



# *Selection Considerations of Exterior Wall Leakage Values for Smoke Control Systems Design*

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James Milke, PhD, Senior Principal Engineer  
Babak Bahrani, Senior Fire Protection Consultant  
Steven M. Strege, Principal Fire Protection Engineer  
Jeffrey L. Paterson, Senior Fire Protection Engineer



# Outline

- Introduction
- Building Survey Data
- Influence of Building Characteristics
- Summary

# Introduction

- Inputs for design analysis of fan capacity for stairwell pressurization systems:
  - Magnitude of leakage associated with building components
  - Location of stairwells
  - Height of building and stairwells
  - Exterior/interior temperatures
  - Area of spaces in building
  - Presence of other shafts
  - Etc.
- Input for leakage of building components provided as leakage ratio:

$$\frac{\text{effective area of leak}}{\text{total surface area of the component}}$$

# Leakage Rates, Handbook of Smoke Control Engineering (Klote, et al., 2012)

Leakage Category	Leakage Ratio (m <sup>2</sup> /m <sup>2</sup> )
Tight	5.0x10 <sup>-5</sup>
Average	1.7x10 <sup>-4</sup>
Loose	3.5x10 <sup>-4</sup>
Very Loose	1.2x10 <sup>-3</sup>



air permeability of air barriers in commercial buildings  $\leq 1.27 \times 10^{-4} \text{ m}^2/\text{m}^2$  [IERC, 2021]

# Early Surveys of Leakage Rates

- Tamura and Shaw, NRCC [1976].
  - Experiments in 8 office buildings
    - 11 to 22 stories
    - constructed in 1960s - early 1970s
    - all included curtain walls.
- Shaw, NRCC [1993]
  - Follow-up of the 1970's study
  - 6 buildings, 5 of which had renovations to exterior boundary
  - Observed changes in leakage rate
    - In 5 renovated buildings, reduction in leakage rate ranged from 0 to 43%.
    - In building that had not been renovated, leakage rate increased by 23% in the 20 years since it was last tested.

# Subsequent Studies

- Emmerich and Persily, NIST, [2011]: Exterior leakage rates did not significantly change from 1960s to 1990s.
- Strege and Ferreira [2017] measured differential pressures in fifteen (15) high-rise buildings in four (4) different cities (Cleveland, Baltimore, Minneapolis, and Philadelphia) during the winter months of January to March 2013.
  - Exterior walls had either fixed glass curtain walls or masonry with fixed windows
  - Leakage of the exterior walls: “loose” category of values in table from Handbook

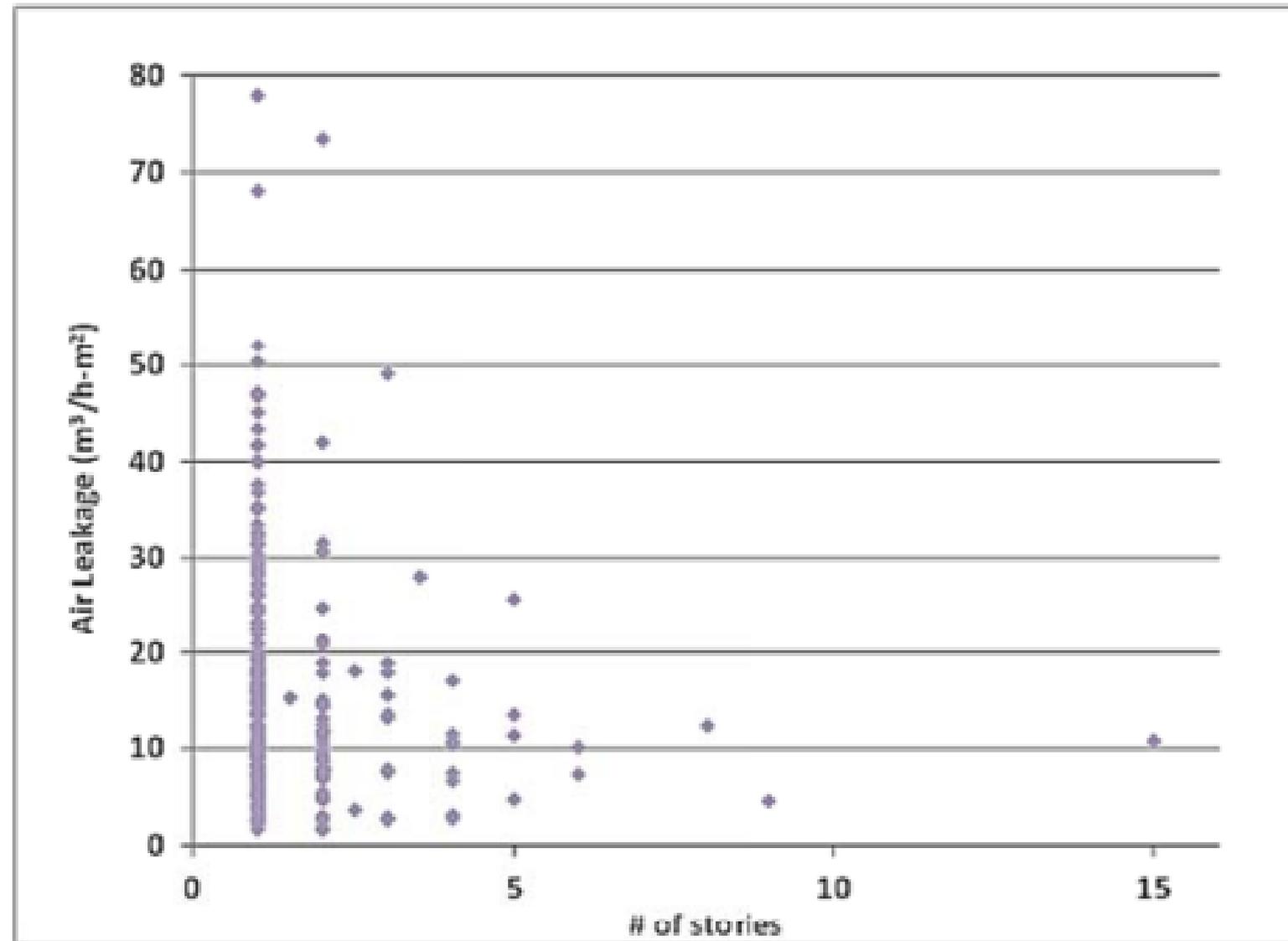
# Building Surveys by Emmerish and Persily [2014]

Dataset	Qty	Mean	Standard Deviation	Minimum	Maximum
<b>2011 Database</b>					
Source 1	9	5.77E-04	4.40E-04	1.49E-04	1.66E-03
Source 2	89	1.29E-03	8.87E-04	1.53E-04	4.74E-03
Source 3	39	7.57E-04	6.96E-04	1.03E-04	3.08E-03
Source 4	88	7.38E-04	3.94E-04	1.30E-04	2.42E-03
Source 5	3	3.33E-04	7.64E-05	2.45E-04	3.86E-04
<b>2014 Database</b>					
Efficiency VT	36	3.67E-04	3.94E-04	2.68E-05	1.85E-03
ASHRAE RP 1478	16	2.68E-04	1.91E-04	5.35E-05	7.80E-04
Washington	18	4.01E-04	1.57E-04	1.15E-04	6.69E-04
Other VT/NH	79	5.66E-04	4.13E-04	5.35E-05	1.75E-03
Other VT/NH	10	3.17E-04	2.45E-04	9.94E-05	8.68E-04
<b>Summary</b>					
Total-2011	<b>228</b>	<b>9.52E-04</b>	<b>7.30E-04</b>	<b>1.03E-04</b>	<b>4.74E-03</b>
Total-2014	<b>159</b>	<b>3.78E-04</b>	<b>3.25E-04</b>	<b>2.68E-05</b>	<b>1.85E-03</b>
Total-all	<b>387</b>	<b>7.45E-04</b>	<b>6.57E-04</b>	<b>2.68E-05</b>	<b>4.74E-03</b>

# Observations (Emmerish and Persily, 2014)

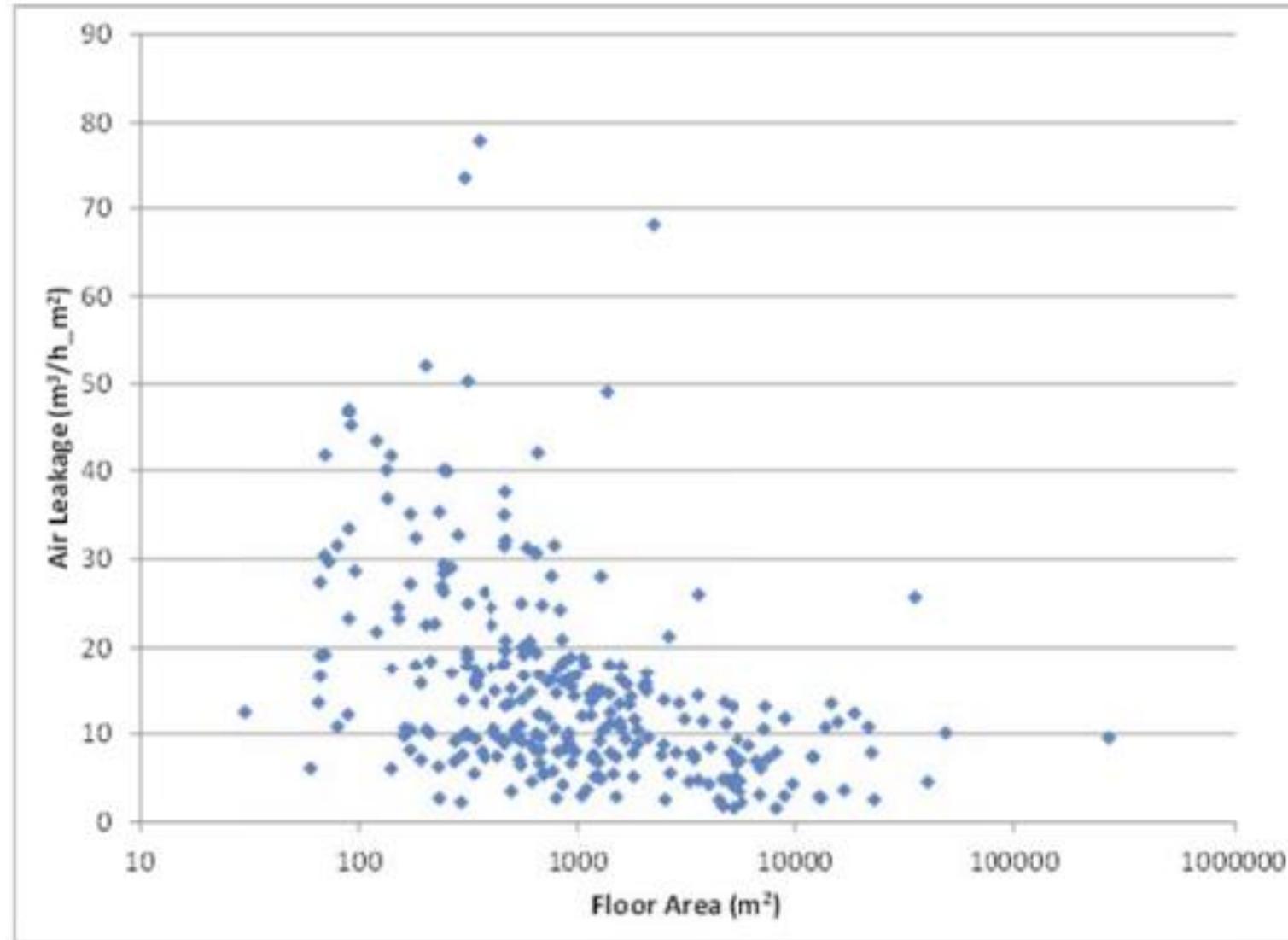
- Average leakage rate of  $7.45 \times 10^{-4} \text{ m}^2/\text{m}^2$  for all 387 buildings: “loose” to “very loose” categories.
- Except for data collected in Washington [Anis, et al., 2013]
  - **all** maximum leakage rates  $>$  leakage rate for “very loose” category

# Leakage Rate vs. Building Height



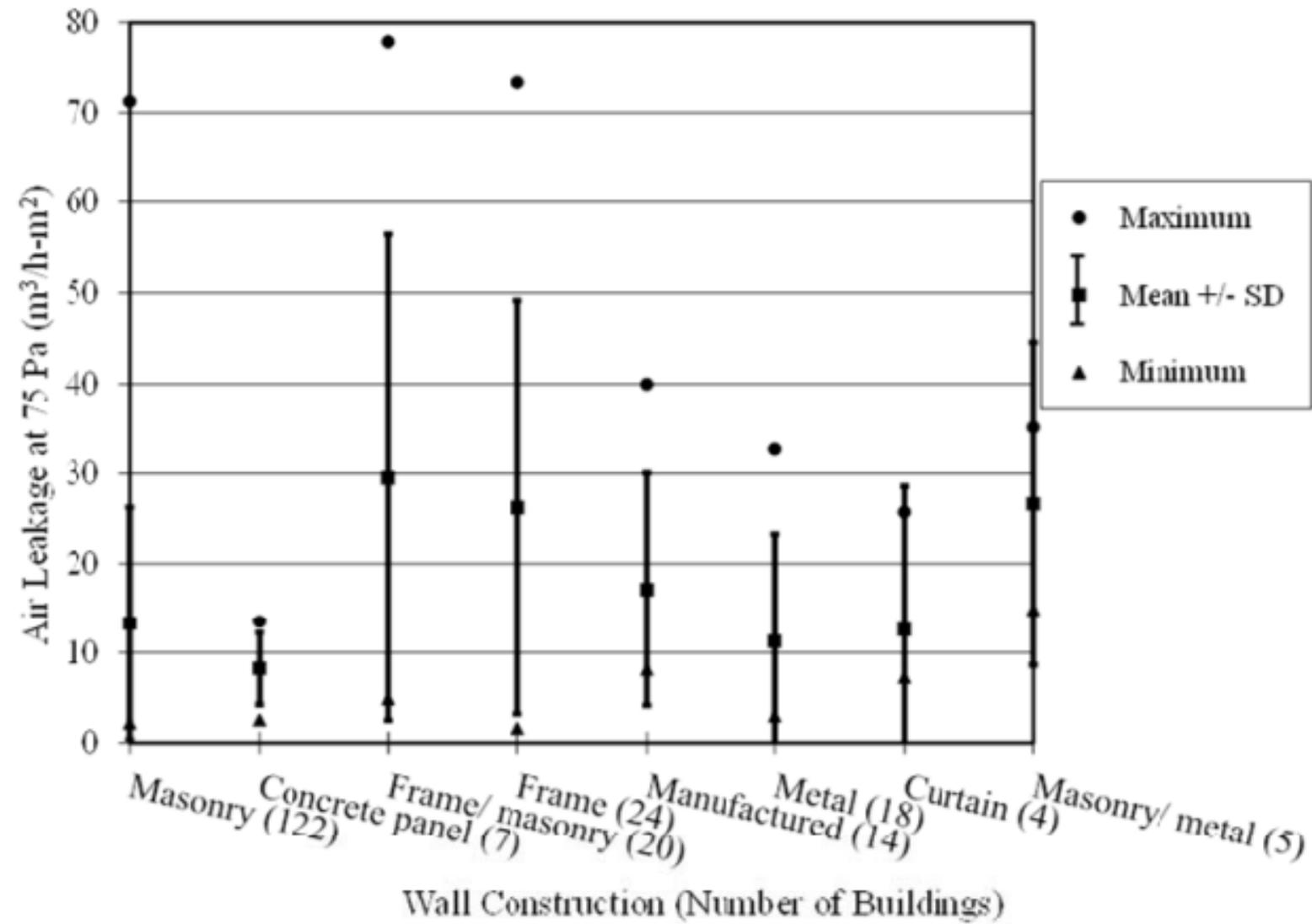
Ref: Emmerish and Persily [2014]

# Leakage Rate vs. Floor Area



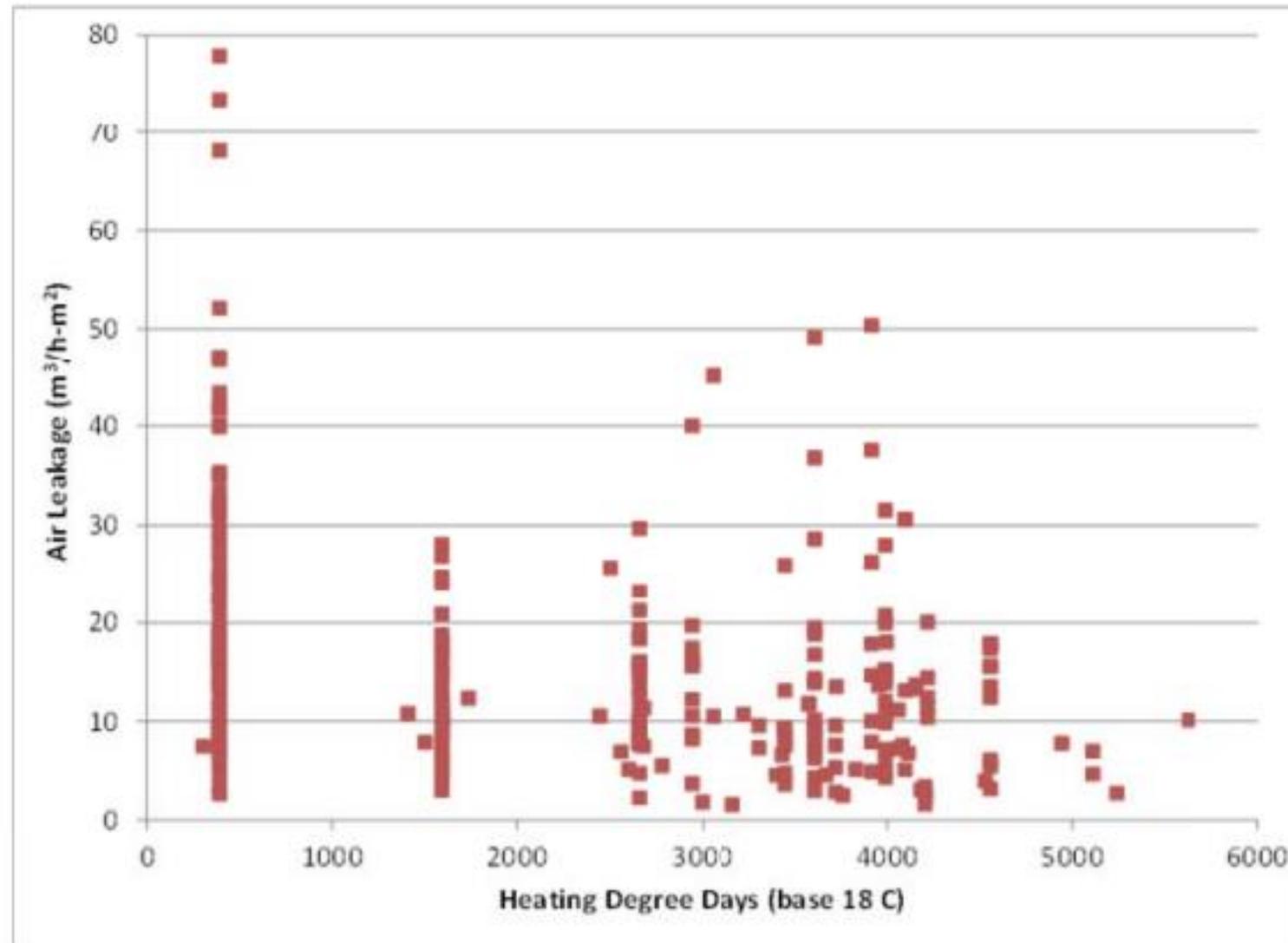
Ref: Emmerish and Persily [2014]

# Leakage Rate vs. Composition of Exterior Wall



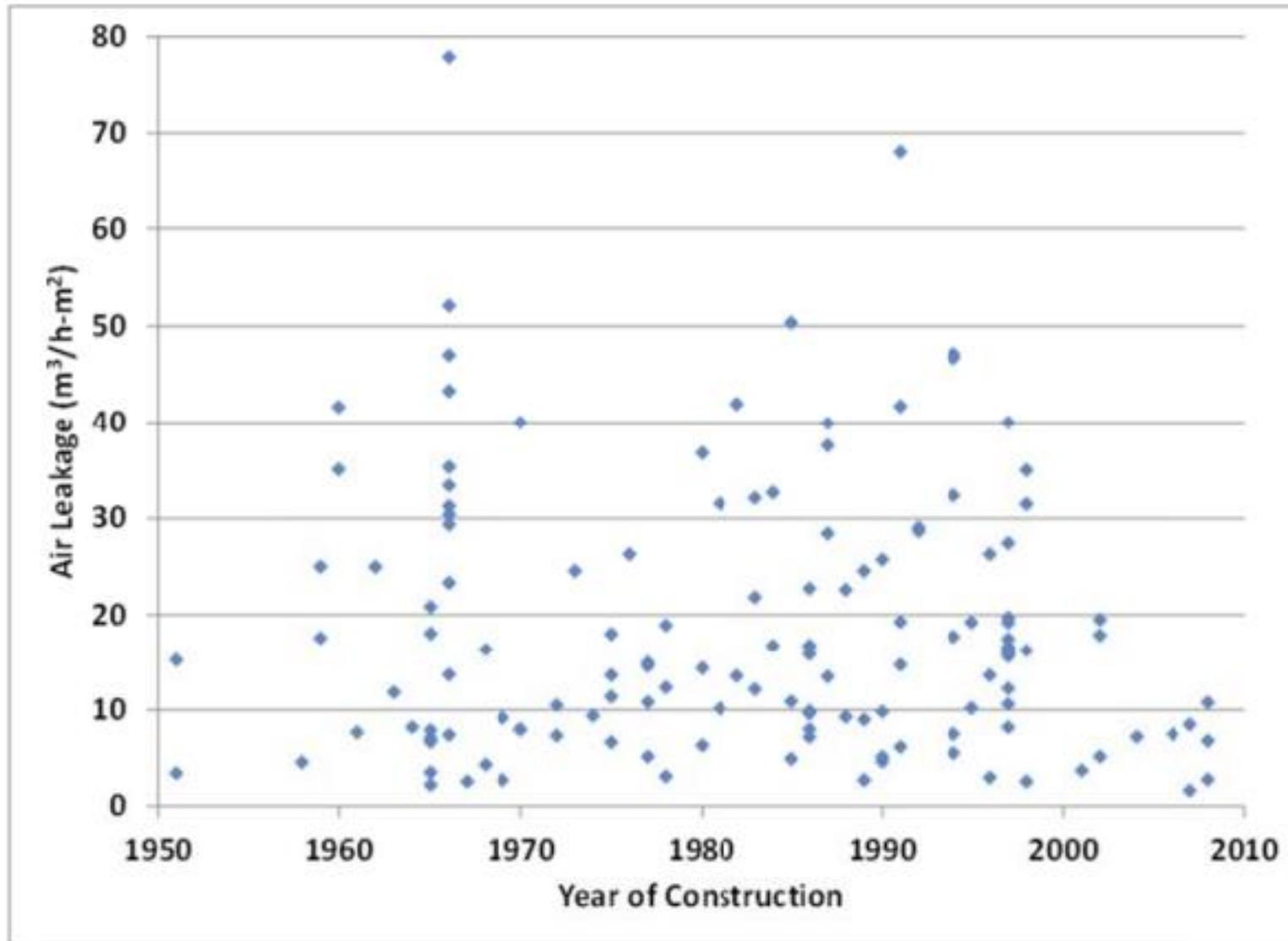
Ref: Emmerish and Persily [2014]

# Leakage Rate vs. Climatic Conditions



Ref: Emmerish and Persily [2014]

# Leakage Rate vs Year of Construction



Ref: Emmerish and Persily [2014]

# Summary

- Informed assumptions about leakage rates can yield improved fan capacity selections and reduce the potential overdesign for fans and ductwork in stairwell pressurization systems
- Previous studies have found that building envelope leakage rates were either “loose” or “very loose”.
- Trends in the Emmerish and Persily database of leakage rates of exterior walls are present for five characteristics of buildings:
  1. Height
  2. Floor area
  3. Age
  4. Composition of exterior wall
  5. Climatic condition

# *Questions?*

Jim Milke

[jmilke@fireriskalliance.com](mailto:jmilke@fireriskalliance.com)