Insight
What is Building Science?

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Defining building science is actually quite difficult, since it means different things to different people. As it has become more popular, the definition has broadened and become less and less precise. Today it seems as though everybody claims building science expertise, from construction foremen, to house energy raters, to insulation salesmen, to energy modelers, and code officials.

So, what is building science? There is, alas, no accepted definition. It should however be clear that building science is not something learned in an 8-hour course or gained by browsing websites. It is in fact a rather large and deep collection of knowledge, some of which is commonly available to building industry practitioners, and some of which requires serious study and unique or extensive experience to gain.

Most of what is called building science in the building industry is actually some combination of good building practice, rules of thumb ("heuristics"), and common sense. But building science has a rigorous core, based on physics and hard-won evidence-based experience (including actual measurements)[1]. Building Science, as used in North America, is neither Building Physics nor Building Technology, but includes significant aspects of both.

[1] This is the reason that an elite group of architects advertise that they practice "evidence-based design". Shockingly, this implies that other architects are basing decisions on factors that are not evidence. The fact that this may be true is likely one of the reasons for the growth in interest in building science and building defect claims.

Building Physics

The application of the scientific fields (heat and mass transport, thermodynamics, material science, meteorology, radiation physics, etc.) to buildings is commonly called Building Physics, especially in Europe. This part of building science allows one to predict the behavior or performance of a building, component, system, or material with some numerical estimate of varying accuracy. However, it is different than building science in that it does not explicitly include field experience, understand workmanship and tolerance limitations, or the building process.

Unfortunately, relatively few people who claim to use building science actually have much expertise or even competency in building physics. In most cases, they rely mostly on their experience and observations or black-box computer models. But knowledge of the physics, or what some call fundamentals, really does make a difference.

To help define what is meant by building physics, some examples may be useful. Building physics would be able to provide answers, that is, reasonably accurate predictions, (using calculators and reference texts) for the following questions:

1. A stainless steel cladding with a solar absorptance of 0.4 and an emittance of 0.2 is proposed for an Arizona office tower. How much would a 4'6" long panel expand when exposed to the summer sun? Assume the panel was manufactured and installed at 60°F (15℃).
2. A north-facing 2x6 wood stud wall with R22 batt, latex painted gypsum, and OSB sheathing with housewrap and vinyl siding separates an indoor climate of 70°F (21℃) and 45%RH and an outdoor climate of 10°F (-12.2℃) and 80%RH. How much moisture will accumulate in the OSB due to diffusion over a 72-hour period? What permeance did you choose for the vinyl siding and paint? Did you assume the permeance of the OSB was constant with moisture content?

3. A duct discharges 200 cfm (95 lps) of air, at 52°F and 80%RH, into a room that has sufficient heat gain to maintain 72F (22℃). If room occupancy releases 2 oz (57 g) water vapor/hour, what RH does the room stabilize at.
4. A low-slope roof wetted by heavy rainfall during construction is stored at 1 gallon of water per square yard (4.5 l/m^2). How much energy would be required to evaporate this water? If the sun delivers 2 kWh of heat energy per sunny day to that square yard of roof membrane, how many such days are needed to just evaporate this amount of stored water? If an interior vapor retarder of 0.2 perms (11 metric perms) is applied over an air conditioned interior space, estimate how many sunny days it will take to dry the water.
5. An office worker sits 4 feet (1.2 m) from a floor-to-ceiling window during a winter evening. If the outdoor temperature is 10°F (-12.2℃) indoors is 72°F (22℃), and the glazing is simple double-glazing, what is the effective temperature the worker feels?
6. What percentage of the year would a desk 3.6 m (12 ft) from a north-facing strip window (VT=0.53) 1.5 m (5') tall and starting 0.9 m (35") from the floor, receive sufficient daylight to allow normal office work?
7. How much water will be absorbed by a dry 70 mm (2-5/8") high clay brick with an uptake coefficient of 0.07 $kg/m^2s^{0.5}$ if placed in contact with water for 90 minutes.
8. A 1" (25.4 mm) diameter hole penetrates the air barrier layer of an enclosure wall system. If no other air tight layers are present, how much airflow would be expected if an air pressure of 5 Pa (0.02" water column) acts.

Most people in the building industry do not need to have the ability to predict performance and behavior at this level of detail. However, it is debatable if one can claim to be a "building scientist" without having sufficient building physics competency to be able to answer about 3 or 4 of this rather random range of sample questions.

Building Technology

Building technology is the body knowledge of products and systems and how they are assembled, tested, and perform. There are many specialists who understand specifics of building technology, such as roofing, waterproofing, glazing, air barriers, etc. However, this is not building science.

Detailed experience of available products and trade skills, practical workmanship limitations, chemical incompatibilities, and failures in service is critically important for the construction industry. However, if this knowledge is not combined with building physics understanding to predict performance, then it is not building science.

Experience and Observation

Evidence-based observation varies widely in accuracy and utility depending on the scale and nature of the observation. For example, the collective experience of thousands of people investigating leaks in thousands of buildings has provided real solid evidence that windows and their rough openings are commonly implicated in rain penetration problems. This high level of evidence trumps physics—no matter what the calculations show, window openings in practice often leak some rain water. One example of one house that uses a certain technology, assembly, process, or technology with success (or failure) is very weak evidence, but this evidence is more useful than none at all. To strengthen it, the scientific principle of replication of the result needs to be sought.

It should be noted, however, that repeating a claim is not the same as repeating an experiment or observation. You are likely onto something when the same phenomenon occurs repeatedly, and you can confirm that it is happening, and understand why, through measurement or careful observation. But a designer or salesperson simply claiming that something worked is no evidence at all, even if these claims are repeated many times in fancy design magazines, articles, and flashy websites. Unfortunately, a lot of evidence does not fall into either the very strong, very weak, or none-at-all categories. Much of it is in the zone between very strong and very weak. Field experiments, surveys, and directed observation are often research projects undertaken to move evidence from the very weak to at least the somewhat-strong category.

Although the scientific method and research are critical, proof of performance in the real world over time remains valuable. In 1971 the pioneering Canadian building scientist Neal Hutcheon wrote:

> *"Trial-by-use, although it was the basis of much of the tradition in building, is by no means outmoded, since satisfactory service is still the real and final proof of adequate performance. There is a vast difference, however, between trial-by-use as the primary way of arriving at prediction and use as a confirmation of prediction based on evidence….*
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> *…. Tradition places the emphasis on how things should be done; science sets out to explain* why *so that the experience can be carried over to different materials and circumstances."*

Experience cannot stand alone for a building scientist however: building physics can often aid in vastly enhancing or explaining experience and observation. When strong experience is supported and explained by good physics, one has some solid building science knowledge to work with.

Consider the following practical example. A hygrothermal simulation models with proper boundary conditions and material properties will show that unvented roofs using spray foam should perform well. The physics are clear and there are thousands of successful roofs with decades of experience in service. However, the same physics used in hygrothermal simulations would also suggest that an unvented roof with low-density fibrous insulation and an interior polyethylene air-vapor barrier membrane will also perform well in cold climates. Alas, field experience has shown that such systems have a high risk of catastrophic failure, because the assumption of perfect airtightness made in the modeling cannot practically be achieved in the field. Experience and observation trumps calculations and simulations in this case.

Modeling

Modeling and simulation can be used to bridge the gap between the building physics and the construction site but it is not a substitute for direct observation and measurement. Modeling and simulation can usually enhance our understanding and explain performance in existing buildings (and their failures) as well as predict the performance of a building or assembly yet to be built.

It is relatively easy to develop a piece of software that embeds the algorithms and physics required to predict heat flow, daylighting, moisture flow or acoustics. However, this does not make someone who uses the software knowledgeable in building physics, any more than it makes someone proficient with Excel a financial analyst. Although rarer, the converse is also true: someone who has enough expertise in physics to create a good software package does not necessarily have experiential knowledge of critically important evidence-based aspects of building science such as the need for sub-sill flashing, the method by which shingles are nailed to pitched roofs, or the likelihood that a flex duct will be kinked or crushed during construction.

Building Science

The position taken here is that building science encompasses at least three overlapping areas of professional expertise: physics, technology, and field experience. Hence, while we can define building science with better precision than is commonly done, there is still wide latitude for interpretation. It is also critical to recognize that different actors in the building industry have a need for different levels and combinations of knowledge, so somewhat different definitions will always be useful.

Specific areas of building science knowledge have been developing, especially in education and academic research. Common areas include building energy, hygrothermal behaviour, indoor air quality and thermal comfort, and lighting and daylighting. Two very clear specializations have developed in the area of acoustics and fire performance.

However, to claim the title "building scientist", one really should have some knowledge of all three: physics, technology and experience. And you should know more building science than someone with 20 years of construction experience, a practitioner who attended a few lectures last year, or a professional who reads web articles once a month.

Afterword: An Attempt at a Definition

Building science is the cross-disciplinary collection of knowledge and experience required to understand and predict many aspects of the behavior (performance) of buildings and their systems, specifically including comfort, energy, air & water tightness, weathering, durability, indoor air quality, acoustics, lighting, economics, and constructability.

Building science draws heavily on the allied fields of structural and mechanical engineering, architecture, and relies on the areas of thermodynamics, heat air and moisture transport and storage physics, human physiology, material science, meteorology, chemistry, solid mechanics, among others.

Hutcheon, N.B. "The utility of building science", reprint of the lecture delivered in 1971. *J. Thermal Env. and Bldg. Sci.* Vol.22, 1989, pp. 4-9.

Building Physics

- the fields of scientific knowledge (heat and mass transfer, thermodynamics, material science) applied to buildings

Building Science

- combines buildings physics and building technology with field experience of what is possible to build and how things actually behave

Building Technology

- the knowledge of products and systems and how they are assembled

