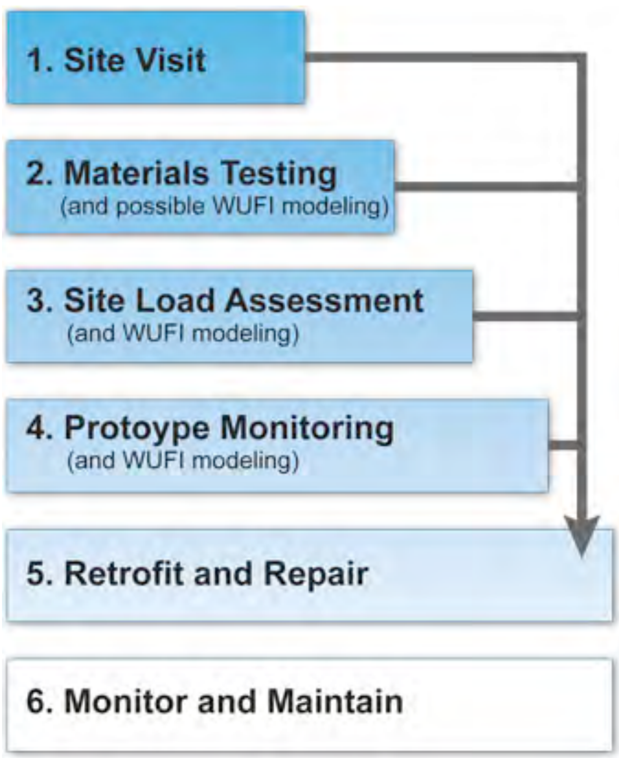
Recommended Freeze-Thaw Risk Assessment Steps

Building Science Corporation has worked with project teams on a wide variety of masonry retrofits, from houses to large buildings, including historical buildings that are North American landmarks. As part of this work, we have been continuously developing and refining tools for assessing freeze-thaw risk for thermal retrofits of masonry walls. There are a variety of tools available—the combination can be selected based on the particular project.

A lack of knowledge of these tools (and when to use them) can lead to either unnecessary avoidance of an insulation retrofit or poorly guided insulation choices that result in premature deterioration. Because each project has different constraints and a different level of risk tolerance, BSC advocates a balanced approach that considers a variety of tools at each of several stages.



Freeze-Thaw Risk: Site Visit

Inspection by a building scientist can often identify existing moisture problems (due to rainwater, rising damp, air leakage, etc.) that must be addressed before any insulation is added. Inspection can also identify buildings that are at the extreme ends of the risk spectrum. For example, if unheated parts of the building exterior (such as a parapet or unused chimney) are in good condition, then there is less risk in making the rest of the exterior colder (as will happen when insulation is added inside the walls). Similarly, if exterior brick currently has high rain exposure due to a broken or missing downspout and is not experiencing degradation, it is unlikely that insulation together with addressing such water management issues will result in new degradation. Site assessments are not foolproof – for example, a chimney might be made of different bricks than the main cladding and a parapet might dry better than an insulated wall because it is exposed to the sun at the back. However, the degree of certainty provided by a site visit is adequate for many projects, and is always a solid starting point for further investigation.

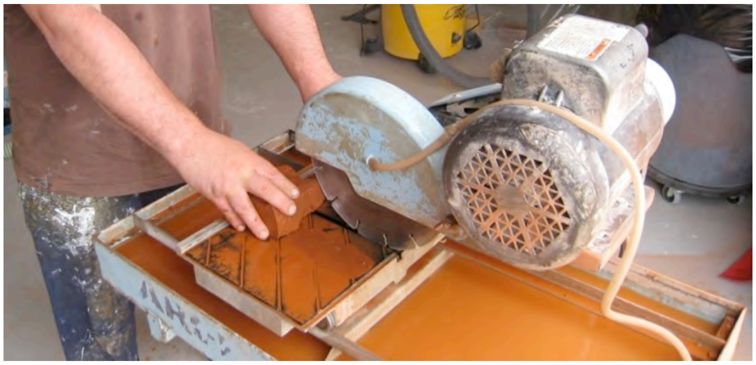
Site inspections should include the interior and exterior of walls and should check for:

- poor masonry details that concentrate water (windowsills, band details)
- poor water management details (disconnected downspouts, roof-wall interfaces)
- existing freeze-thaw damage (parapet, chimney, at-grade, below windows)
- rain leaks (are they large/small? Often/rare? Active/inactive?)
- rising damp issues
- air leakage condensation issues
- interior condensation issues
- air sealing and thermal bridging issues
- brick construction details (are all bricks similar? Are there obvious replacements?)

Next Steps

- If a site visit reveals needed repairs, then the repairs should be done; if there is strong evidence that a retrofit will be safe, it can proceed. Regular maintenance and monitoring should follow this work.
- If the level of uncertainty is too high, more evidence should be gathered through material testing.

Freeze-Thaw Risk: Material Testing



In many projects, the risk is not clear from inspection alone. Material testing is the next step in evaluating risk. Samples are removed from the building being assessed and shipped to our lab.

Lab tests can include dry density, A-value (absorption or liquid water uptake rate), and saturation moisture content (storage). However, the primary method used by BSC to assess the risk of freeze-thaw damage is frost dilatometry. Frost dilatometry, as first developed by Fagerlund[1], involves putting thin slices of brick through multiple freeze-thaw cycles until damage is measurable. This process produces a measure of S_{crit} (the Critical Degree of Saturation) – the point of saturation at which a given masonry material will fail. By estimating the typical degree of saturation for a building, and comparing it to S_{crit}, the risk of freeze-thaw damage can be predicted. Freeze-thaw cycling below S_{crit} has low risk of damage, but above S_{crit}, damage can occur after relatively few freeze-thaw cycles.

Unlike methods that provide pass-fail measures of freeze-thaw "resistance", the frost dilatometry approach allows the material resistance to be compared to predicted moisture loading and ambient temperatures. A wall on the edge of a cliff overlooking the ocean will see a great deal more driving rain than a wall in a sheltered neighborhood in the mid-west. So instead of a brick simply "passing" or "failing," different brick can be suitable for one exposure but not the other.

In other words, this method produces realistic, usable data – data that can inform decision-making. Refining this methodology for commercial applications has been a significant part of BSC's freeze-thaw research.[2]

Next Steps

- If available data about environmental conditions is adequate, use hygrothermal modeling to assess the predicted rain load relative to $S_{crit.}$
- If additional site load data is needed, gather it through site load assessment.
- In some cases, materials testing in combination with a site visit can provide a good indicator of risk. For example, if testing reveals a medium to high critical saturation point, and the building's rain exposure is likely to be low, an experienced consultant may be able to judge freeze-thaw risk without the need for hygrothermal modeling.

[1] Fagerlund, G., "The critical degree of saturation method of assessing the freeze/thaw resistance of concrete", Journal of Structures and Materials, 10.58, pp 217-229, 1977.

[2] For a more detailed account of this method, see Straube, Mensinga, and Schumacher, "Assessing the Freeze-Thaw Resistance of Clay Brick for Interior Insulation Retrofit Projects", Thermal Performance of the Exterior Envelopes of Whole Buildings XI International Conference, December 5-9, 2010 in Clearwater, Florida

Freeze-Thaw Risk: Site Load Assessment

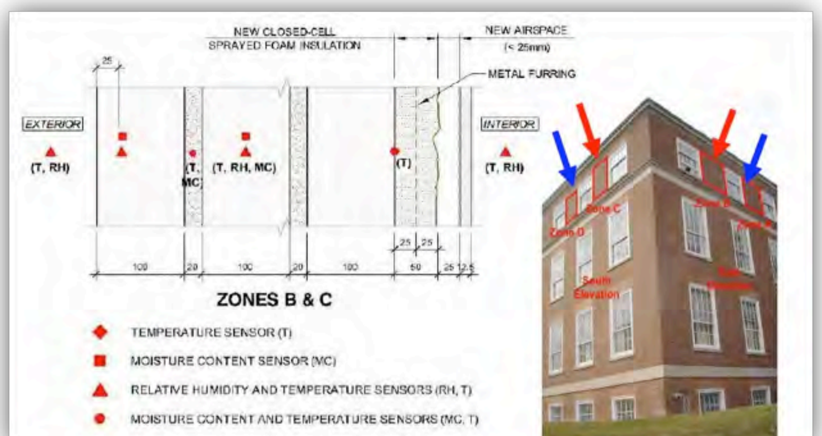
Most of the moisture that masonry walls must deal with comes from wind-driven rain. Unfortunately, the amount of driving rain that a given wall will encounter is difficult to predict with any certainty. Estimates can be made based on a building's shape and features, local terrain/shielding, and local climate (see BSD-148: Simplified Prediction of Driving Rain on Buildings: ASHRAE 160P and WUFI 4.0). However, conservative assumptions should be used when providing such estimates. Monitoring of rain deposition with driving rain gauges provides more accurate data, and can reveal unexpected effects such as microclimate wind patterns or small surface features affecting runoff. By replacing estimates with data, site load assessment can provide a higher degree of certainty with fewer conservative assumptions. The end result is a more useful and reliable picture of risk.

Next Steps

- Use data about environmental conditions to assess the predicted rain load relative to $S_{crit.}$
- If a higher degree of certainty is needed, for example in the case of highly significant historical buildings, consider prototype monitoring.

Freeze-Thaw Risk: Prototype Monitoring

In some cases, the risk of adding interior insulation is still not clear enough even after materials testing and site load monitoring. In these situations, a small area of the building can be retrofitted and closely monitored before proceeding to insulate the whole building. By creating a prototype of the anticipated project, real-world data about wetting, temperatures, and moisture content patterns can be compared to computer model results. The model can then be adjusted to better predict the effects of insulating the whole building.

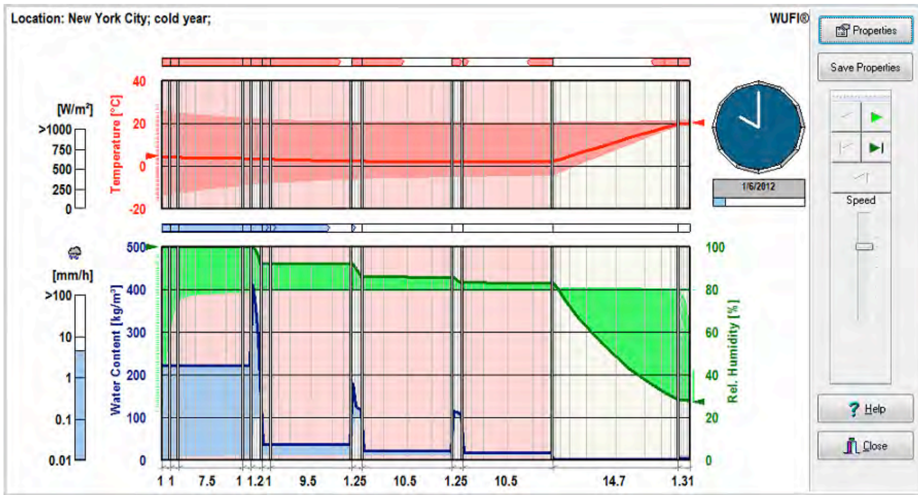


Monitoring requires a significant investment of time and resources, and is therefore appropriate only for buildings where a high level of certainty is required and the necessary time and resources are available.

Next Steps

- Use data from prototype monitoring to improve computer model predictions.

Freeze-Thaw Risk: Hygrothermal Modeling



There are cases where hygrothermal modeling is simply unnecessary. For example, materials testing may reveal that the brick in a wall has a very high critical saturation point – meaning that it will not fail even given high rain exposure immediately preceding freeze-thaw cycles. An experienced consultant may be able to judge the risk of degradation low in this situation – especially if the consultant has conducted a thorough site assessment. However, in most cases risk is difficult to predict. Hygrothermal modeling can be extremely helpful in analyzing a variety of data to see how different factors might impact the overall risk level. Because simulations are based in part on assumptions and incomplete data, they should be planned and interpreted in combination with other assessments. At the end of the day, judgment is required to decide on an acceptable level of risk.

BSC uses collected material properties, local airport weather data, and wall assembly details to run simulations in WUFI. Our analysis method varies depending on the time and budget available but is always conducted by WUFI experts as part of a larger assessment process.

Next Steps

- If more data is needed to refine the hygrothermal model, gather this data (e.g. site load assessment).
- If modeling in combination with other assessments yields a strong enough assessment of risk, a decision about retrofitting can be made.

Freeze-Thaw Risk: Repair/Retrofit

Each retrofit project is unique: the building's features and historical significance, the site conditions, and the time and money available for assessment all vary. The goal of assessment should be to determine— to a reasonable degree of certainty—what actions will best meet the building owners' goals. By going through the assessment process step-by-step, the consultant can select the assessment tools that have the best chance of supporting confident decision-making within the project's budget. In most cases, a way can be found to proceed with insulating with minimal risk of freeze-thaw damage. In some cases, insulating must be postponed until underlying problems are dealt with. It is also sometimes the case that insulation should be avoided, either because the risk to masonry is too high, or because the level of risk cannot be determined with adequate certainty given the project's budget or other constraints.

Freeze-Thaw Risk: Maintain and Monitor

If insulation is added, regular maintenance will help to minimize any risk. Most masonry walls fail because water management systems are not maintained; when walls are insulated, the damage caused may be greater. It is therefore critical to check and repair details such as downspouts and roof flashing. It is also useful to proactively check outside for signs of masonry deterioration (e.g. crumbling mortar), since interior signs of damage (e.g. water leakage) might be less obvious in an insulated wall.

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