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Effect of Overhang on Wind-driven Rain Load of a Mid-rise Building: Field Measurements

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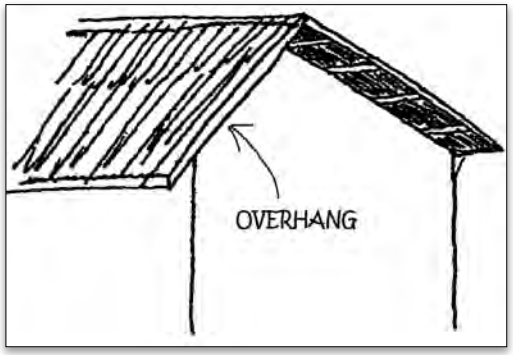
Wind-driven rain (WDR)

- The rain given a horizontal velocity by wind, falling obliquely
  - Major source of moisture damage
  - Knowledge of WDR is essential for design of durable envelopes and Heat, Air and Moisture (HAM) modeling as boundary conditions
  - WDR is the least known among climatic loadings
  - Overhangs are a classical solution, but their effects are not known quantitatively, especially for mid-rise & high-rise buildings



Wind-driven rain

Semi-empirical model:

$$I_{WA} = I_A * C_R * C_T * O * W$$

I_{WA} = Wall index

C_R = Terrain roughness coefficient

C_T = Topography coefficient

O = Obstruction factor

W = Wall factor

$$I_A = \frac{2}{9} \Sigma v * r^{8/9} * \cos(D - \theta)$$

I_A = Airfield index

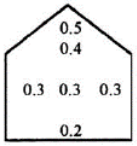
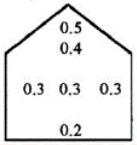
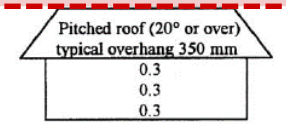
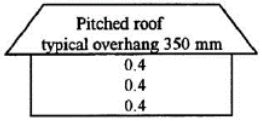
v = Hourly mean wind speed in m/s

r = Hourly rainfall total in mm

D = Hourly mean wind direction from north

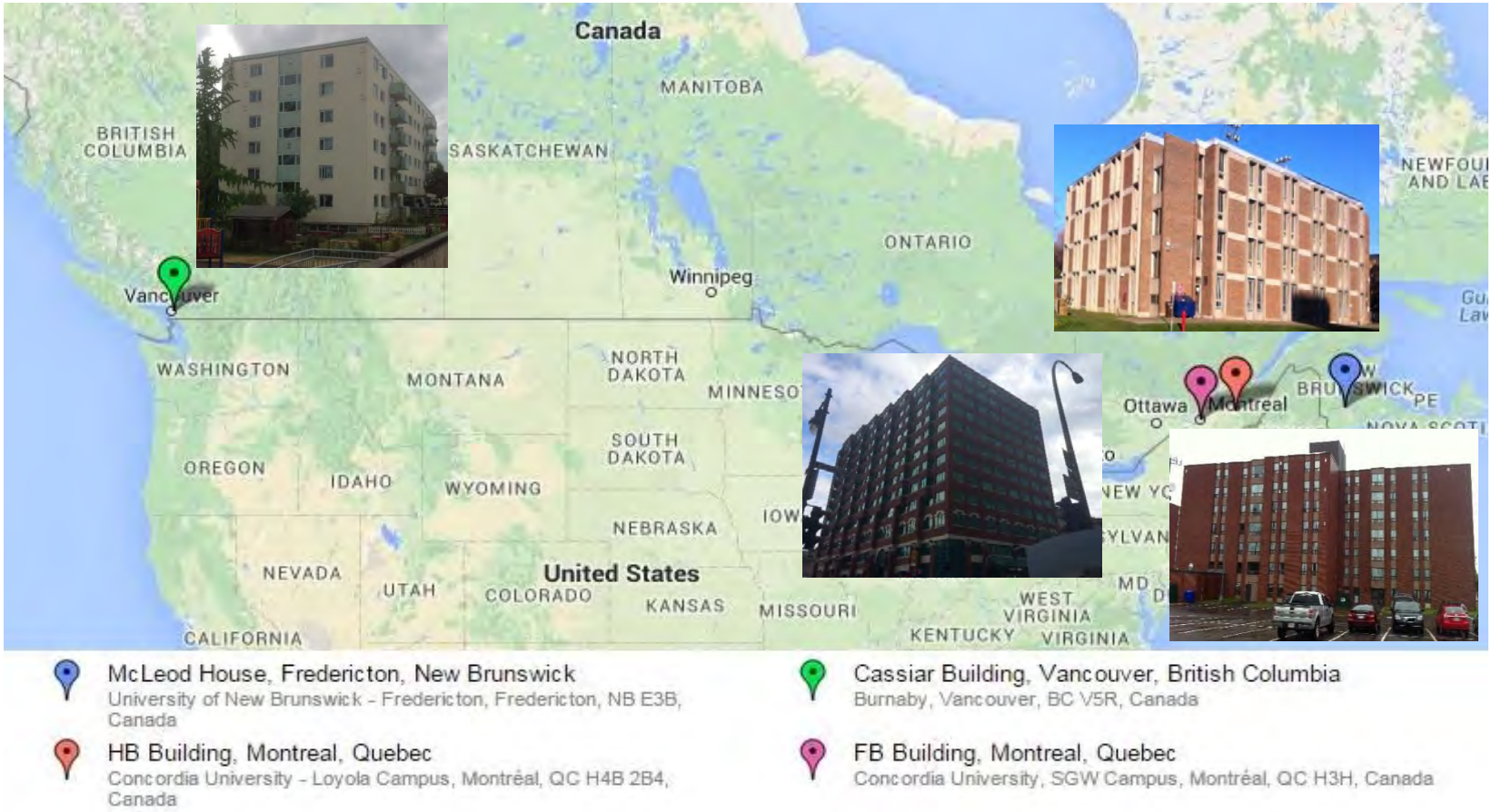
θ = Wall orientation relative to north where $\cos(D-\theta)$ is positive

ISO Proposed Wall Factors

Description of wall	Average value	Distribution
Two storey gable	0.4	
Three storey gable	0.3	
Multi storey flat roof	0.2 for e.g. ten storey, but higher intensity at top	0.5 for top 2.5 m 0.2 for remainder
two storey eaves wall	0.3	
three storey eaves wall	0.4	
two storey flat roof (pitch <20°)	0.4	

ISO 15927-3: Calculation of a driving rain index for vertical surfaces from hourly wind and rain data

Field measurements of WDR



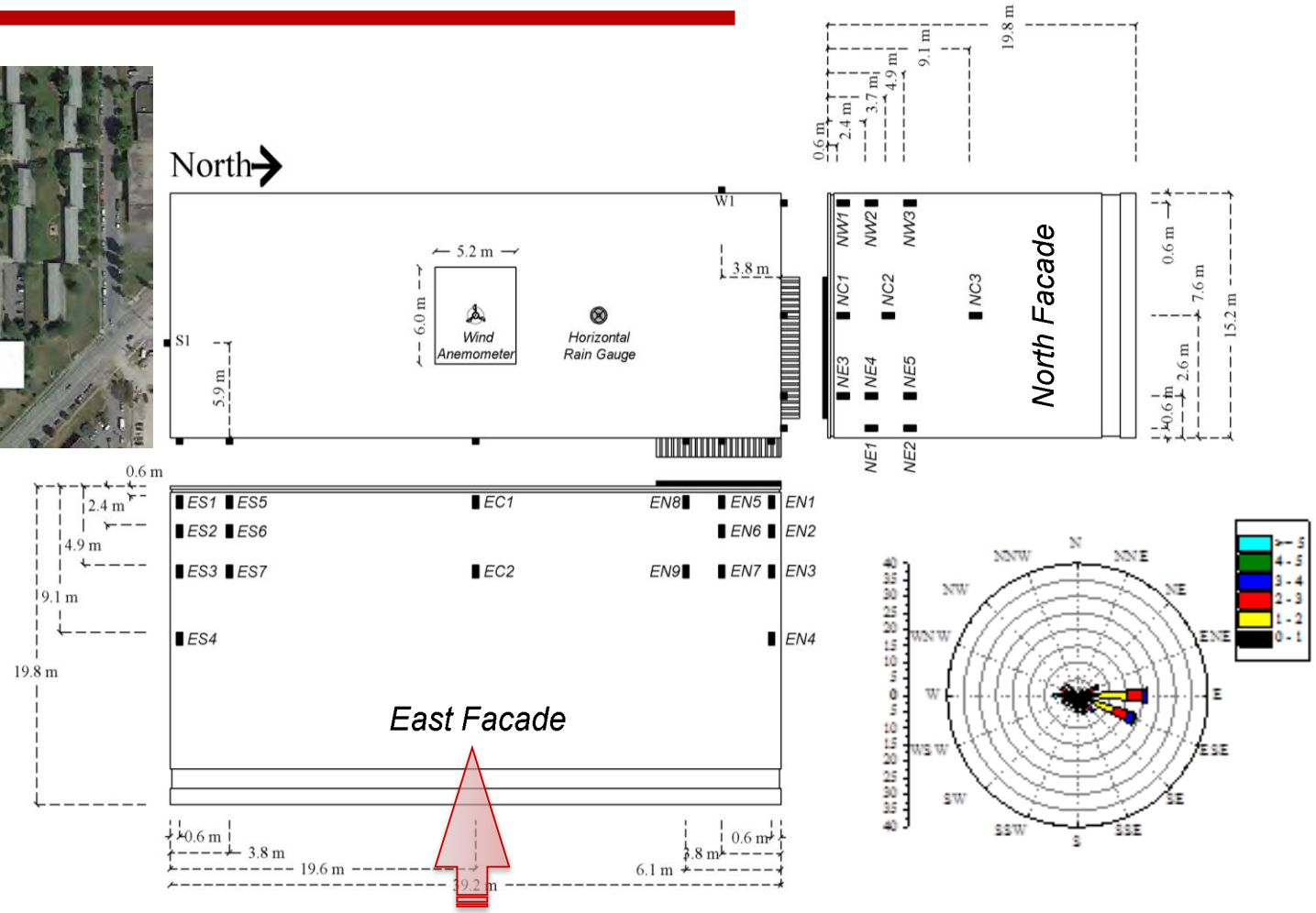
Locations of test buildings (*Source: Google maps*)

Objectives

- Quantify the effectiveness of roof overhang in reducing WDR loads on building façades through filed measurements
- Provide data to validate CFD model to be used for a systematic study of various overhang designs
- Provide recommendations on effective roof overhang design for different types of buildings and climates

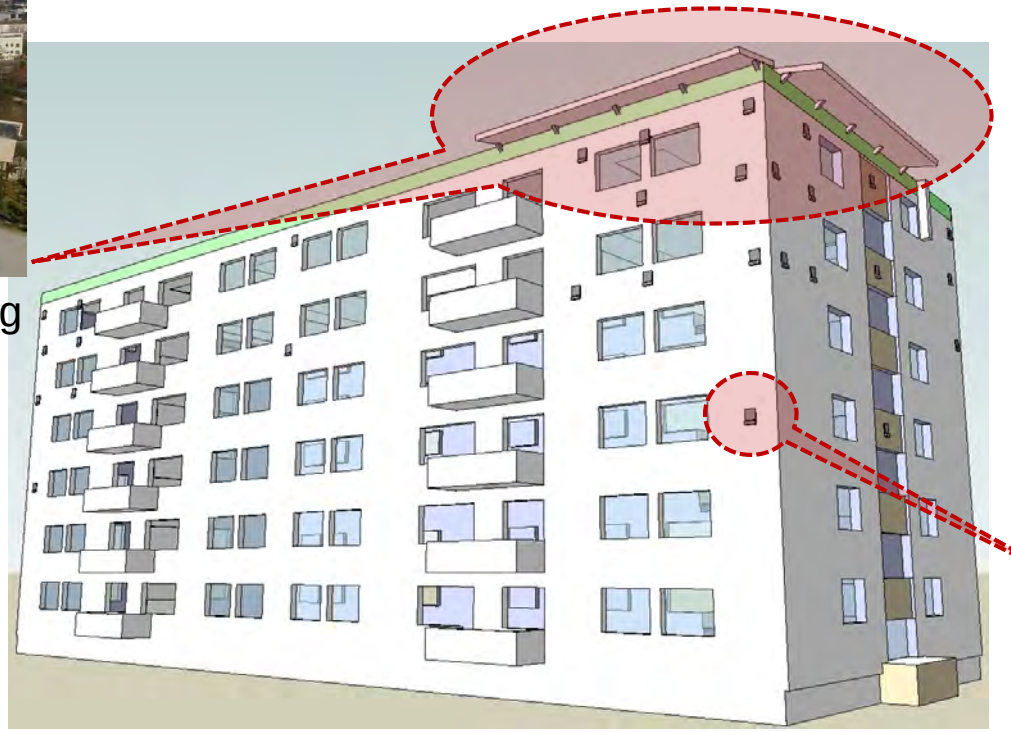
Test Building in Vancouver Canada

(Aug. 2013 to June 2017)



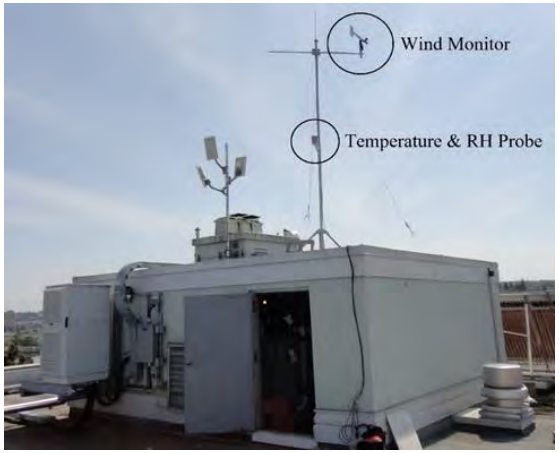
prevailing wind direction

Retractable overhang



- ✓ Wind speed
- ✓ Wind direction
- ✓ Temperature
- ✓ Relative humidity
- ✓ Horizontal rain
- ✓ Wind-driven rain

Customized WDR Gauge



Rooftop Weather Station

Horizontal Rain Gauge

Data collection and processing

Field measurements started from August 2013 to March 2017. This period is divided into four sub-periods:

1. No Overhang: 16 August 2013 to 1 December 2014 (456 days)
2. 4 feet OH (1.2 m): 2 December 2014 to 1 March 2015 and 3 December 2015 to 21 April 2016 (263 days)
3. 2 feet OH (0.6 m): 2 March 2015 to 2 December 2015 (275 days)
4. 3 feet OH (0.9 m): 22 April 2016 to 31 March 2017 (346 days)

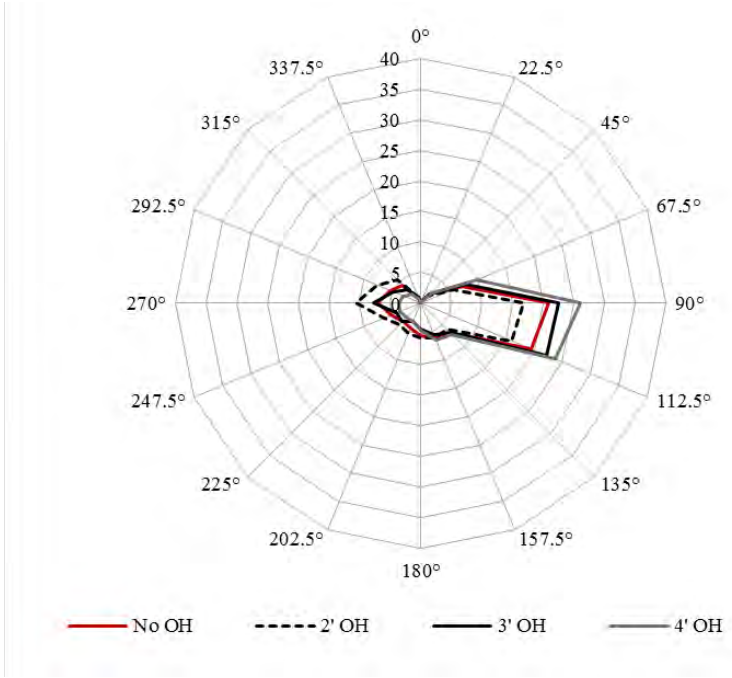
No Overhang

0.6 m Overhang

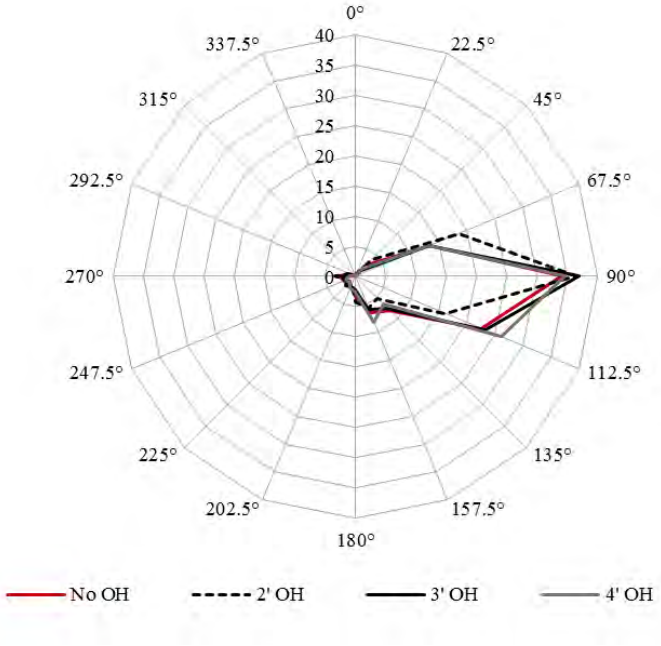
1.2 m Overhang

RESULTS

- On-site weather conditions for each sub-period



(a) All hours



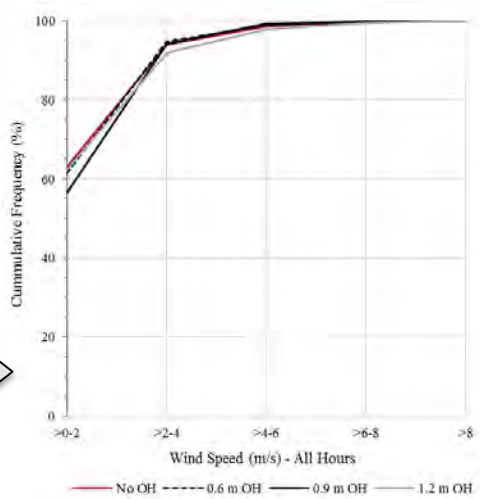
(b) Rain hours

Wind direction frequency

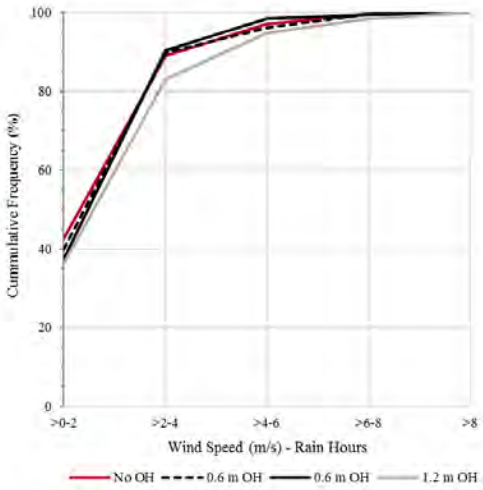
RESULTS

- On-site weather conditions for each sub-period

Cumulative frequency distribution of wind speed

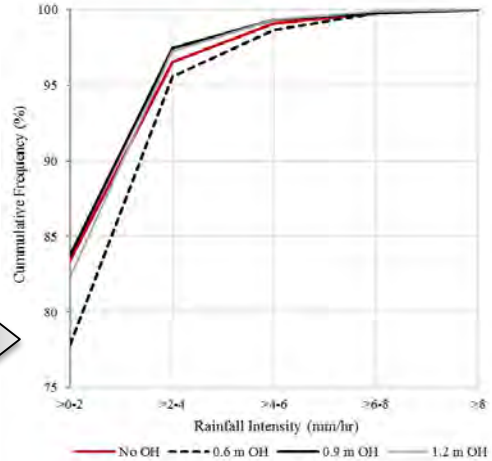


(a) All hours



(b) Rain hours

Cumulative frequency of rainfall intensity

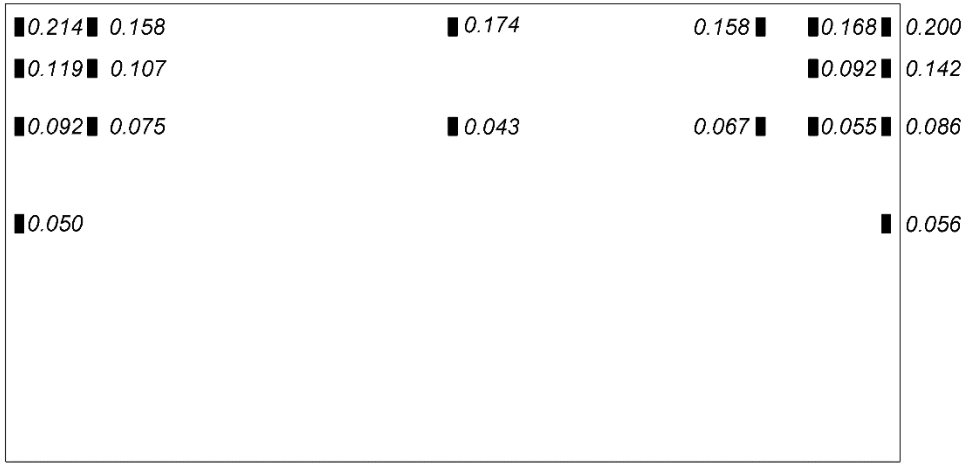


RESULTS

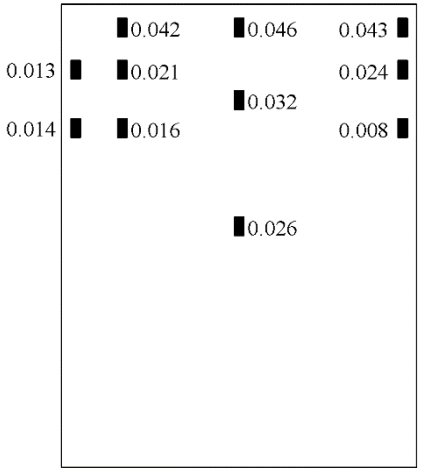
Spatial Distribution of WDR

Catch ratio:

$$\eta = \frac{R_{wdr}}{R_h}$$



East façade



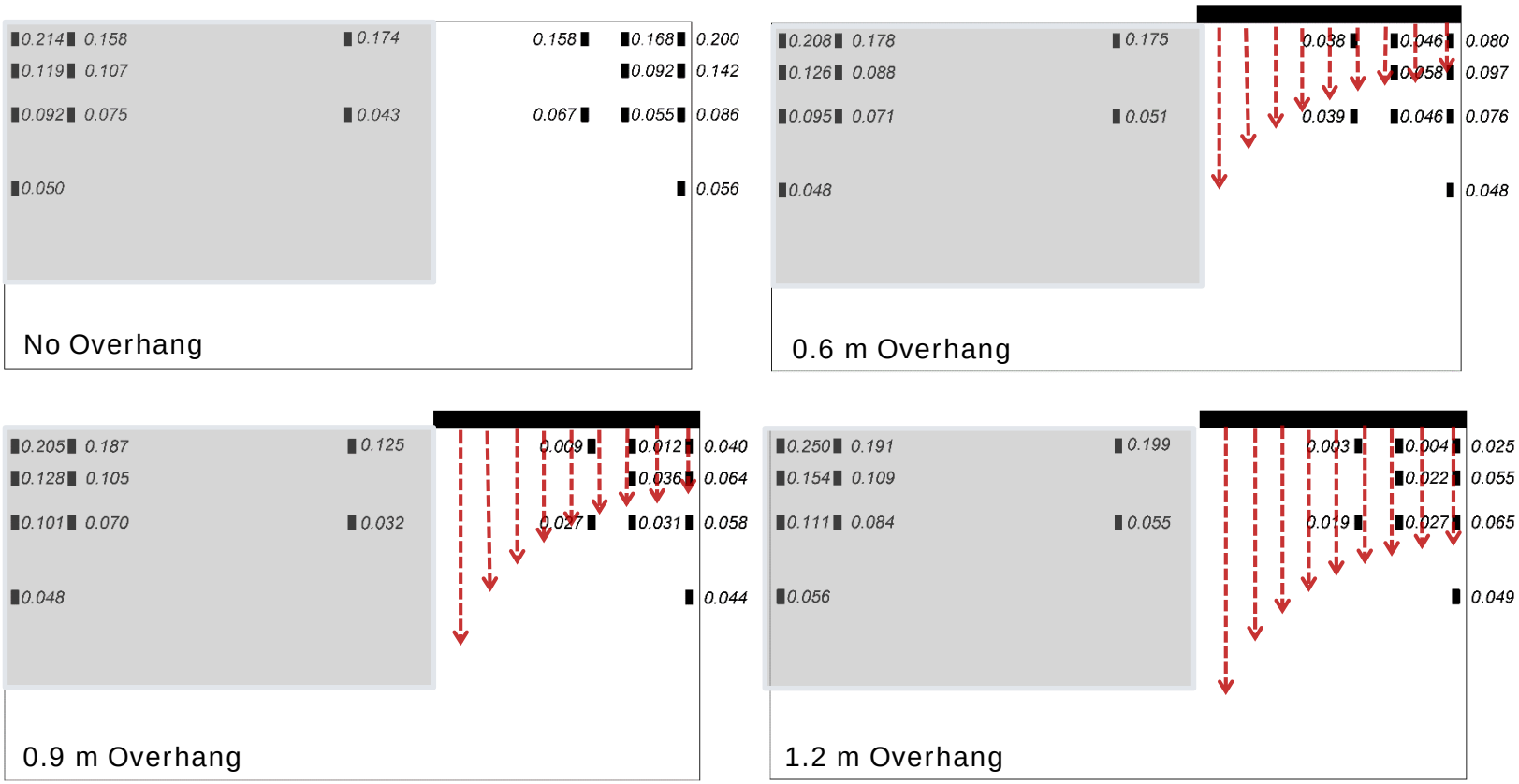
North façade

<u>Observation for the period without overhang</u>

- Symmetrical distribution of WDR across the east facade during the period without overhang
- Top corners are the most wetted followed by the top and side edges
- Wetting increases from the bottom of the facade to the top and from the middle of the facade to the sides.

RESULTS

Overhang Effectiveness



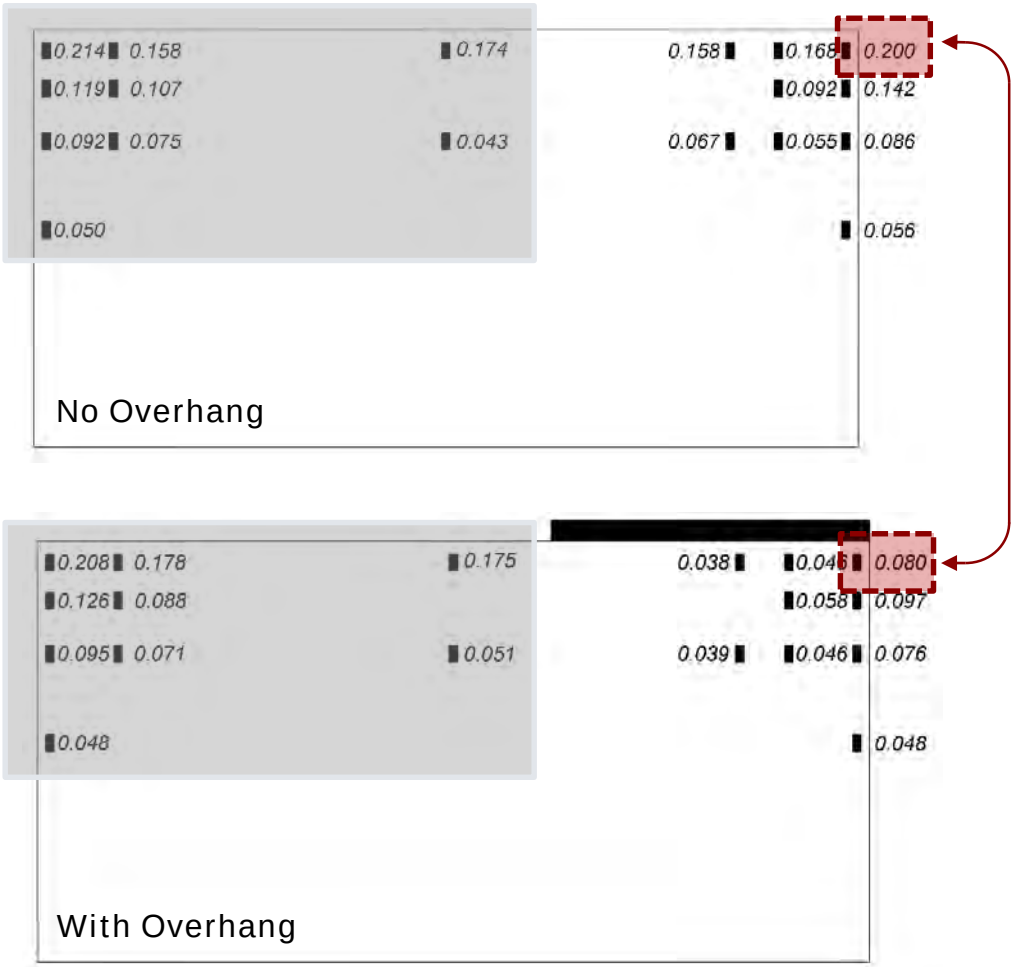
Catch ratio on the east façade

RESULTS

Overhang Effectiveness

- Method 1: Similarity

  comparing the catch ratios at the gauge locations that are directly under the overhang (gauges EN1 to EN9) in one rain event with the catch ratios at the same gauge locations in a similar rain event without overhang.



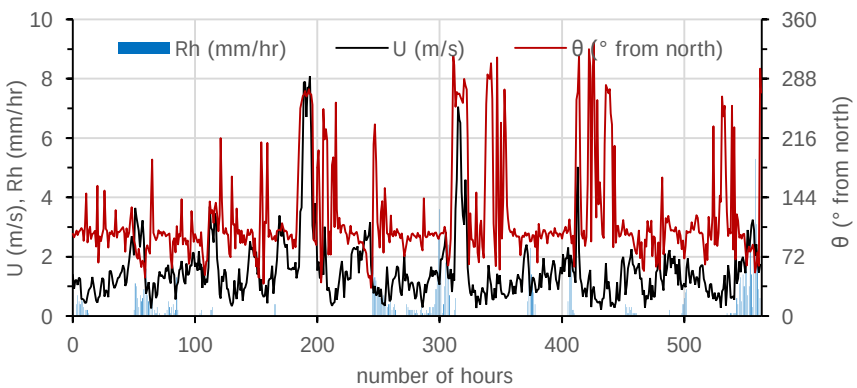
RESULTS

Overhang Effectiveness

- Similar Rain Events

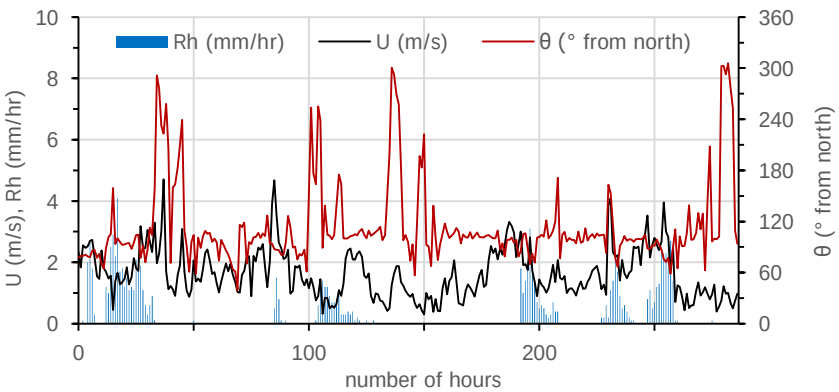
Both rain events should have similar meteorological characteristics including wind speed, wind direction and rainfall intensity, which results in similar catch ratios at locations without overhang

WDR Gauge	Catch Ratios	
	RE 6 (No OH)	RE 54 (0.9 m OH)
EC1	0.101	0.105
EC2	0.021	0.018
ES1	0.111	0.101
ES2	0.062	0.061
ES3	n/a	0.054
ES4	0.025	0.019
ES5	0.085	0.100
ES6	0.057	0.044
ES7	0.035	0.029



RE6: October 2013, No Overhang

Total Rain fall: 111.5 mm
Average of WS: 1.46 m/s
Average of WD: 93°



RE54: October 2016, 0.9 m Overhang

Total Rain fall: 103.4 mm
Average of WS: 1.96 m/s
Average of WD: 100°

RESULTS

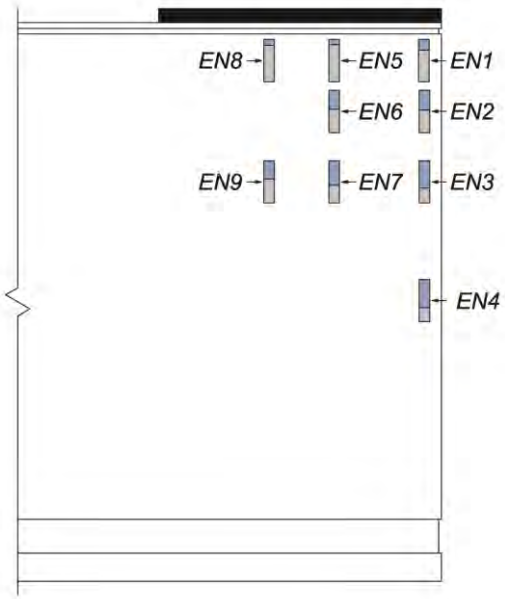
Overhang Effectiveness

- Method 1: Similarity

WDR Gauge	Catch Ratios		Overhang Effectiveness (%)
	RE 6 (No OH)	RE 54 (0.9 m OH)	
EN1	0.108	0.022	80
EN2	0.096	0.036	63
EN3	0.049	0.042	15
EN4	0.038	0.026	33
EN5	0.093	0.003	97
EN6	0.050	0.012	76
EN7	0.034	0.012	63
EN8	0.093	0.001	99
EN9	0.045	0.010	78
EC1	0.101	0.105	
EC2	0.021	0.018	
ES1	0.111	0.101	
ES2	0.062	0.061	
ES3	n/a	0.054	
ES4	0.025	0.019	
ES5	0.085	0.100	
ES6	0.057	0.044	
ES7	0.035	0.029	

Catch ratios and overhang effectiveness on the east façade for rain events 6 and 54

$$\text{OH Effectiveness} = \frac{(\eta_{\text{no OH}} - \eta_{\text{OH}})}{\eta_{\text{no OH}}} \text{x } 100$$



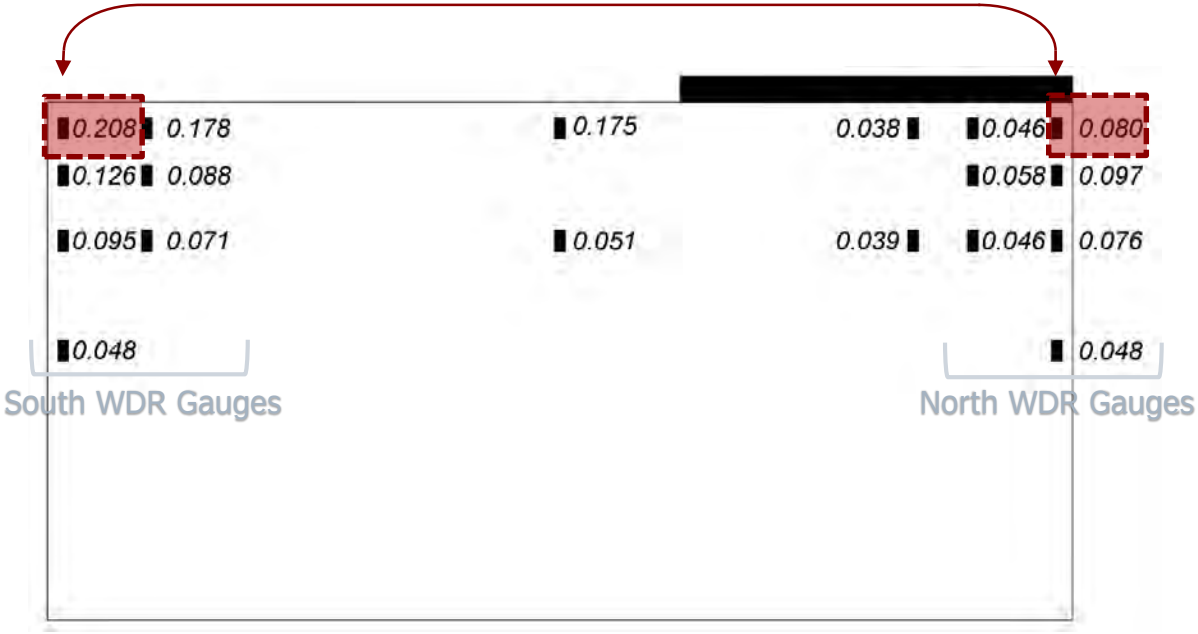
North side of east façade

RESULTS

Overhang Effectiveness

Method 2: Symmetry

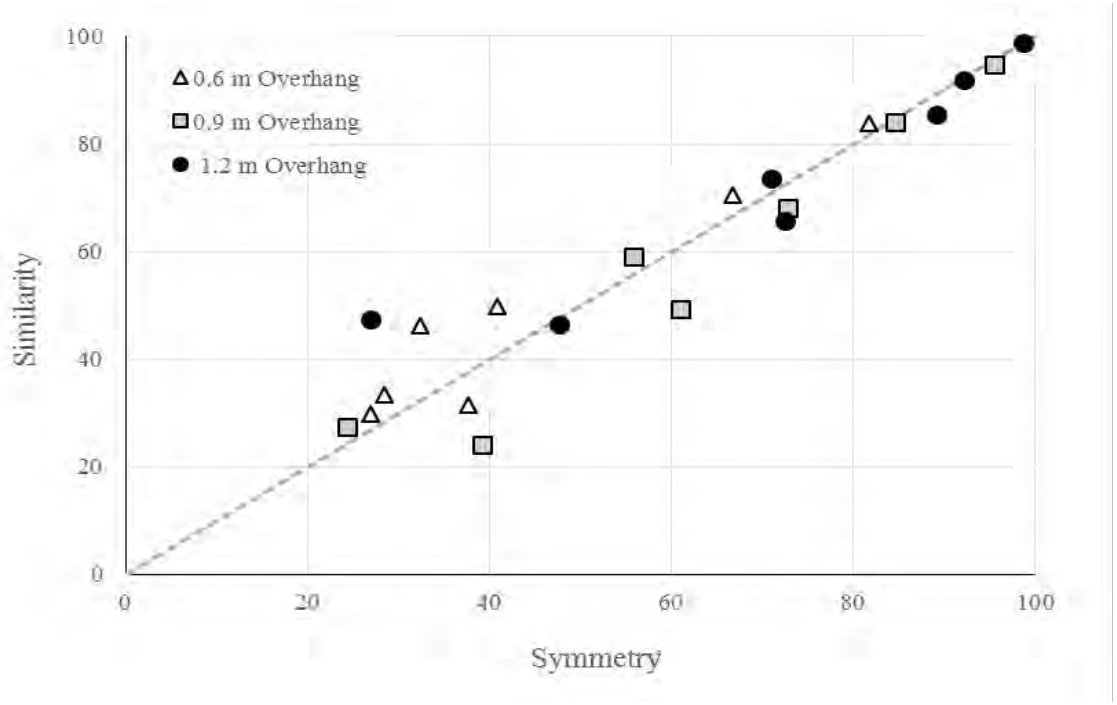
Comparing the catch ratios at gauge locations underneath the overhang on the north side of the façade (EN1 to EN7) to those on the south side of the façade (ES1 to ES7)



RESULTS

Overhang Effectiveness

- Similarity versus Symmetry



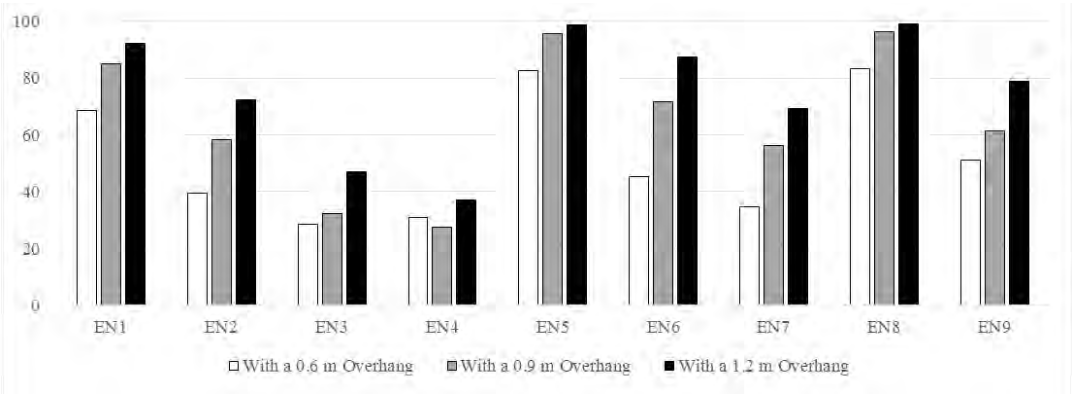
- In general, there is a good agreement between these two methods with a difference within 20%;
- Better agreement with larger overhang

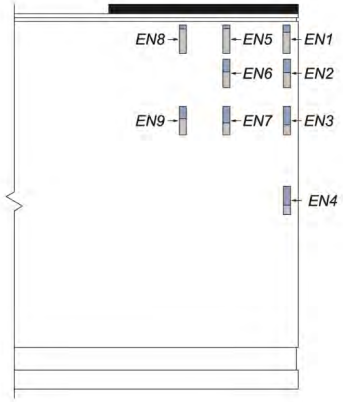
RESULTS

Overhang Effectiveness

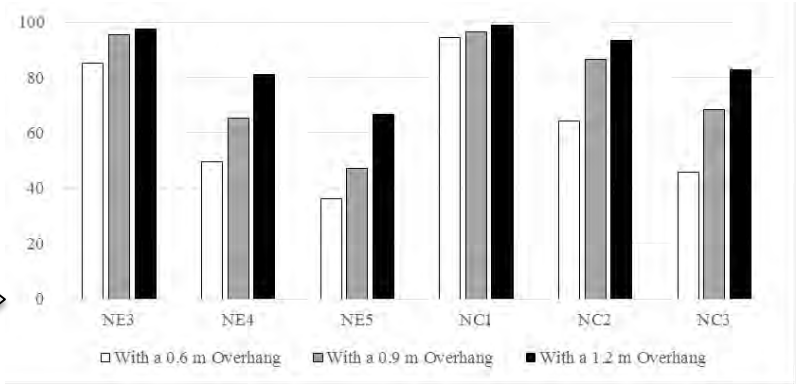
- At Each Rain Gauge Location
  - Similar trend is observed on both façades
  - With the increase of overhang size, protection increases

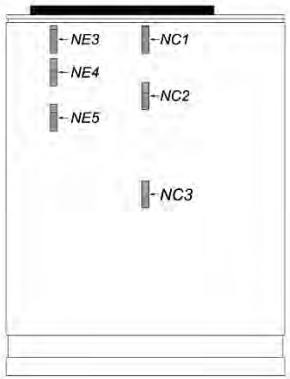
East Facade





North Facade

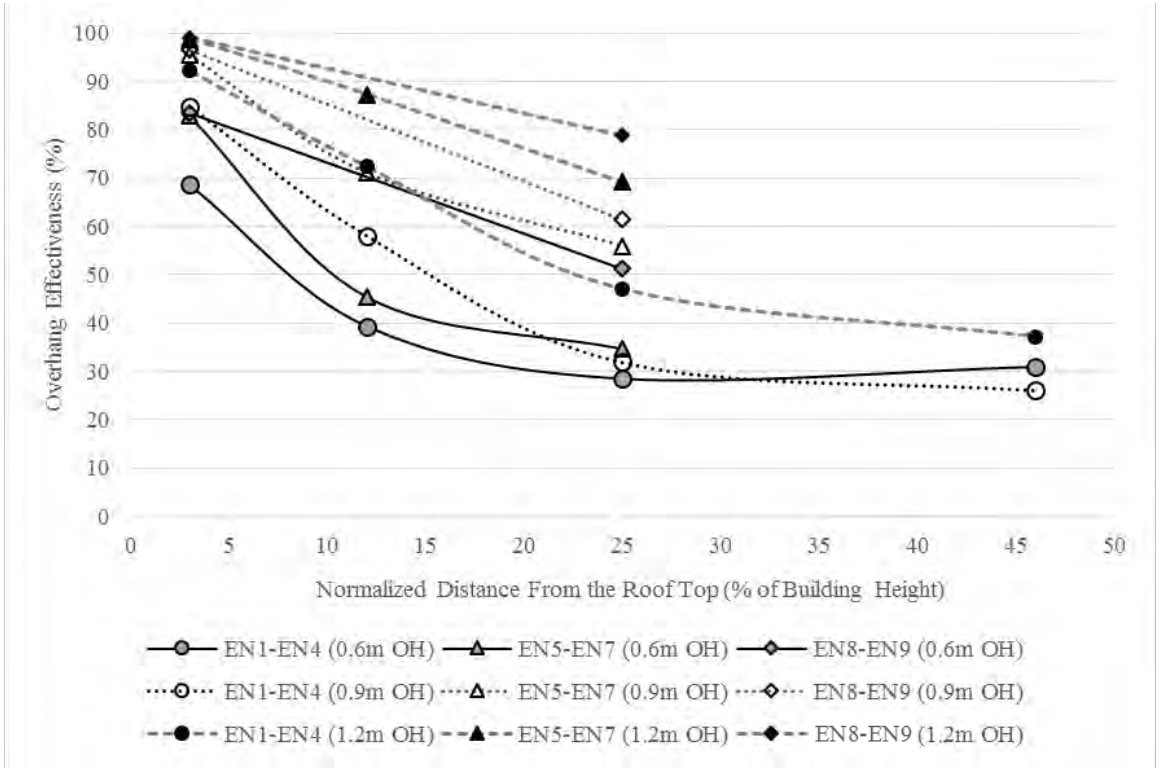


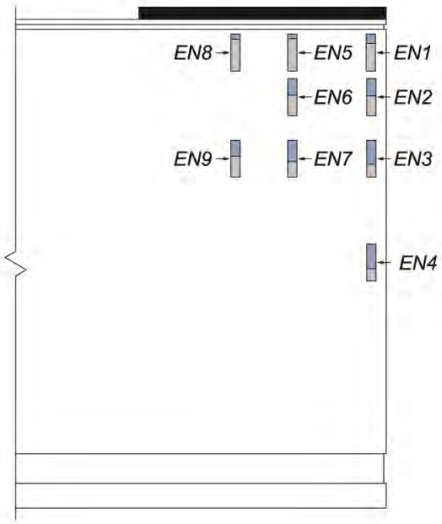


RESULTS

Overhang Effectiveness

- At Each Rain Gauge Location





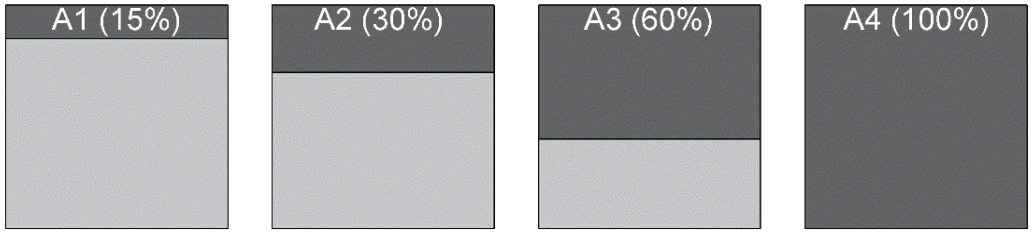
Effectiveness of overhangs on the east façade with regard to distance from the roofline

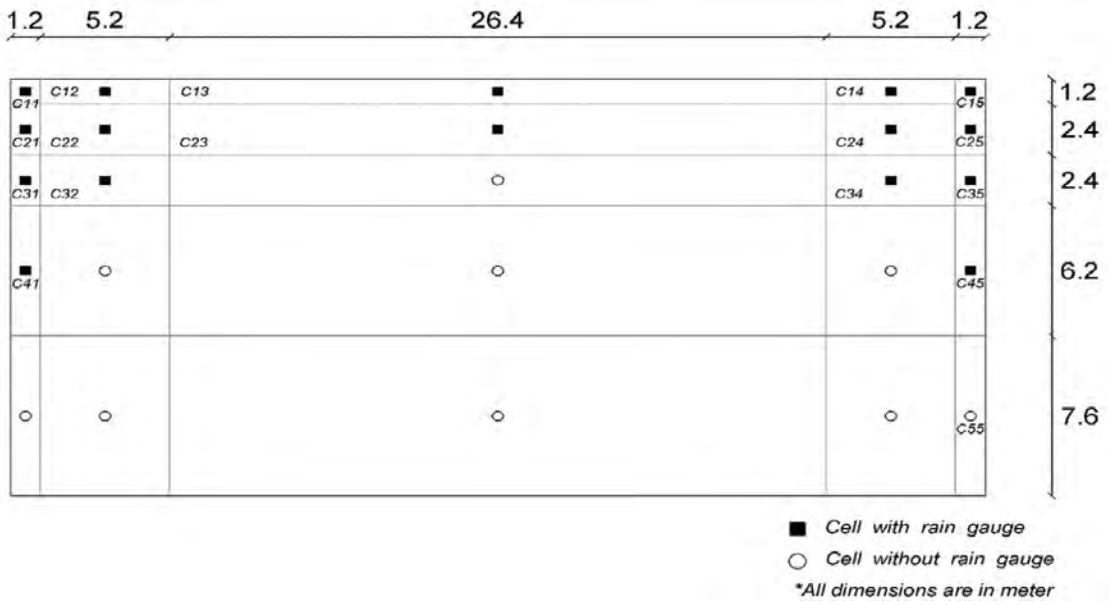
RESULTS

Overhang Effectiveness

- Area weighted overhang effectiveness

$$\bar{\eta} = \frac{1}{\sum_{i=1}^{n} A_i} \sum_{i=1}^{n} \eta_i \, A_i$$

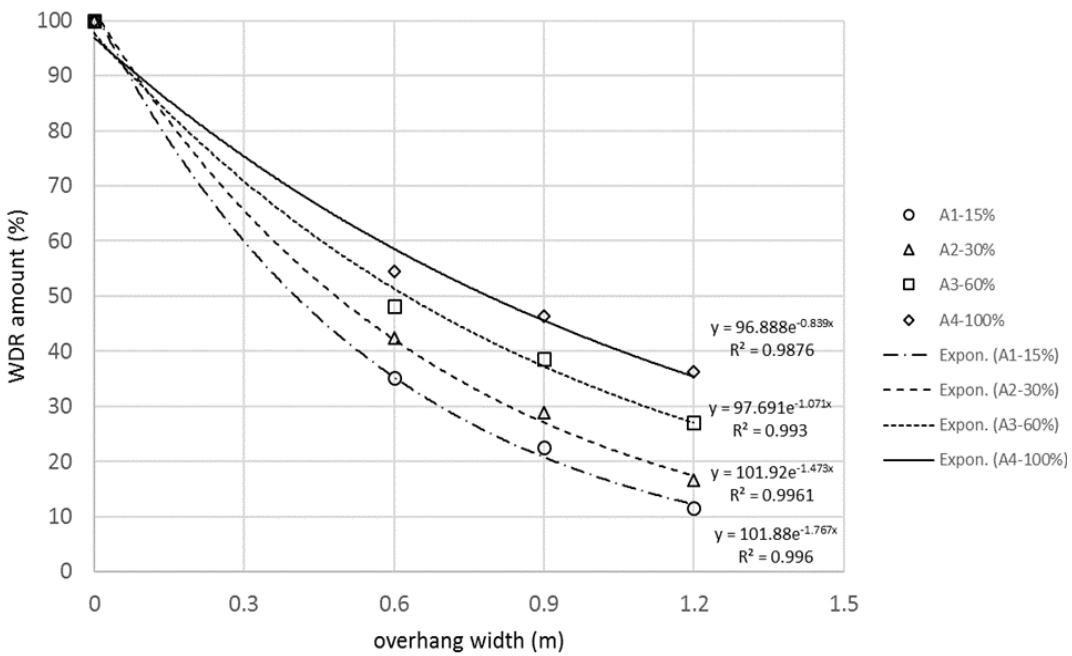




RESULTS

Overhang Effectiveness

- Area weighted overhang effectiveness



- Exponential correlation between overhang size and overhang effectiveness
- Greater protection for the upper portion of façade
- The total amount of WDR impinged on the façade can be reduced by:
  - ✓ 45% with a 0.6 m overhang
  - ✓ 54% with a 0.9 m overhang
  - ✓ 68% with a 1.2 m overhang

Conclusions

- For the particular climate characterized by long rainy winters with mild wind and rain, the overhang is effective and significantly reduces WDR for this six-story building, especially for areas directly underneath the overhang.
  - The protection increases from the side edge to the center and from the bottom to the top of the façade.
  - The protection provided by the overhang can extend to about half building height.

Conclusions

- The larger the overhang, the greater the protection
  - An exponential relationship with a quite good correlation is observed between the overhang width and overhang effectiveness based on the available data points
  - Given that about 70% of the total amount of WDR impinged on the façade is received by the top 30% of the façade area, overhangs that can shelter the top 30% of the façade can effectively protect the façade from WDR wetting

Acknowledgement

- Financial supports
  - NSERC Strategic Research Network for Engineered Wood-based Building Systems (NEWBuildS)
  - BC Housing
  - Faculty of Engineering and Computer Science of Concordia University
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