EXPERIMENTAL ANALYSIS OF DIFFERENT OPERATIONAL CONFIGURATIONS FOR SINGLE SIDED NATURAL VENTILATION AS PART OF A LOW ENERGY RETROFIT

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34th AIVC Conference, Athens, Greece, 25th & 26th Sept 2013

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Background & Context

- CIT refurbished 3% of 29,000m^2 1974 building as pilot project
- Aimed at delivering nearly zero energy performance in retrofit
- Single sided ventilation chosen as cooling strategy
- Alternative ventilation opening solution in retrofit
- Undertaken a comparative analysis of existing and retrofit spaces

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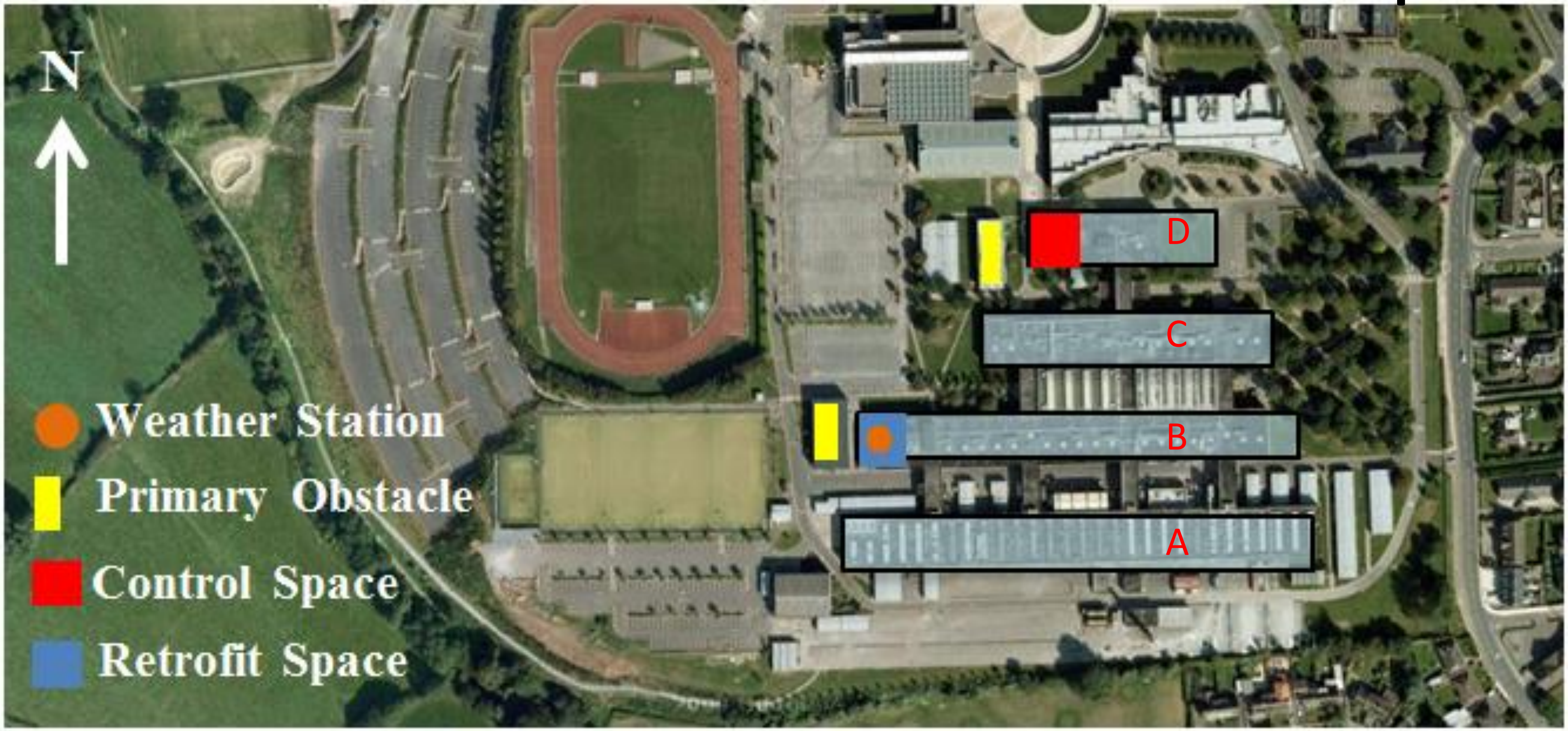
Objectives

- Measure time-averaged ventilation rate for the retrofit and control spaces under different conditions
- Compare time-averaged ventilation rate for different retrofit ventilation opening configurations
- Investigate the effect of wind & thermal forces during tests
- Investigate relative strength of zone vertical air temperature difference to envelope temperature diff.

Retrofit Space & Control Space - Location

CIT Main Campus



29,000m^2 existing 1974 building wings A - D

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Long Term & Short Term Local Climate

Month	Cork Airport TMY3 95th Percentile			Summer 2013 95th Percentile**		
	G_h (Wh/m^2)	T_a (°C)	WS (m/s)	G_h (Wh/m^2)	T_a (°C)	WS (m/s)
May	742	17.2	10.0	730	16.0	6.3
June	815	19.5	9.3	826	20.6	5.0
July	**707**	**20.7**	**9.0**	**795**	**25.0**	**4.3**
August†	662	20.0	9.3	567	19.1	4.7
September*	574	19.4	9.0	-	-	-

† Data up to 15th August only for short term; *Data not yet available for short term; **Data taken from zero2020 weather station

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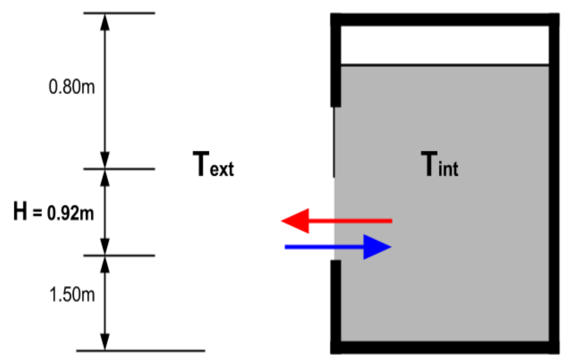
Control Space

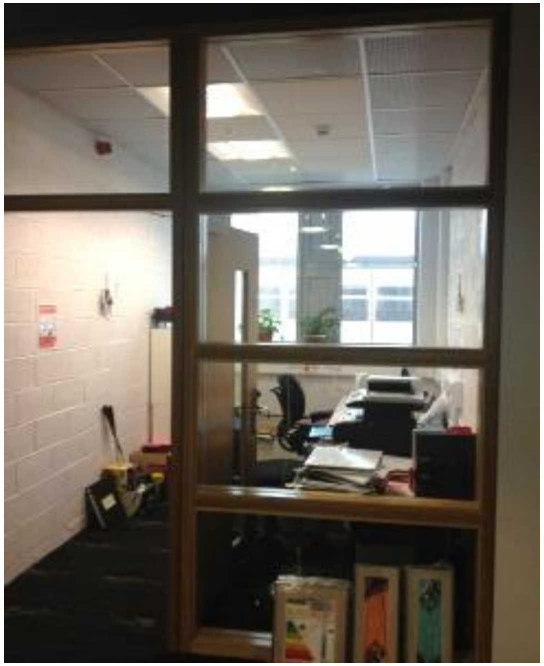
External West Facing First Floor Zone

Zone Interior

Configuration	Vent Opening Type	Schematic Envelope Flow Model
CS/1.0/M $0.32m^2$		

Retrofit Space

Retrofit Space External



RE Zone Interior

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Fenestration Module

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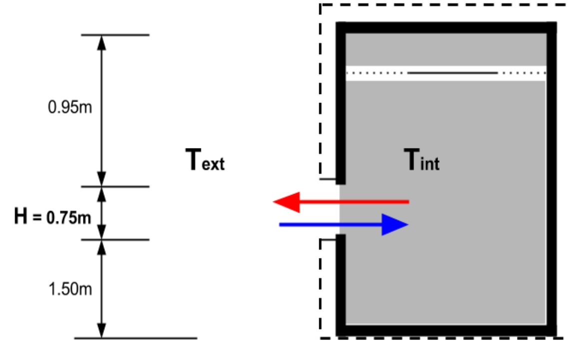
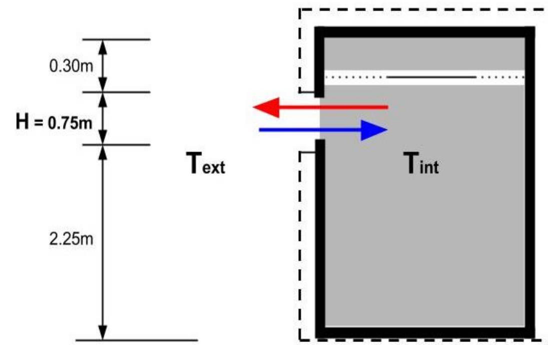
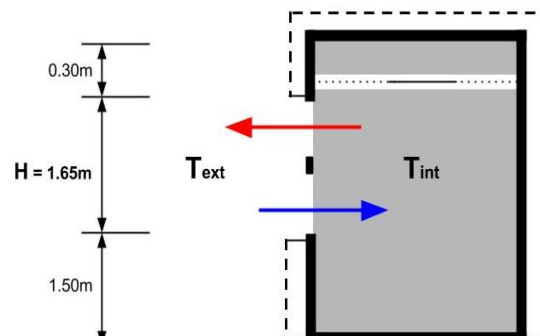
Retrofit Space Ventilative Cooling Configuration

Configuration	Vent Opening Type	Schematic Envelope Flow Model
RE/2.0/M $0.21m^2$		
RE/3.0/A $0.21m^2$		
RE/4.0/M/A $0.42m^2$		

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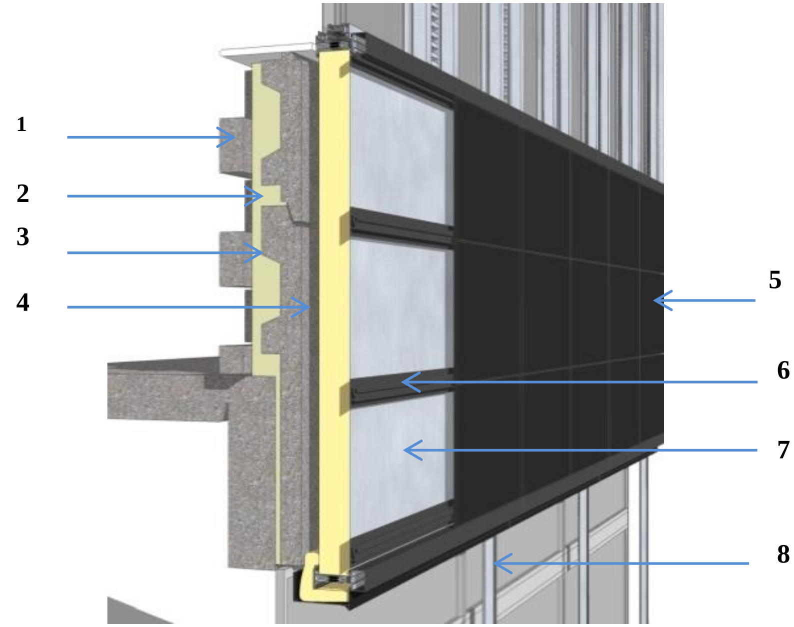
Properties of retrofit opaque wall

Location	ω/φ (W/mK) / h	f (W/mK)	U_{wall} (W/m²K)	$U_{fenestr.}$ (W/m²K)
Control Space	**5.49 / 1.017**	**0.608**	3.633	6.0
Retrofit Space	**5.92 / 0.963**	**0.004**	0.090	0.84

<u>Opaque external wall retrofit details</u>

Component 1-4 existing structure boundary

Component 5-8 new external envelope boundary



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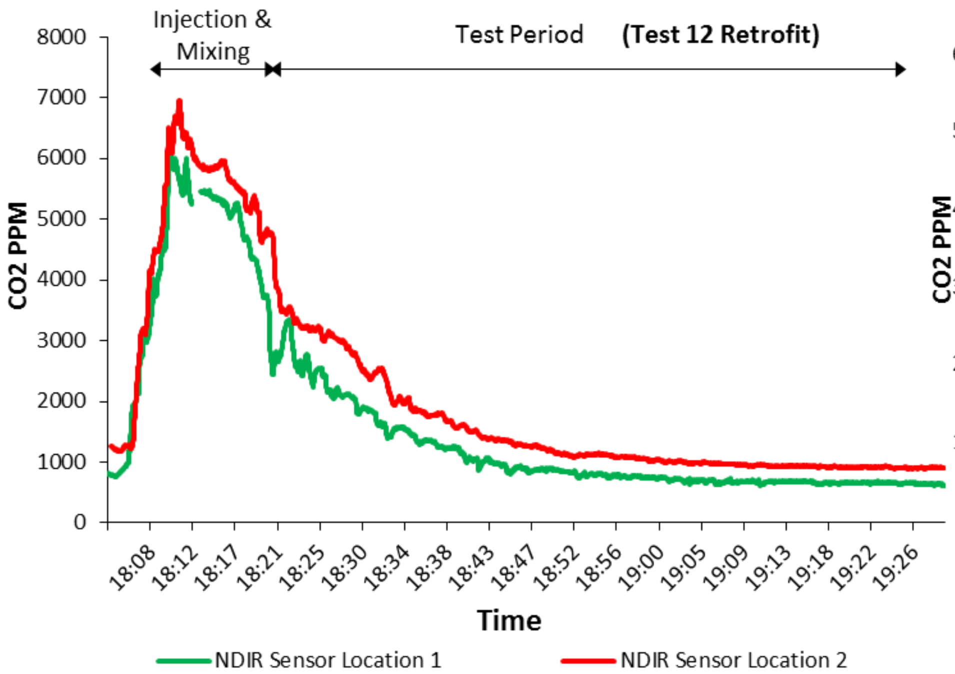
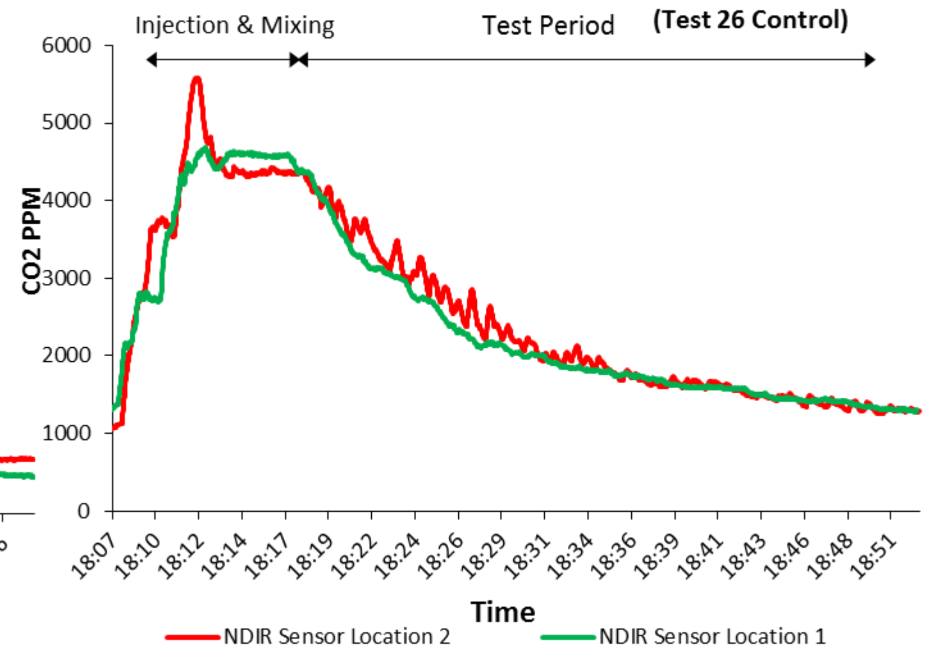
Tracer Gas Decay Method - Test Conditions





Config.	No of tests	Range of test durations	Average Conc. uniformity	Start PPM Range (Adj.)	End PPM Range (Adj.)	Average B.G. PPM (%)
CS/1.0/M	**13**	24 – 90 min	**5.11 %**	2776-5743	386-1286	10.3
RE/2.0/M	**6**	26 – 77 min	**3.10 %**	3129-4687	495-1583	12.3
RE/3.0/A	**6**	31 – 50 min	**3.47 %**	3105-3787	865-1424	13.4
RE/4.0/A/M	**13**	30 – 161 min	**4.73 %**	2546-4198	334-1179	13.0

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Ventilation Rate Measurement Results

Control Space test results

Test Config.	Max ACH^{-1}	Min ACH^{-1}	Std. Dev.	Ave ACH^{-1}	Occ. < 3.0 ACH	Occ. < 1.5 ACH	WS Range (m/s)	No. of Windward/ Leeward tests	ΔT_{ie} Range (°C)
CS/1.0/M	***4.7***	***1.2***	*1.2*	***2.8***	7	4	1.41-5.20	9/4	4.2-8.9

Retrofit Space test results

Test Config.	Max ACH^{-1}	Min ACH^{-1}	Std. Dev.	Ave ACH^{-1}	Occ. < 3.0 ACH	Occ. < 1.5 ACH	WS Range (m/s)	No. of Windward/ Leeward tests	ΔT_{ie} Range (°C)
RE/2.0/M	***3.6***	***1.3***	*0.9*	***2.1***	1	2	1.36-5.24	4/2	0.5-5.5
RE/3.0/A	***2.8***	***1.1***	*0.9*	***1.7***	0	2	3.33-4.24	1/2	1.1-5.3
RE/4.0/A&M	***3.7***	***0.5***	*0.9*	***2.5***	5	3	1.52-4.47	7/6	0.4-7.1

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Analysis of Dominant Forces

Archimedes number, $Ar = (Gr/Re^2)$ described as:

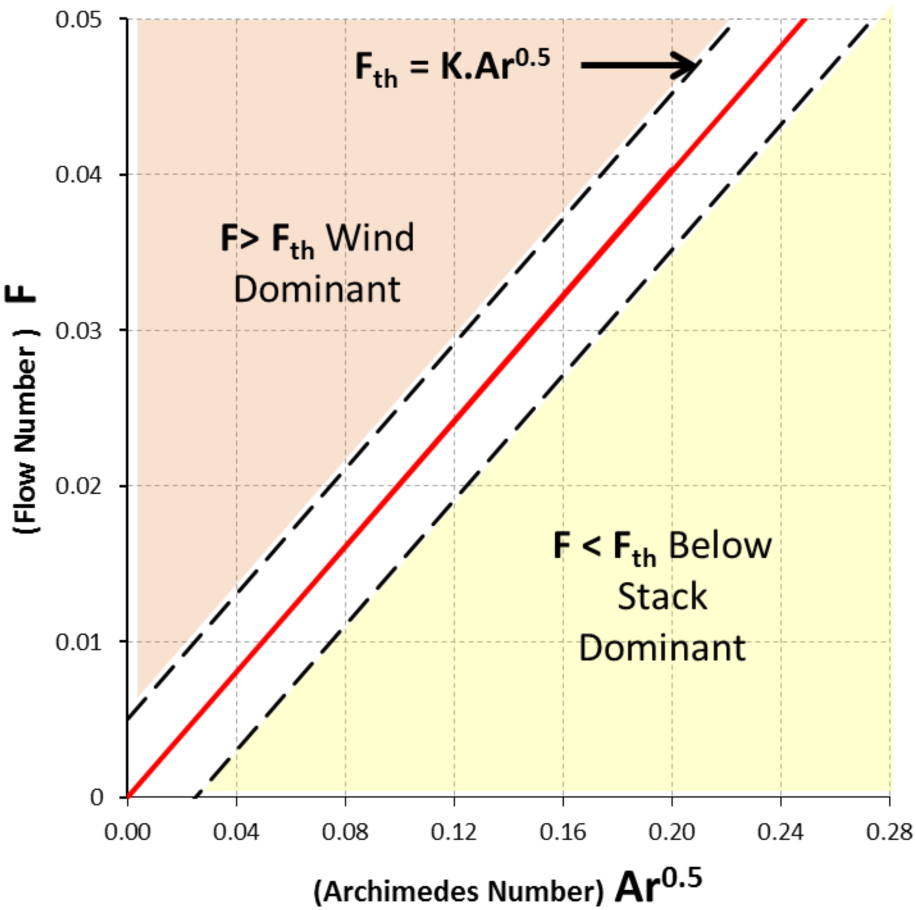
$$Ar^{0.5} = \frac{\Delta TgH}{Tv_{wind}^2}$$

Dimensionless Flow number, F, described as:

$$F = \frac{q_{ACH}}{A_{eff}v_{wind}}$$

The use of a flow number due to thermal stack effect alone, F_{th}, is introduced to the plot.

$$F_{th} = K.Ar^{0.5} \text{ (Stack Dominant)}$$



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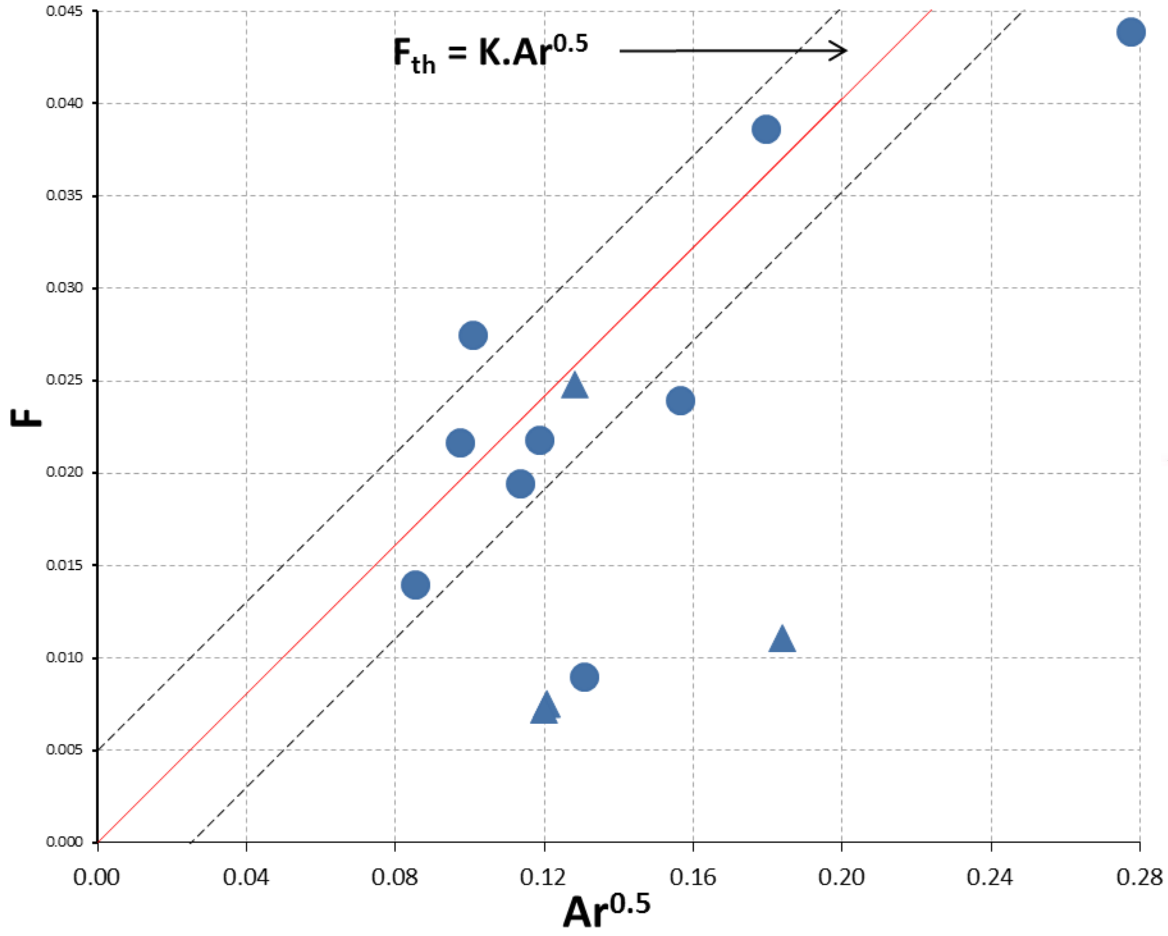
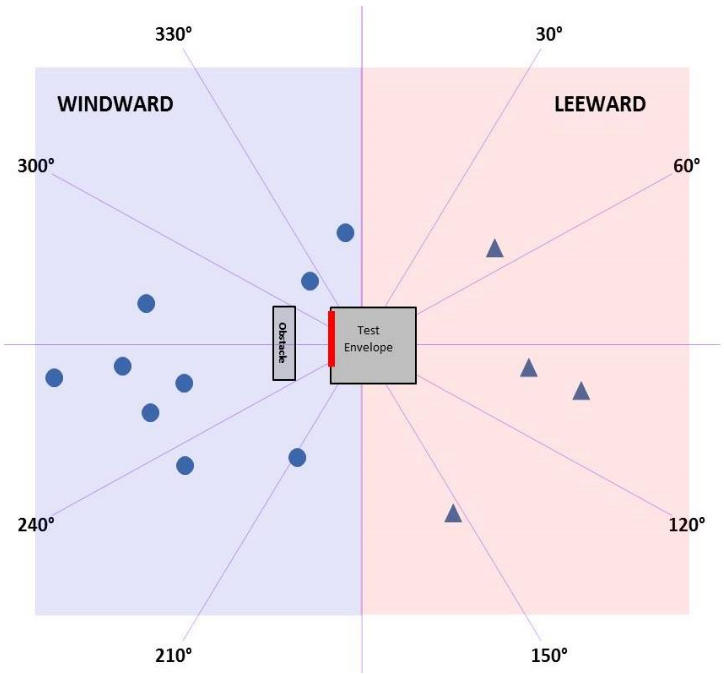
Warren Plot for CS Config





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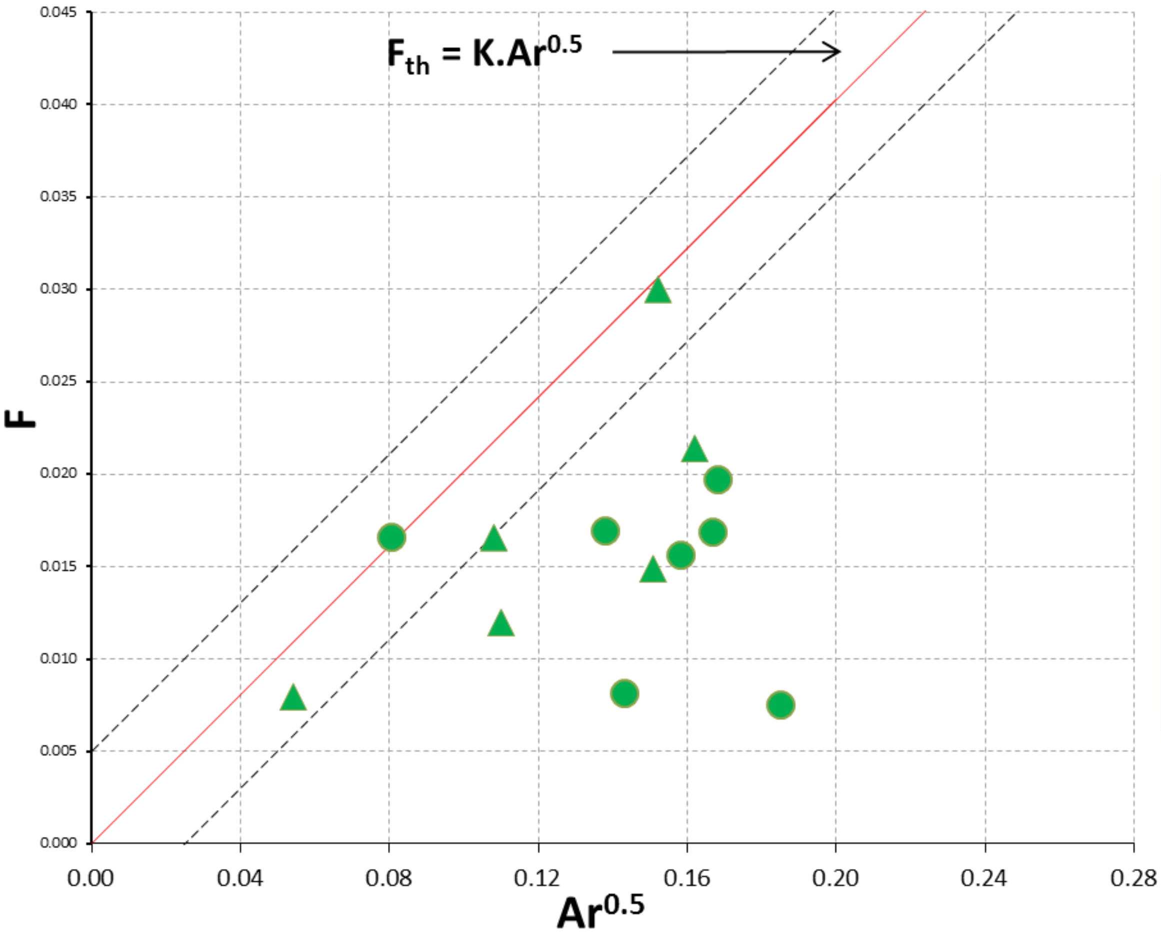
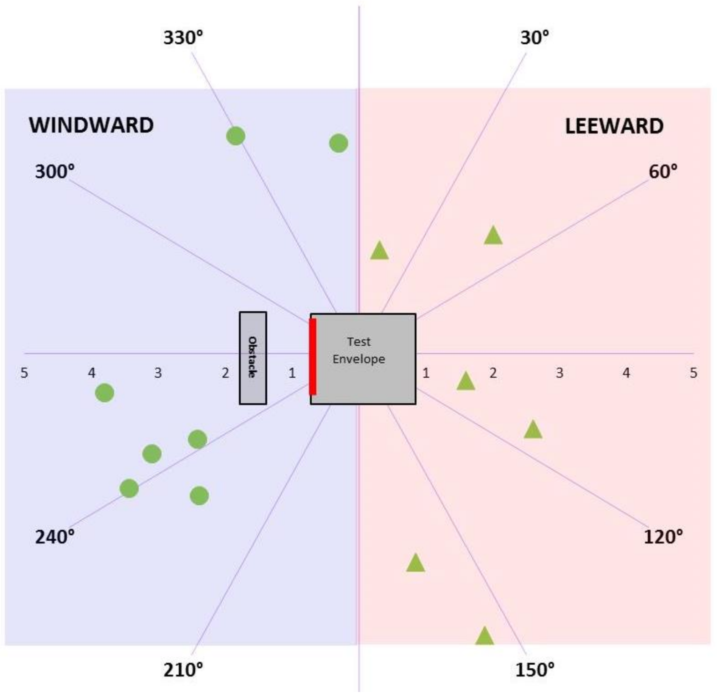
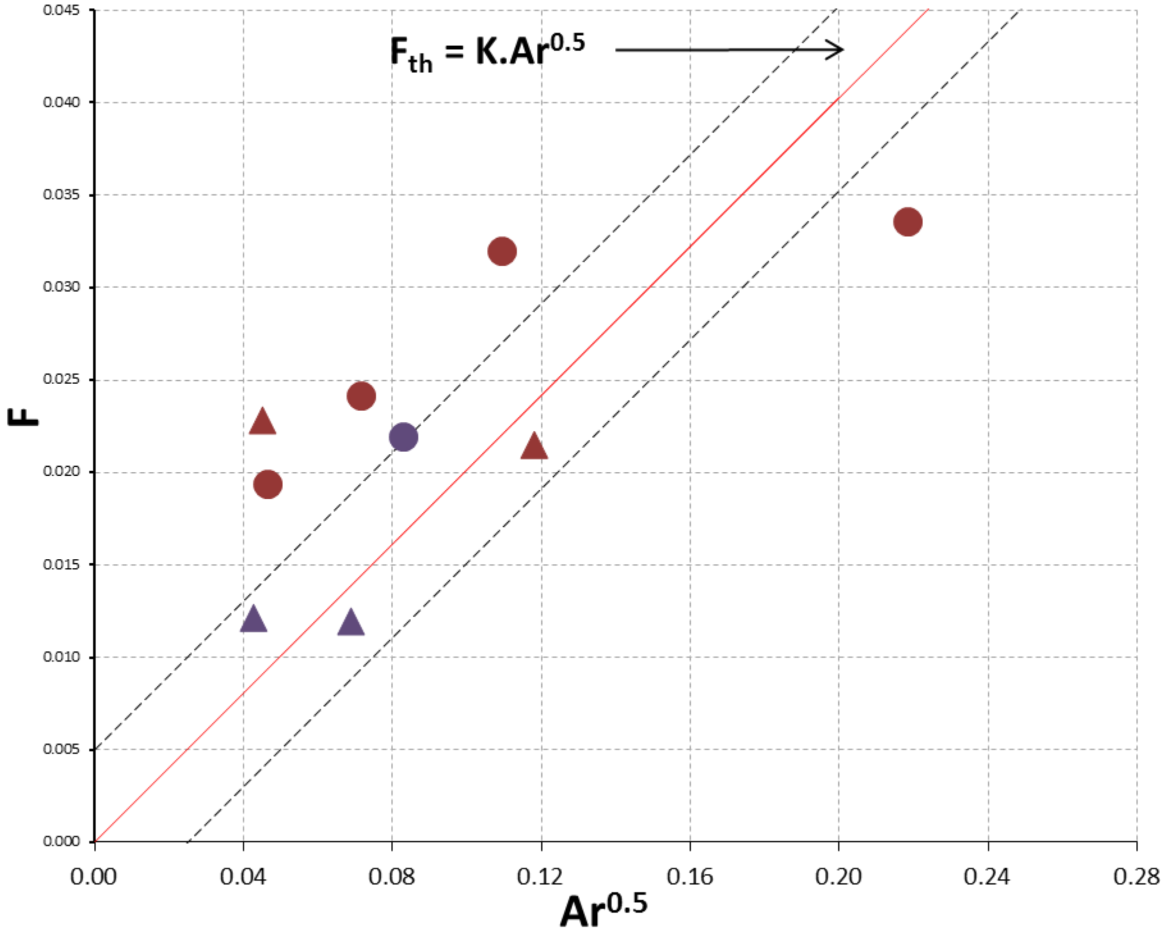
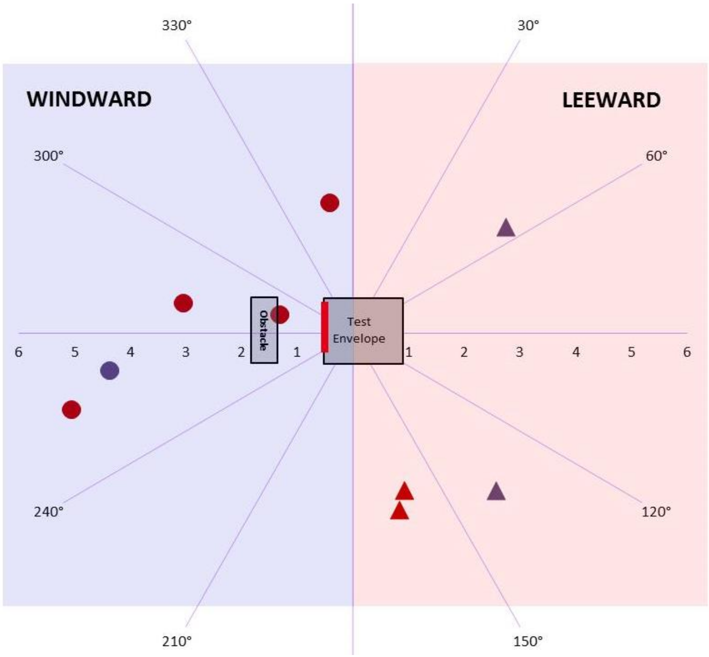
Warren Plot for RE Config





Warren Plot for RE2.0 & RE3.0 Config





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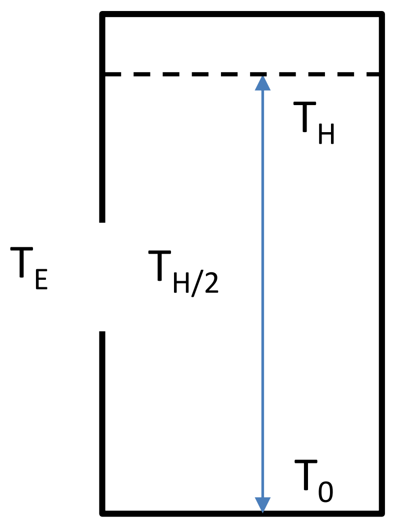
Analysis of Thermal Stratification

The stratification factor (*Str Fr*) $= \frac{Stratification\ Temp\ Difference}{Envelope\ Temp\ Difference} = \frac{\Delta T_s}{\Delta T_{ie}} = \frac{T_H - T_0}{T_{H/2} - T_E}$

StrFr Results for Test conditions close or equal to F_{th}

Config	Test	Str Fr	$\lvert F-F_{th} \rvert$	Km^{-1}	Kappa
CS/1.0	3	**0.227**	0.002	0.49	0.95
CS/1.0	4	**0.551**	0.002	0.94	0.76
CS/1.0	27	**0.565**	0.001	1.00	0.72
CS/1.0	2	**0.621**	0.003	1.81	0.64
RE/2.0	29	**0.700**	0.002	1.30	0.57
CS/1.0	14	**1.051**	0.003	3.20	0.38
RE/3.0	25	**1.111**	0.002	1.20	0.31
RE/3.0	16	**1.125**	0.004	0.60	0.13
RE/4.0	32	**1.438**	0.001	0.80	0.01
RE/4.0	24	**1.809**	0.000	1.20	0.01



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Summary of StrFr Data

20th June – 19th July 2013 Values *Str.Fr* ($\Delta T_s/\Delta T_{ie}$) Data

Space.	Occupied hours (09:00-18:00)				Unoccupied Hours (18:00-09:00)			
	50th	75th	95th	% occ hrs >1	50th	75th	95th	% occ hrs>1
Control	0.411	0.691	1.19	**9.0%**	0.192	0.333	0.622	0.0%
Retrofit	0.202	0.609	2.59	**14.5%**	0.157	0.290	0.611	2.2%

Analysis of overheating criteria retrofit and control space

Space.	**hrs>25°C (%Σhrs)***	**hrs>28°C (%Σhrs)***
Control	34	**17**
Retrofit	33	**3.5**

**Based on 981 working hours May-September*

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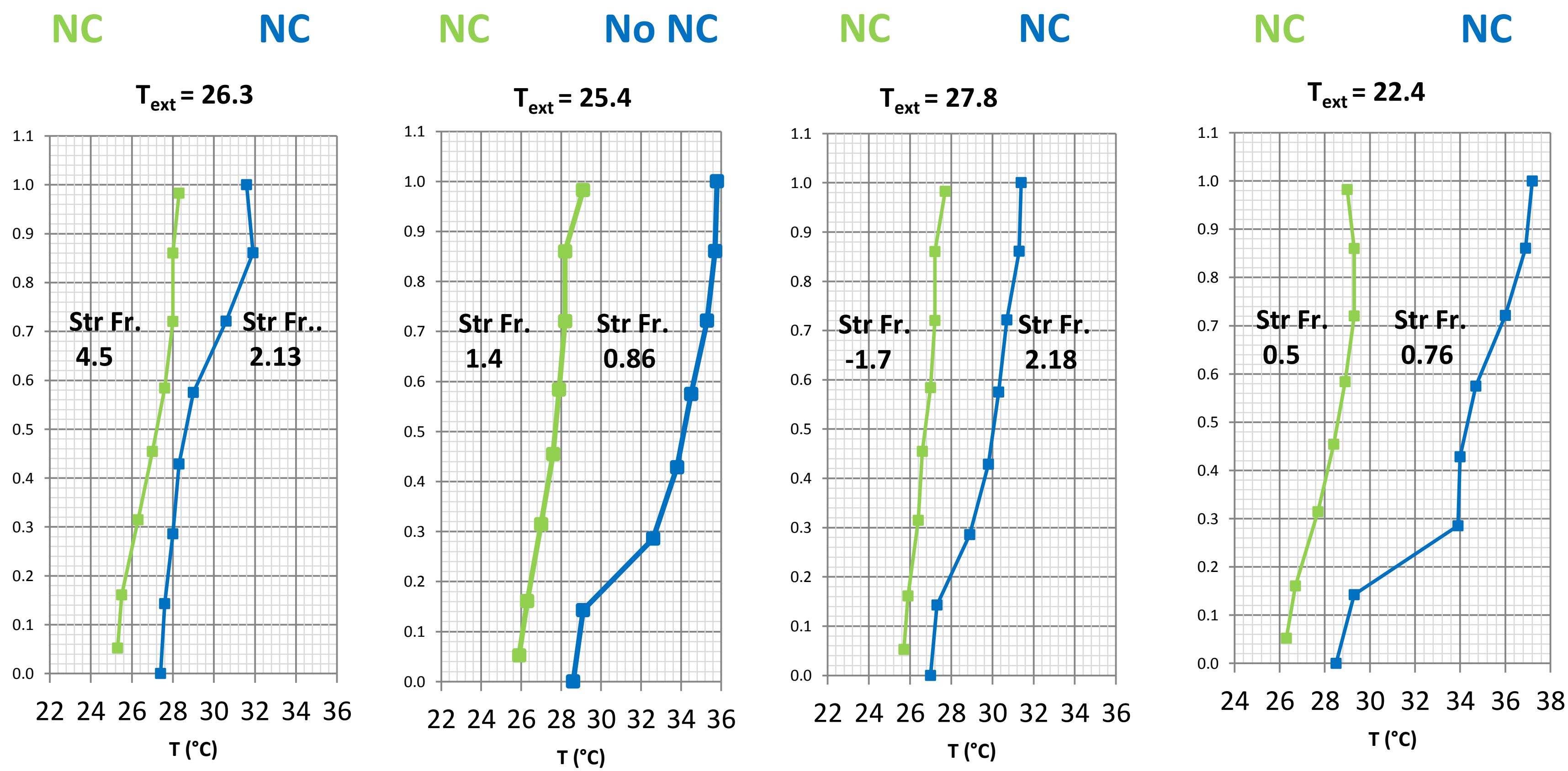
Vertical Temperature Distribution



12-Jul **15:30**

10-Jul **16:45**

13-Jul **16:50**

18-Jul **20:00**

RE vs. CS stratification

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Conclusion & Future Work

- Retrofit works modified the internal environment
- Time averaged ventilation rates generally lower in Retrofit
- Ventilation opening characteristics as important as thermophysical properties
- Influence of wind conditions on ventilation rates is complicated by local obstacles at the site nearby the CS and RE spaces
- Retrofit had higher relative stratification strength compared to the existing building
- Stratification profiles more linear in retrofit compared with control space

Thank You