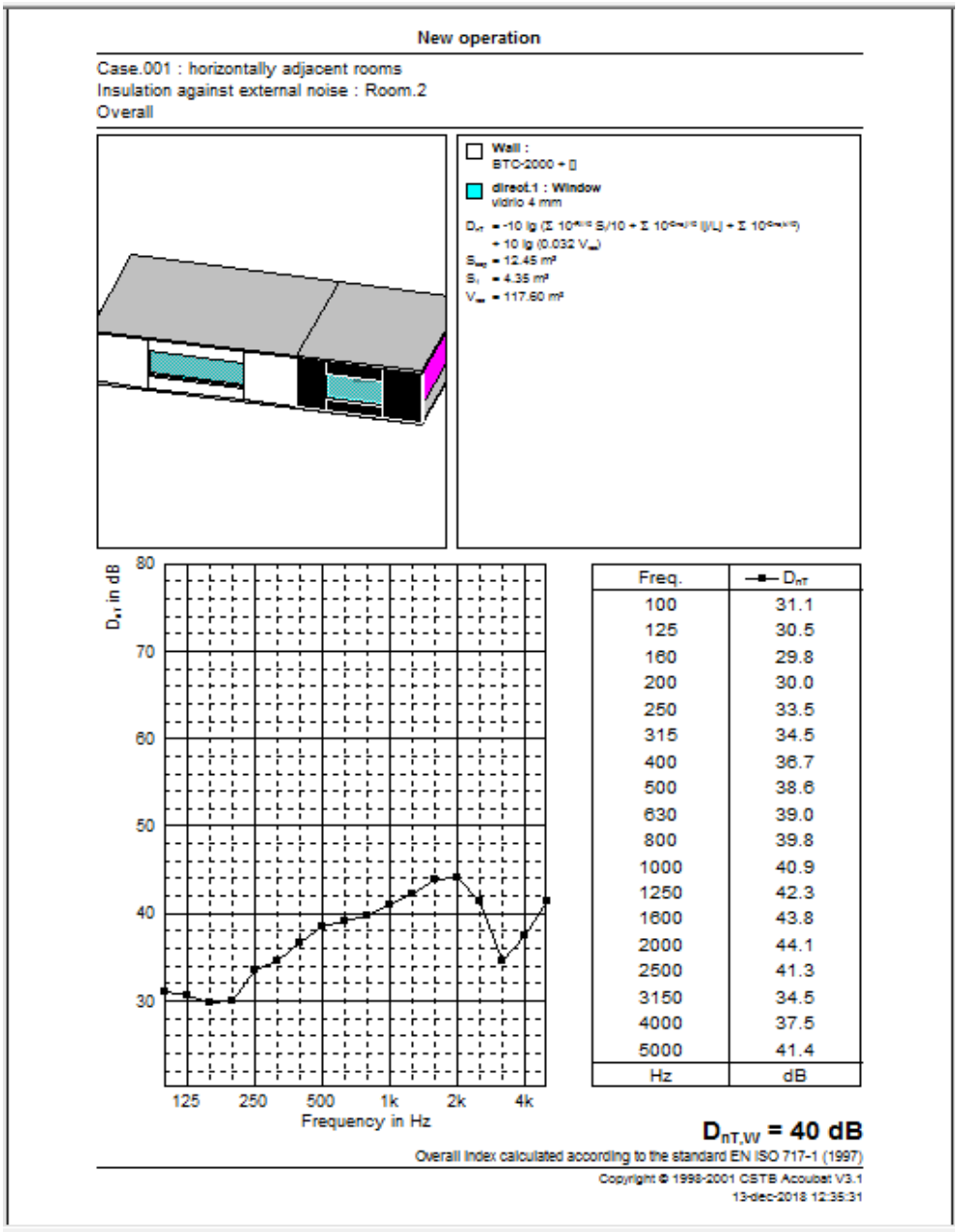


Freq.	R
Hz	dB
100	22.1
125	21.4
160	20.6
200	20.7
250	24.3
315	25.3
400	27.5
500	29.4
630	29.8
800	30.6
1000	31.7
1250	33.1
1600	34.8
2000	35.2
2500	32.3
3150	25.1
4000	28.1
5000	32.0

R_w (C_i;C_{tr}) = 31 (-2;-3) dB
R_{nose} = 29 dB(A)
R_{route} = 28 dB(A)

Values estimated from laboratory measurements.
Data supplied by user

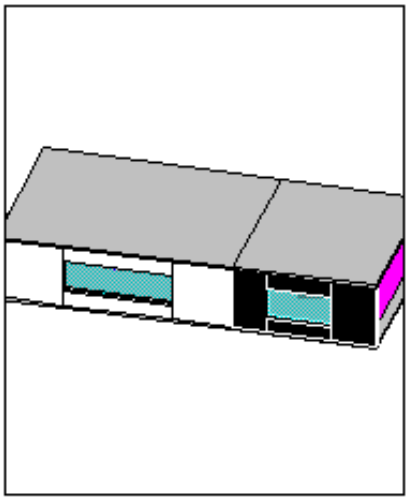
First, the Airborne sound insulation was computed for the outside wall with windows.



After that, the airborne insulation between classroom and teachers offices was computed.

New operation

Case.001 : horizontally adjacent rooms
Insulation against horizontal airborne noise : Room.1 => Room.2
Overall



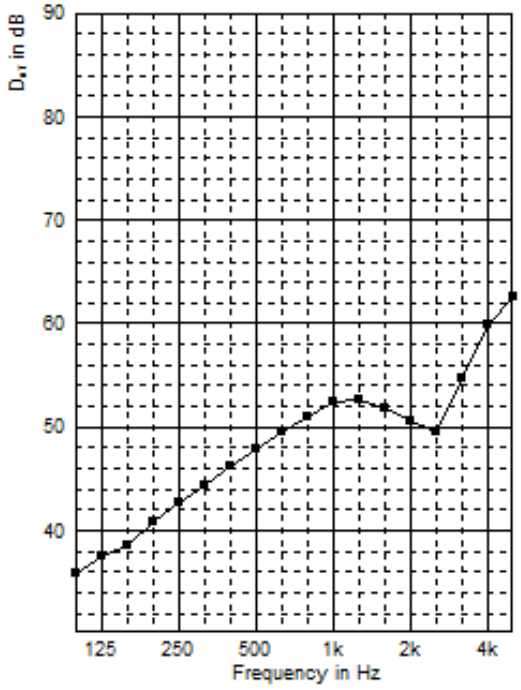
Direct : Structural supporting wall
BTC-2000

Lateral.1 : Floor
béton 12 cm + ▯x2

Lateral.2 : Internal partition
BTC-2000

Lateral.3 : Floor
béton 12 cm

Lateral.4 :
BTC-2000 + ▯x2



Freq.	D_{nT}
100	35.8
125	37.6
160	38.6
200	40.9
250	42.8
315	44.4
400	46.1
500	47.8
630	49.5
800	51.0
1000	52.4
1250	52.6
1600	51.7
2000	50.6
2500	49.6
3150	54.8
4000	59.9
5000	62.7
Hz	dB

$D_{nT,W}$ = 50 dB

Overall index calculated according to the standard EN ISO 717-1 (1997)

13-dec-2018 12:36:04

Calculation of Reverberation time for classroom

Areas	a (m)	b (m)	number	S (m^2)	S_{clear} (m^2)
Door	0,9	2	1	1,8	**1,8**
Cealing (one side)	9,94	4,367	2	86,8	**86,8**
Floor	9,94	7,42	1	73,8	**73,8**
Window north side	1,12	1,5	4	6,7	**6,7**
Window south side	1,12	1,5	5	8,4	**8,4**
Wall first dimension	9,94	3,6	2	54,6	**37,7**
Wall first dimension	7,42	3,6	2	53,4	**53,4**

Tab. 1: Classroom properties

Surface	**α_m (-)**	**f (Hz)**					
Area (m^2)	**A_i (m^2)**	**125**	**250**	**500**	**1000**	**2000**	**4000**
Lime plaster	α_{m1} (-)	0,02	0,02	0,03	0,04	0,05	0,05
178,0	A_1 (m^2)	**3,56**	**3,56**	**5,34**	**7,12**	**8,90**	**8,90**
Simple window 6 mm	α_{m2} (-)	0,1	0,06	0,04	0,03	0,02	0,02
15,1	A_2 (m^2)	**1,51**	**0,91**	**0,60**	**0,45**	**0,30**	**0,30**
Concrete floor	α_{m3} (-)	0,02	0,03	0,03	0,03	0,04	0,07
73,8	A_3 (m^2)	**1,48**	**2,21**	**2,21**	**2,21**	**2,95**	**5,16**
Door	α_{m4} (-)	0,14	0,1	0,06	0,08	0,1	0,1
1,8	A_4 (m^2)	**0,25**	**0,18**	**0,11**	**0,14**	**0,18**	**0,18**
Occupants seated	A_{i5} (m^2)	0,16	0,24	0,56	0,69	0,81	0,78
51	A_5 (m^2)	**8,16**	**12,24**	**28,56**	**35,19**	**41,31**	**39,78**
Desk	A_{i6} (m^2)	0,5	0,4	0,45	0,45	0,6	0,7
51	A_6 (m^2)	**25,50**	**20,40**	**22,95**	**22,95**	**30,60**	**35,70**
SUMMARY	A (m^2)	**40,46**	**39,50**	**59,77**	**68,07**	**84,24**	**90,02**
Sabina	α_S (-)	**0,15**	**0,15**	**0,22**	**0,25**	**0,31**	**0,34**
Eyring	α_E (-)	**0,16**	**0,16**	**0,25**	**0,29**	**0,38**	**0,41**
Absorbtion in the air	m (m^{-1})	0,00	0,00	0,00	0,00	0,00	0,00
	4mV (m^{-1})	0,00	0,00	0,00	0,00	0,00	0,00
Sabina	T_S (s)	1,51	1,54	1,02	0,90	0,72	0,68
Eyring	T_E (s)	**1,39**	**1,43**	**0,90**	**0,78**	**0,60**	**0,56**
	T_0 (s)	**0,647**					
	T_E/T_0	**2,15**	**2,21**	**1,39**	**1,20**	**0,93**	**0,86**
$T_{limit,\ down}$ (s)		0,65	0,8	0,8	0,8	0,8	0,65
$T_{limit,\ upper}$ (s)		1,2	1,2	1,2	1,2	1,2	1,2
		NOT OK	NOT OK	NOT OK	NOT OK	OK	OK
Resolution		**NOT APPROVED**					

Tab. 2: First calculation of reverberation time without any adjustments

Surface	**α_m (-)**	**f (Hz)**					
Area (m^2)	**A_i (m^2)**	**125**	**250**	**500**	**1000**	**2000**	**4000**
Lime plaster	α_{m1} (-)	0,02	0,02	0,03	0,04	0,05	0,05
91,2	A_1 (m^2)	**1,82**	**1,82**	**2,73**	**3,65**	**4,56**	**4,56**
Simple window 6 mm	α_{m2} (-)	0,1	0,06	0,04	0,03	0,02	0,02
73,8	A_2 (m^2)	**9,12**	**5,47**	**3,65**	**2,73**	**1,82**	**1,82**
Concrete floor	α_{m3} (-)	0,02	0,03	0,03	0,03	0,04	0,07
1,8	A_3 (m^2)	**1,48**	**2,21**	**2,21**	**2,21**	**2,95**	**5,16**
Door	α_{m4} (-)	0,14	0,1	0,06	0,08	0,1	0,1
73,8	A_4 (m^2)	**0,25**	**0,18**	**0,11**	**0,14**	**0,18**	**0,18**
Occupants seated	A_{i5} (m^2)	0,16	0,24	0,56	0,69	0,81	0,78
51	A_5 (m^2)	**8,16**	**12,24**	**28,56**	**35,19**	**41,31**	**39,78**
Desk	A_{i6} (m^2)	0,5	0,4	0,45	0,45	0,6	0,7
51	A_6 (m^2)	**25,50**	**20,40**	**22,95**	**22,95**	**30,60**	**35,70**
Reed ceeling	α_{mt1} (-)	0,25	0,43	0,92	0,66	0,65	0,69
86,8	At_1 (m^2)	**21,70**	**37,33**	**79,87**	**57,30**	**56,43**	**59,90**
SUMMARY	A (m^2)	**68,03**	**79,66**	**140,08**	**124,18**	**137,85**	**147,11**
Sabina	α_S (-)	**0,25**	**0,30**	**0,52**	**0,46**	**0,51**	**0,55**
Eyring	α_E (-)	**0,29**	**0,35**	**0,74**	**0,62**	**0,72**	**0,79**
Absorbtion in the air	m (m^{-1})	0,00	0,00	0,00	0,00	0,00	0,00
	4mV (m^{-1})	0,00	0,00	0,00	0,00	0,00	0,00
Sabina	T_S (s)	0,90	0,77	0,44	0,49	0,44	0,41
Eyring	T_E (s)	**0,78**	**0,65**	**0,31**	**0,37**	**0,32**	**0,29**
	T_0 (s)	**0,7**					
	T_E/T_0	**1,11**	**0,92**	**0,44**	**0,52**	**0,45**	**0,41**
$T_{limit,\ down}$ (s)		0,65	0,8	0,8	0,8	0,8	0,65
$T_{limit,\ upper}$ (s)		1,2	1,2	1,2	1,2	1,2	1,2
		OK	OK	NOT OK	NOT OK	NOT OK	NOT OK
Resolution		**APPROVED**					

Tab. 3: Second calculation with influence of reed ceiling covering

Annex 6 - Natural ventilation calculation

By simple calculation we can determine needed airflow rate, that will ensure fulfilling requested limit. Considering ASHRAE standard we can assume following formula for needed airflow rate:

$$Ve = \frac{m_{CO2}}{(\Psi_{max} - \Psi_e) \times 10^{-3}} \text{ [m}^3\text{/h]}$$

m_{CO2}: production of CO2 by one person according to its activity

Ψ_{max}: maximum concentration of CO2

Ψ_e: CO2 concentration in outside air

In following calculation, if the needed airflow rate fill be achieved, room will be considered as approved by this regulation.

Example of calculation for classroom:

Parameter	Value	Unit
Number of people	51	
CO2 concentration in outside air	350	ppm
maximum concentration of CO2	1200	ppm
production of CO2 by one person	19	l/h
Needed airflow rate	22,4	m3/h
volume of room	374,0	m3
Needed airflow rate	950	m3/h
Needed airflow rate	2,5	1/h
Class time	50	min
Break	10	min

Tab. 1: Calculation of airflow rate for CO_2 limit

Annex 7 - Water supply system calculation:

Calculation of total water consumption

School occupants			
Day area		Residential area	
Students	250	Students	250
Teachers	16	Teachers houses	96
Volunteers	8	Volunteers	8
Staff		Staff	
Watchmen + keepers	4	Keepers	2
Doctor + nurse	3	Dormitory	2
Kitchen	6	Summary	358
Kitchen office	2		
Summary	289		
Recalculation to equivalent occupant			
Coefficient for day area	0,33		
Coefficient for residential area	1		
Summary EO	454		

Tab. 1: Summary of school occupants

Days in the year	365
Weekends	104
School holidays	60
Public holidays	12
Total number of school days	189

Tab. 2: Estimating school days in Zamia context

Water consumption students in day school	
Activity	l/person/day
Toilet	50
Basin (cleaning hands + drinking)	25
summary	75,0
Coefficient for schools	0,333
Total consumption	25
Water consumption teachers in day school	
Activity	l/person/day
Toilet	75
Basin (cleaning hands + drinking)	40
Cooking and cleaning	65,0
summary	180
Coefficient for schools	0,333
Total consumption	60
Water consumption other staff in day school	
Activity	l/person/day
Toilet	75
Basin (cleaning hands + drinking)	40
Cleaning	15
Shower	50
summary	180
Coefficient for schools	0,333
Total consumption	60

Water consumption in student dormitory houses	
Activity	l/person/day
Toilet	25
Basin (cleaning hands + drinking)	10
Shower	25
Total consumption	60
+ Laundry house	18
Water consumption in staff houses	
Toilet	25
Basin (cleaning hands + drinking)	10
Shower	25
House cleaning and washing clothes	18
Cooking + washing dishes	9
Total consumption	87

Tab. 3: Water consumption in students buildings

Calculation of total water consumption			
Water consumption	l/per person	persons	summary (l/day)
Day school area			
Students	25	250	6250
Teachers offices	60	24	1440
Staff	60	15	900
Kitchen (per meal)	25	289	7225
Laboratory	10	100	1000
Cook workshop	25	100	2500
Sick bay	120	15	1800
Laundry house	18	250	4500
Summary day area			25615
Residential area			
Students accommodation	60	250	15000
Staff houses	87	108	9396
Summary residential area			24396
Summary (l/day)			50011
Summary (m3/day)			50,0
Average water consumption (l/per person/per day)			110
Average water consumption (m3/per person/per day)			0,11
Year average water consumption	Days	consumption/day (m3)	Consumption/year (m3)
Day part	189	25,615	4841,24
Residential area	365	24,396	8904,54
Summary			13745,8

Tab. 4: Total water consumption.

Check of calculation

Type of the buildings	m3/year x number of people	m3/year
Other type of school (without boarding part)	18x290	5220
Residential units	35x358	12530

Tab. 5: Figures by Vyhláška č. 120/2011 Sb. standard

Utility water calculations:

Water consumption students in day school		
type of water	Drinking	Utility
Total consumption (l)	8,325	16,65
Percentual values (%)	33,33	66,67
Water consumption teachers in day school		
type of water	Drinking	Utility
Total consumption (l)	34,965	24,975
Percentual values (%)	58,33	41,67
Water consumption other staff in day school		
type of water	Drinking	Utility
Total consumption (l)	34,965	24,975
Percentual values (%)	58,33	41,67

Water consumption in student dormitory houses		
type of water	Drinking	Utility
Total consumption (m3)	35	25
Percentual values (%)	58,33	41,67
Water consumption in staff houses		
type of water	Drinking	Utility
Total consumption (m3)	62	25
Percentual values (%)	71,26	28,74

Tab. 6: Drinking water and utility water consumption

Drinking water needed			
Water consumption	l/per person	persons	summary (l/day)
Day school area			
Students	8,3	250	2081,25
Teachers offices	35	24	839,16
Staff	35	15	524,475
Kitchen (per meal)	25	289	7225
Laboratory	10	100	1000
Cook workshop	25	100	2500
Sick bay	12	150	1800
Summary day area			15969,885
Residential area			
Students accommodation	35	250	8750
Staff houses	62	108	6696
Summary residential area			15446
Summary (l/day)			31415,89
Summary (m3/day)			31,4
Average water consumption (l/per person/per day)			69
Average water consumption (m3/per person/per day)			0,07
Drinking water needed			
Year average drinking water need	Days	consumption/day (m3)	Consumption/year (m3)
Day part	189	15,969885	3018,31
Residential area	365	13,502	5637,79
Summary			8656,1

Tab. 7: Drinking water need

Annex 8 - Wastewater calculations

Blackwater production			
Blackwater production	l/per person	persons	summary (l/day)
Day school area			
Students	16,7	250	4163
Teachers offices	25,0	24	599
Staff	25,0	15	375
Summary day part			5137
Residential area			
Students accommodation	25	250	6250
Staff houses	25	108	2700
Summary residential area			8950
Summary (l/day)			14086,525
Summary (m3/day)			14,1
Average blackwater production (l/per person/per day)			31
Average blackwater production (m3/per person/per day)			0,03

Year average blackwater production	Days	consumption/day (m3)	Consumption/year (m3)
Day part	189	5,136525	970,80
Residential area	365	8,95	3266,75
Summary			4237,6

Tab. 1: Blackwater production

Septic tank calculation	Day area	Units	Residential area	Units
Number of occupants	289	persons	358	persons
Coefficient	0,33	(-)	1	(-)
Person equivalent	96	(-)	358	(-)
Blackwater production	5,14	m^3	8,95	m^3
Average blackwater production	0,054	(m3/per person/per day)	0,025	(m3/per person/per day)
Coefficient for sewage space	1,5	(-)	1,5	(-)
Time of holding up the sewage	3	days	3	days
Needed volume of septic tank	23,1	m^3	40,3	m^3

Tab. 2: Septic tank calculation

Annex 9 - Hot water need

Hot water need			
Hot water need	l/per person	persons	summary (l/day)
Day school area			
Students	7	250	1750
Teachers offices	12	24	288
Staff	12	15	180
Kitchen (per meal)	15	289	4335
Laboratory	5	100	500
Cook workshop	17	100	1700
Sick bay	10	150	1500
Summary day part			10253
Residential area			
Students accomodation	28	250	7000
Staff houses	40	108	4320
Summary residential area			11320
Summary (l/day)			21573
Summary (m3/day)			21,6
Average hot water need (l/per person/per day)			48
Average hot water need (m3/per person/per day)			0,05
Year average hot water need	Days	consuption/day (m3)	Consumption/year (m3)
Day part	189	10,253	1937,82
Residential area	365	11,32	4131,80
Summary			6069,6

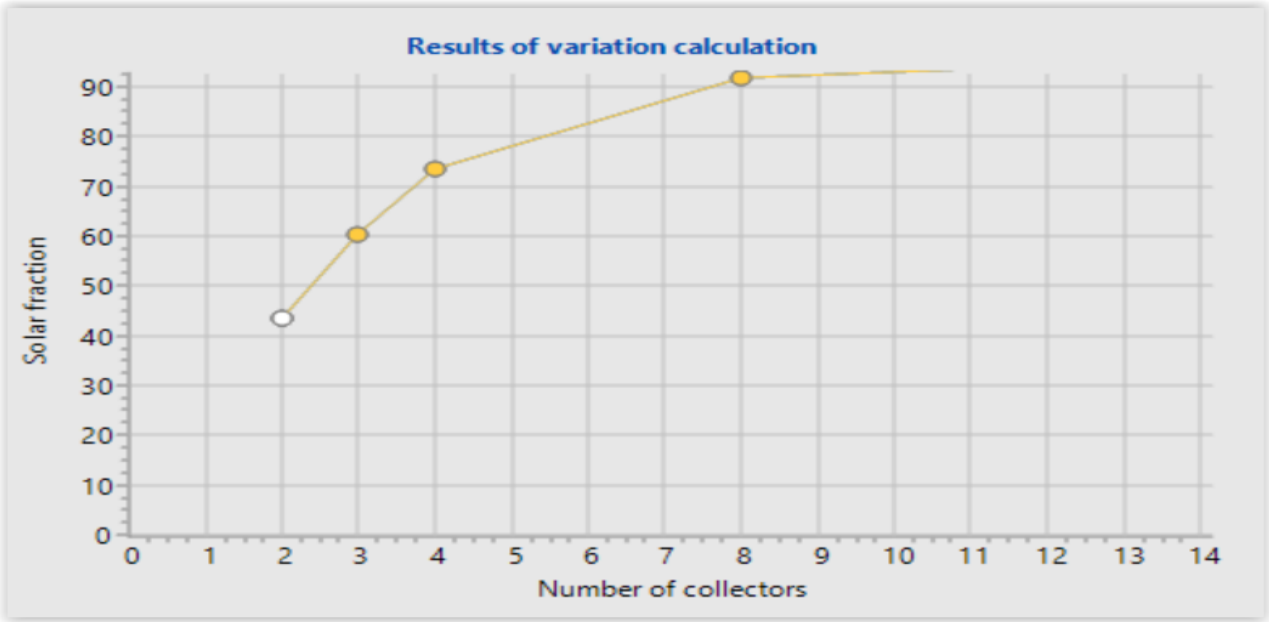
Tab. 2: Total hat water need

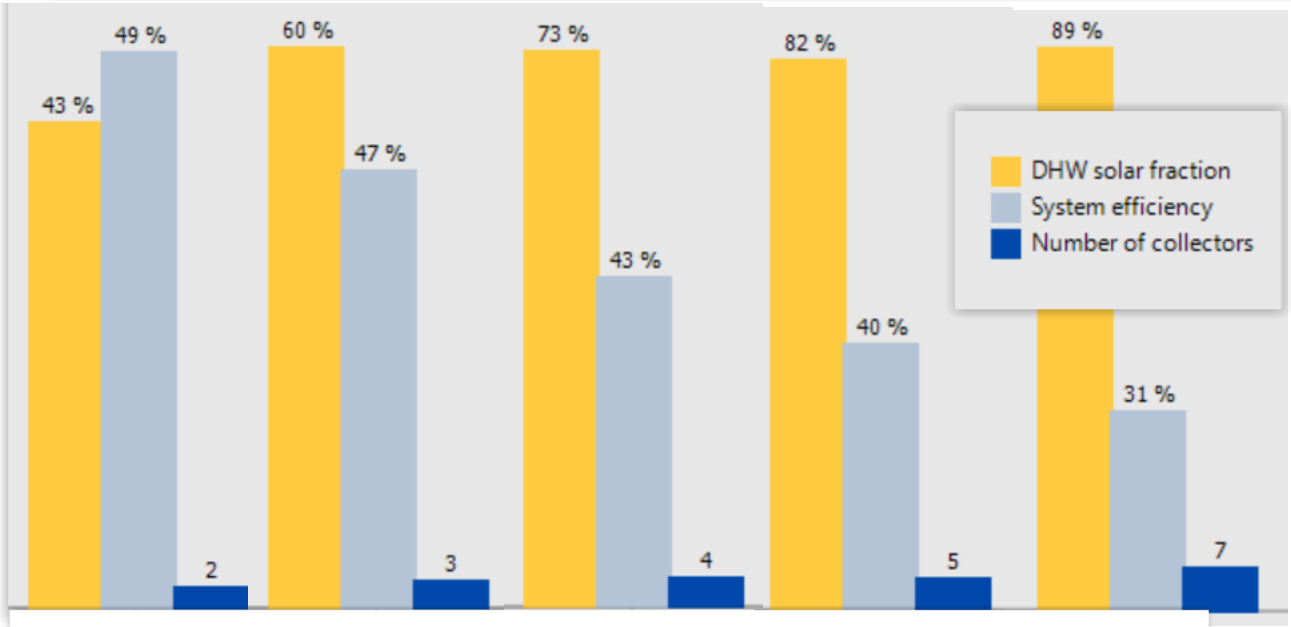
Hot water tank calculation	Utility block	Student dormitory unit	Staff house
Number of people	36	8	6
Water need per person [l]	6	28	40
Total water need [l]	216	224	240
Designed water tank [l]	300	300	300
Day capacity of tank [day]	1,4	1,3	1,25

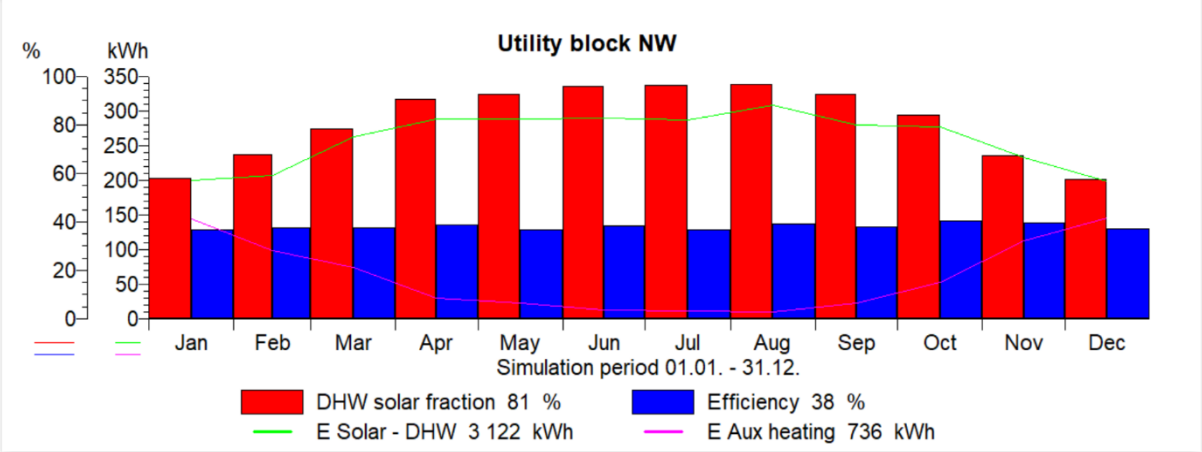
Tab. 3: Water tank volume calculation

Annex 10 - Solar water heating system calculation by T*SOL 2018:

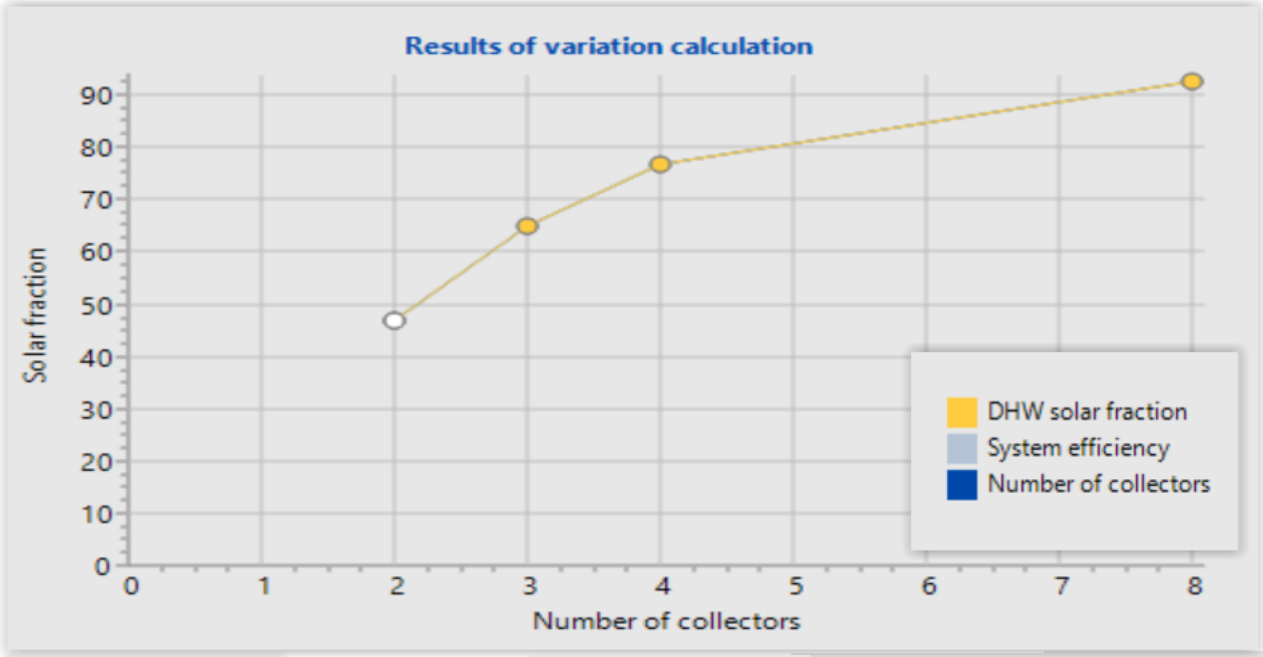
Utility block (North-West orientation)

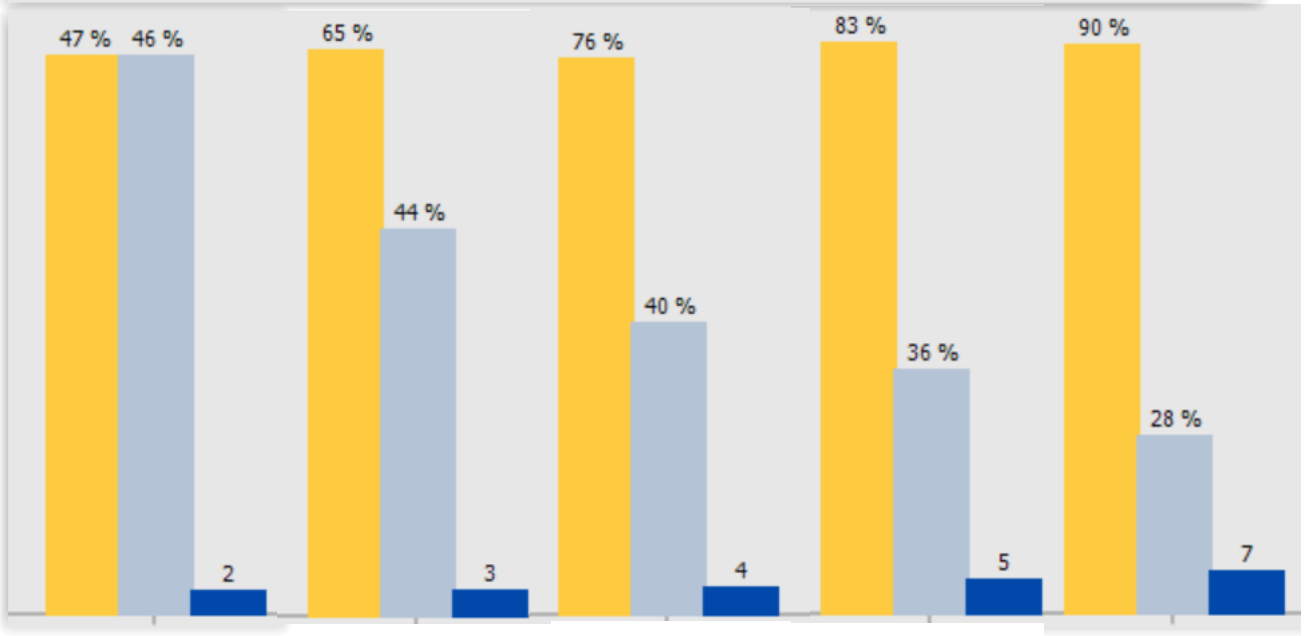


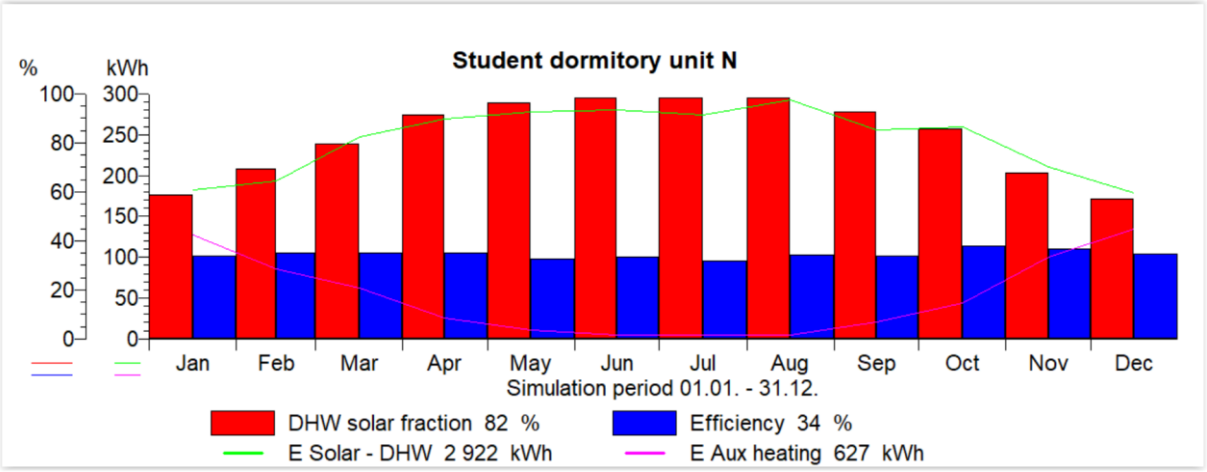




Student accommodation units (North orientation)







Stuff house (North-east orientation)