Rethinking Enclosures: Lineages

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Abstract

The conceptual framework for a standard approach to building enclosure is based on the idea of separation, routed in the Western metaphysical tradition of the division of man from nature. The separation speaks to a traditional approach to comprehending our physical world in dualities. Accordingly, most built environment problems are positioned as issues of separation and isolation. This technical solution, with its underlying philosophical foundation, is found in approaches to zero-energy housing and sustainable building with the super-sealed box and the isolation of inside and outside. There is a possible argument to be made that if the underlying metaphysics can be questioned, there might be an alternative approach to the wall which is not at first apparent.

Based on this proposition, this paper proposes an alternative conceptual framework in which to think about environment and built assemblies. It approaches the space between what is normatively considered inside and outside not as a divider, but as a mediating or connecting system. Various operational factors are isolated in lines of inquiry, such as temperature regulation, moisture balance, social protection and representation, service delivery, light transmittance, and visibility. The relationship between each of the elements within various lines are explored, and a single line is examined in more detail.

This paper is purposefully exploratory in nature. The result of this study is a conceptual framework to drive further research, as well as a preliminary and limited investigation of a single line of inquiry to test for viability of the approach. Ultimately, the concern is whether this produces an advantage to sustainability issues in terms of environment, cost, health and energy.

1. Introduction

The problem of developing a wall is generally thought of as a technical or scientific problem. It is often reductionist in nature, satisfying quantitative factors of physical protection and environmental protection. However, the wall is part of a larger system of thought about the built environment and is affected by underlying metaphysical beliefs held by a society. In the Western world, these beliefs affect the relationship between man and the world through dualism, the idea that there is a representation of reality that we understand through perception and a true reality accessible through reason (Rorty 1979; Baudrillard 1994). Further influences for architecture, and built space, are found in the tradition of meaning through Truth (Hacking 2000), ideas of autonomy as progress (Pippin 1999) and art as social responsibility (Morris 2003). However the one with which we are concerned for this inquiry is a cultural belief of the separation of man from nature driven by metaphysical dualism and concepts of binary oppositions.

Dualism was inherited from the Greeks through the philosophy of Plato and Aristotle, reinforced by Cartesianism and institutionalized by Immanuel Kant. It separates "essence and accident, substance and property, and appearance and reality"(Rorty 1999). In practical terms, this metaphysical basis presents our lives as distinct and discreet from our environment. The Enlightenment replacement of a mystical university with Reason also encouraged this sense of separation by presenting humankind and human culture as separate from animals and nature. Most contemporary philosophers who have affected architecture are attempting to find ways around this issue including Jacques Derrida (Derrida 1981), Michel Foucault (Foucault 1972), Donald Davidson (Davidson 2006), Martin Heidegger (Sharr 2007), and Gilles Deleuze (Ballantyne 2007). This attempt was through language as the focus of study rather than experience, a focus which opened up cultural constructs and multiple co-existing histories

However, while these philosophers attempt to address the influence of Dualism and mitigate its effect, most of these intellectual positions maintain the binary oppositions beyond dualism. Dominant philosophies affecting architecture, like post-structuralism, simply pointed out the inherent power differential between the members of the binary opposites, positioning one member of the pair as a degenerate of the other but left the structure in place. These pairs have been instrumental in developing meaning in Western culture and flavour how we view the world and our relationship to it. It is very difficult not to think in terms of a thing and its opposite. Inside is opposed to outside. They are considered separate environments. There is even an argument presented by Richard Rorty that it may not even be possible to think without such oppositions (Rorty 1999).

However, Rorty and the Pragmatists as well as Deleuze and Guattari offer counter-positions which negate issues of binary opposition in how they relate to man and environment. Pragmatist philosophers presents an integration of Darwinian evolutionary theory that invests man back into the natural as an animal which is capable of symbolic language (Rorty 1999; Misak 2007) while Deleuze and Guattari introduce the concept of the assemblage which includes events, things, emotions and effects so by-passes the discreet object fixation our mind-body pair reinforces (Deleuze, Guattari 2005).

It is the Deleuze and Guattari position which is explored as an operational idea though this paper, as the concept of assemblage presents the wall in terms of a systems approach rather than a discreet problem. The systems approach, and associated connections to social, cultural and aesthetic issues, makes the proposal for a wall fundamentally a design problem in its fullest sense, one that includes sociology, anthropology, engineering, aesthetics and economics.

The nature of this paper is exploratory and experimental. The intention is to formulate a point of origin for further inquiries. while introducing some initial ideas following the adaptation of assemblages into an architectural syntax. The paper is divided into two sections. The first, Theoretical Framework, explores a theoretical framework from which to explore multiple lines of effect and function of the wall. The second section, Praxis, inquires into possible applications of the theoretical position. Several lines of inquiry are explored as probes into the concept. A single line is then developed through to built proposal in order to test both the potential and validity of the approach.

2. Theoretical Framework

A theoretical framework, or applied philosophy constructing a cohesive system of thought about a subject, will allow for systematic conceptual development through the design agenda. It will be used as a tool to reconsider the question of inquiry, in this case the enclosure, address the concerns listed above and allow alternative access to the idea of association and assembly. The framework will also have to implicitly address systems and system theory as a complex organization negotiating multiple narratives.

One of the strongest cases in considering system theory in design during recent years can be extracted from the philosophical work of Gilles Deleuze and Felix Guattari. In particular, it is their writing and thoughts about the assemblage which can be adapted to be used as a tool applied to the rethinking of enclosure. In their words, “We will call an assemblage every constellation of singularities and traits deducted from the flow--selected, organized, stratified--in such a way

to converge (consistency) artificially and naturally;" (Deleuze, Guattari 1987). An assemblage is then a series of connections between objects (bodies and machines) which are in the process of arrangement. The assemblage is neither the objects themselves, nor a composite object created by the aggregation of singular objects into a unified whole. It is inherently concerned with field effects and networks made of more than just physical form. The assemblage is the act of association. It is a fluid process.

2.1 About Assemblages

The interesting thing about assemblages, for the application to architectural design and technology, is that they are constructed not only of objects, but also actions, events, and passions. In this way, the traditional idea of a discreet object can not be defined in the terms of an assemblage due the assemblage's lack of concern with firm, fixed and stable boundaries of an object. An assemblage can not be formed if contained within a single discrete object, as it is the process of associating multiple fragments of objects together, including the phenomenological setting, emotional state and other less tangible events. What the assemblage recognizes at the core of its structural system is things, events and emotions in the world are intimately linked. It does no good to isolate and analyse a fragment of the world if that sample doesn't involve all aspects of that thing which might affect its presence/operation/existence. The assemblage is a way of thinking about all the interconnected elements which fully construct the extended occupation of a form/event in social space. The discreet object, be it building, wall, or sculpture, is shown not to really ever be separated from context, culture or environment. Identity is denied in the assemblage as it is the network of effects and usage which rise to importance.

Involved in this re-conceptualization of access to our environment and objects, the construction of an assemblage denies the traditional metaphysical duality concept of binary opposition. As well, traditional issues of meaning *(or knowing)* are also avoided as assemblies are anti-essentialist, as in the purpose of their existence is contained in what they do rather than some external Aristotelian idea about truly knowing a thing (their eternal essence) (Rorty 1999). An assemblage is based on use rather than meaning.

The assemblage does not consider binary opposites as important as meaning is not found in the singular space between two objects. Instead, *the assemblage as a whole expresses.* Expression is caused by the association of a series of 'things' and their relations to the theme which organized the association of elements. The idea of expressing is the key to understanding the concept of

assemblage. This expressing should not be mistaken as an act of signification *as assemblages are not concerned with meaning.* Instead, a fundamental purpose of the assemblage is relevance. In fact, an assemblage can not be an assemblage without this relevance. Relevance is important over signification, or meaning, or truth, or identity (Stivale 2005). Instead of asking *what* something means, the question of the signifier and Western metaphysics, the assemblage instead asks, *how does it function?* Another way to approach the same question is to pose it this way; *what does it [the assemblage] do? or what is its [the assemblage's] effect?*

2.2 Shifting organization

The issue of fluidity and shifting associations should be addressed briefly. Elements of the assemblage can separate and re-form based on perspective, viewpoint and definition of issue. Several elements of one assemblage can be present as members in a second assemblage, a third and so on. This is how fluidity can occur while still addressing a stable association. There is a larger ramification: as stated earlier, the assemblage allows the removal of the idea of discrete objects. The wall is a discrete object, there is wall and not-wall. We consider the wall as an identifiable object with a termination, surface and volume. Concepts of *inside and outside*, or exterior and interior, are discreet ideas when speaking of enclosure. There are boundaries and defined edges as one concept transforms into the other, but individually, they are firmly defined by their opposite. Inside is not outside. The same is true of the terms of 'technology' and 'human'; it is either in one category or the other. However, metaphysical dualism and the binary oppositions of Western thought defines that *which is by that which it is not.* The assemblage circumvents this concept. Instead, there are only vectors and connections between things which then create the whole. This is not discrete. The object with its defined boundary is a player in an action, not the thing itself. Only by how it acts in accordance with others does it have significance. Opposites cannot exist; everything becomes a part of something else. For example, the classic dichotomy between human and machine would not exist as an assemblage for both discreets would be part of a vector which would not be concerned with their wholeness. It would only consider fragments of traditionally what is thought of as a whole. The same construct can be applied for the concepts of inside and outside. Instead of these large discreet ideas, which are traditional opposites, fragments and aspects of each of the specific conditions of the environments would be associated with relevant moments of other objects, actions and emotions.

2.3 Effect/Quality

The proposition of an assemblage as the conceptual construct of understanding and designing our environment challenges traditional categories of judging success. Single or simplistic categories such as cost of construction or appearance in terms of social status are denied by the complexity of the systems solution. An organism may have multiple outcomes, pressures and associations based on being formed of several assemblages. Some of these assemblages which represent aspects of the thing may reinforce, or conflict with, parts of other assemblages present. The issue becomes there isn't a single line of success that can be highlighted. It is hard to quantify. In order to analyse and refine a design system, two factors need to be considered as a final result. These are effect and quality.

Effect is the terminal node in the assemblage and addresses the *what does it do* question. The effect might be technical, psychological, physical, emotional or experiential. The category of result will be determined based on the effects of the associated elements of the assemblage. A single thing may have presence in multiple assemblages and each of these presences might and will be treated with a different category of success determined by effect.

Quality, in turn, is not used as the term which addresses the aspect of a thing which makes something distinct or distinguished. Instead it is related to effect. Qualities are the embodiment of traits or aspects within the assemblage which shape and define their effects. As in the situation of effect, each line of the assemblage will have different definitions and successes in terms of qualities.

3. Praxis

As we move from the theoretical and continue into praxis, core concepts need to be translated to address embedded bias within each particular discourse. In order to identify the nuances when addressing praxis, the term lineage will be used instead of assemblage to mean a particular strand of associations within a larger network. This will be done to separate the philosophical ideas of assemblage from the architectural application of the strategy.

3.1 Traditional Philosophy of Walls

The traditional wall assembly consists, both conceptually and physically, of an absolute separation between *outside and inside.* The better the wall isolates these two environments, the more successful the wall is considered. In operational terms, the strength of a standard wall is its ability to stop thermal

transfer and eliminate the migration of water across its depth. Normative material would include rigid or batt insulation for thermal isolation, non-porous plastic for moisture isolation, interior drywall or plaster and hard shell to protect from the elements and UV deterioration. In the last several decades many attempts have been pursued for a more efficient and sustainable wall such as structurally insulated panels, strawbale and wheatboard. These are still premised on very high isolation factors, decreasing the conduction of heat across the thickness of the wall and being impenetrable to moisture. The result is still one which is based on the absolute separation of two environments.

However, there are limitations to this standard approach. The operation of the wall tends to be only as good as the assembly of its parts, i.e. how well the installation of insulation was performed, whether any rips in the vapour barrier occurred or other on-site construction process issues. Super-insulated walls with high R-values are presently available, really no different in building construction than large refrigerators and cold rooms. However, habitable dwellings are not single function cold rooms with sealed and gasketed doors. There are social and habitation functions which preclude multiple, often conflicting, ways the interior volume needs to operate. It is these idiosyncrasies of habitation which introduce points of failure in the philosophy of isolation. Failure occurs not in the wall as a single element when looked at in isolation but how it interacts in a network called *an enclosure*. The enclosure, in this sense is a lineage and includes the physical wall, but is also the threshold in the socio-cultural space of habitation. It includes issues of privacy, status, air quality, micro-climate, protection. Mechanically, the enclosure includes all the other elements which make occupiable space operational such as vents, services, windows, doors, chases and services , corners connections, and plane connections (roof to wall, etc). Each of these elements introduce a possible point of failure into the wall network. Add to this on-site construction, adverse climatic conditions, lack of control and oversight during construction and installation. In short, the performance of the whole is compromised by the conflict between the parts, resulting from the ideas of separation, isolation, and fragmentation.

In additional to the failures associated with creating a super insulated and sealed volume and then poking it full of holes, seriously affecting performance, there are the associated results of creating a sealed environment: (1) A philosophy of isolation creates issues of poor indoor air quality with the loss of infiltration and air exchange. (2) Product offgasing, such as carpets and cabinets, add to the deterioration of air quality. Alternative strategies to mitigate such negative effects of this isolation need to be devised, many of which continue to interfere

with the operation of the insulated shell. There is, in short, a conflict in theory between the idea of isolation and the sustained quality of environment.

This conflict is beginning to be addressed by research into dynamic insulation and 'breathing walls' (Straube, Acahrya 2009; Imbabi 2006; Dimoudi, Androutsopoulos, Lykoudis 2004; Hines 1999; Taylor, Webster, Imbabi 1999; Taylor, Imbabi 1998). These alternative proposals endorsing a more open approach to the wall allow either moisture migration, air migration, or both, across the depth of the wall. However, this is only a small aspect of the entire network of elements which make up an enclosure. Ultimately, these explorations accept the same standard conceptual framework to which it is critical, and only addresses issues of thermal transfer and relative humidity.

3.2 Application

Extending the concept of assemblage to the idea of the wall, the formulation of wall, as it exists traditionally in architecture, is both too broad and too discrete. If the wall is redefined, or the perception of the wall is filtered, in terms of a machinic assemblage, this is what occurs: there is either no wall or there are multiple regulators within a space defined traditional as a singular wall. The wall is an inert object when defined formally; it is a barrier between the opposites of inside and outside. However, when the machine 'wall' is defined not by what it is but by what it does, there are instead a series of vectors and movements which make up what we consider a 'wall'. Vectors include the physical, the emotional, the active, and the operational. It is the combination of aspects of the vectors around a particular effect is what we shall call a lineage. Although the physical manifestation of the wall is undeniable fact, in design terms, the wall is a multiplicity which is the space between the body and the construct of world, extending past material composition.

It is possible to define focuses for the multiple lineages of wall. In order to do so, the question becomes, *what does the wall do?* Asking the question this way, the wall unfolds, defining several functions. Lines of these functions are related to human health, psychological wellness, social standing, physical protection, and the ability to thrive. These are not categories in which other items are found, however, each of these terms can be found within the lineages as operators. There are other related items which, more traditionally, define the functioning of the wall such as temperature regulation, moisture regulation (humidity), moisture regulation (precipitation), light regulation, visual transmission, service transfer, social barrier, social filter, social projector and social barrier. None of these terms are fixed or exclusive categories, nor is there

a hierarchy established which defines order and association. We will examine three lineages below in order to clarify the thought process: (1) social barrier lineage, (2) light transmittal lineage, and (3) physical comfort lineage.

Any one of these lineages will have origins and threads of effect and qualities which are individually defined by the idea of their function or operation. For example, the social barrier lineage would include issues of social protection control such as privacy, visibility and projection of status or position within society. These can be redefined as occupying social, visual, perceptual and psychological dimensions (see Figure 1). Following even one of these threads within the lineage of social barrier, psychological effects can be associated with physical presence. Social status is linked with ideas of massing, as well as material richness and material symbolic content. There is a second symbolic content thread which is delivered by cultural detailing, the representation of particular forms through ornamentation or traditionally represented forms with historical connotations. In the Western world, think of the single family residences with pediments two stories high and fluted columns marking the front entrance, referencing Classical Greece. This is the operation of symbolic content at the cultural detail level. The colour of a surface paint, or expensive material such as slate, marble or cedar contains symbolic content at the material level. Much of the social barrier lineage pertains to the surfaces which project out into the social sphere. It connects multiple scales together from material detailing to massing. More than this, it is not only the outer surface or visual part of the wall cladding which is involved in this lineage, but also how view is allowed into the enclosure as a site of representation. This is not considering physical access or occupation but simply how that part of the interior space is made visible to the exterior sphere. There will be natural connections at this point with other lineages such as light transmittal or view but the key is there doesn't have to be these connections. Each, lineage can solve the relationships in different ways, if those ways are more efficient as a solution.

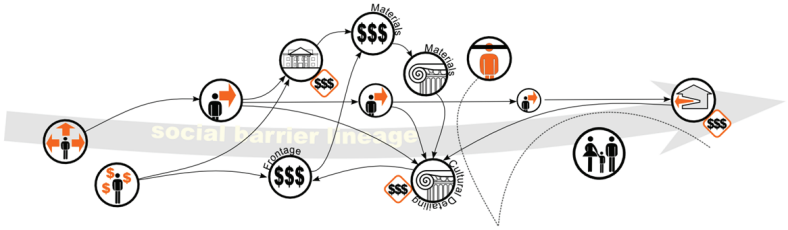


Figure 1: Social Barrier Lineage (see Appendix A for legend)

Examining the light transmittal lineage (see Figure 2), all aspects of the electromagnetic radiation emanating from the sun will need to be included, as they all have effects on human life and well-being. What is commonly called sunlight,

instead of being solely connected to issues of thermal gain and visibility (the ability to see in the natural wavelength that our eyes have biologically evolved to process), also becomes a primary link in human health in terms of emotional wellness and sleep cycles. Looking at the relationship between enclosure and daylight, the solar radiation wavelengths have different functions and effects. The light transmitting lineage can isolate and operationalize each wavelength. Electromagnetic radiation can be subdivided into three major categories, infra-red, visible light and ultra-violet. In turn, both infra-red and ultra-violet have A, B, and C variants based on wavelength bands. While visible light is important for our ability to use our critical organs, the eyes, there are health and psychological effects by the interaction of infra-red and ultra-violet rays. Vitamin D is produced by the association of UVb and direct light; serotonin, connected to wakefulness and positive moods, is related to direct sunlight exposure. There are also issues of too much light as melatonin production is suppressed by the presence of light and is needed to regulate our sleep/wake cycle. Infra-red wavelengths are important for heat and producing the range of life sustaining temperatures. For an enclosure, the thermal gain of direct radiation or radiant heat can be a positive and negative aspect. This leads to seasonal cycles, as the requirements for thermal gain flip from summer to winter in a four-season system. In the winter cycle, thermal gain is permissible while in the summer cycle, it is discouraged. The production of the lineage separates infra-red thermal gain from indirect and visible light. Instead of traditional means of shading or blocking direct sunlight, of which the infra-red is only part, the lineage highlights that only the thermal component of the light needs to be removed all year round, if it can either be stored, dissipated or released based on current climatic needs. The function which identifies this operation is a heat sink, introduced to wick the infra-red out of the visible light bands during all seasons. Storage is proposed and can be integrated into other lineages, ideally physical comfort.

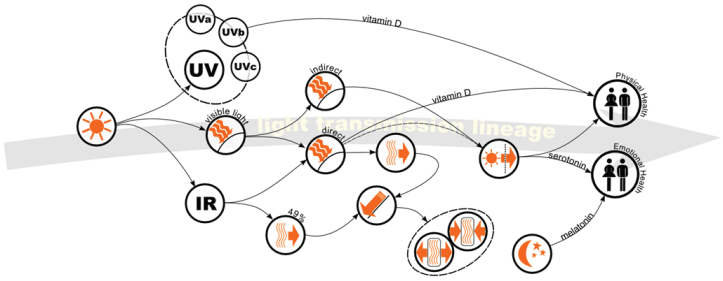


Figure 2: Light Transmittal Lineage

The role of the enclosure in the creation of a micro-climate for human physical comfort is a major operation of the wall. This is normally defined in terms of temperature. Traditional wall design does not factor in humidity, which

is considered the responsibility of the mechanical conditioning of the space. However, temperature and humidity are tightly intertwined in determining human comfort. As reported in the classic report by N. B. Hutcheon for the National Research Council of Canada, "The value in summer at which 97 per cent of the subjects were comfortable was 71 degrees Effective Temperature, which corresponds to conditions of 82 degrees (Fahrenheit) at 10 per cent (relative humidity), 76 degrees (F) at 50 per cent (RH) and 71 degrees (F) at 100 per cent relative humidity. Correspondingly, the value for winter conditions at which the greatest proportion of subjects was comfortable was about 68 degrees, which can be obtained with 78 degrees at 10 per cent and 72 degrees at 50 per cent relative humidity." (Hutcheon 1968). Effective or apparent temperature, the relationship between temperature and humidity, can be considered a primary operational factor in the physical density of the wall. The development of a physical comfort lineage will have to address this relationship.

Traditionally, the insulative nature of the wall is seen as a way to separate the interior space from exterior space by the isolation of thermal differences. Standard wall construction (wood stud, vapour barrier, batt insulation, cladding and drywall) does not take into account moisture and humidity *regulation,* excepting the vapour barrier, designed to eliminate the transfer of moisture. Trends in developing research examining dynamic insulation do take into account the effective temperature .(Dimoudi, Androutsopoulos, Lykoudis 2004; Taylor, Imbabi. 1998). These have shown how air and moisture movement through wall masses can increase the efficiency and internal air quality of the regulated space. However, they do not address the entire concept of enclosure and only make slight variations to existing concept of wall. This variation is replacing the existing insulation with a "breathable" or dynamic type and eliminating the vapour barrier.

If the purpose of the threshold (i.e. wall) between exterior and interior space is considered not to isolate the space but to regulate the space, a series of other possible vectors of operation occur. These are represented in the physical comfort lineage found in Figure 3.

There are several points raised by examining each of the effects in this lineage. Moisture wicking becomes part of moisture regulation during warm weather and may include multiple paths including a layer in the lineage to remove the moisture and store it, or addressing air movement of the interior space which will aid in the evaporation of perspiration. In cold weather, the reverse operation is a priority, with the release of stored moisture back into the environment. In most cases, shifts in seasons (in four season regions) will have different lineage flows. A "catch and release" philosophy is built into the

lineage as understanding for the efficient use of existing resources. Batteries, or medium to long term storage, is a key element to the seasonal shift and is reinforced with short term storage and regulation.

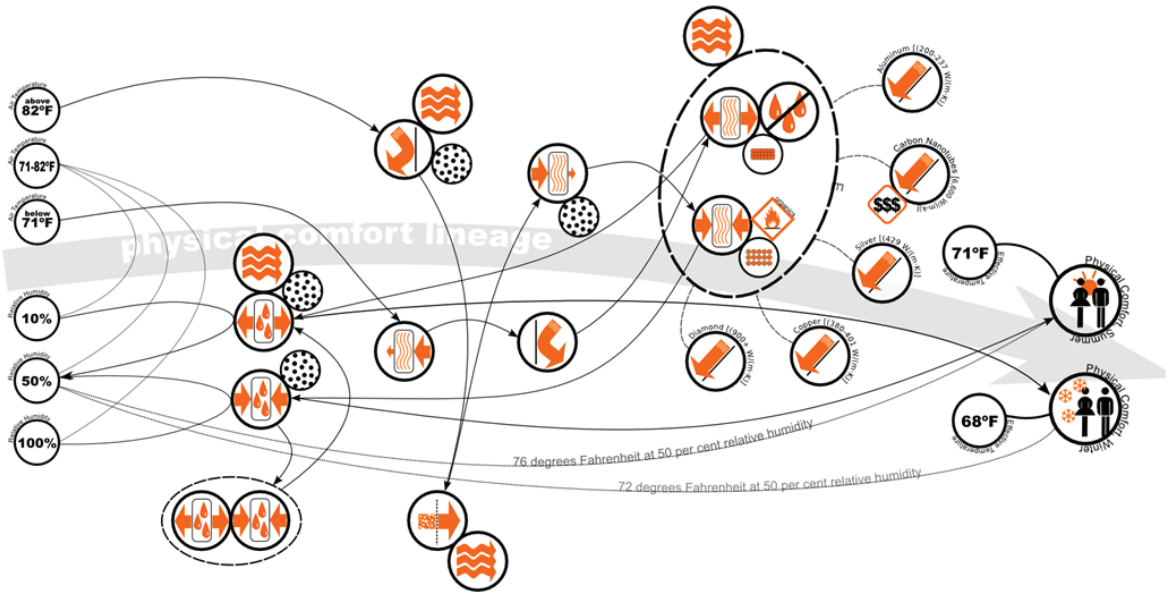


Figure 3: Physical Comfort Lineage

Moving up in scale from the wall or enclosure, the lineage will need to recognize micro-climates, even within the 'house'. Bathrooms have short-burst moisture venting, but that moisture rich air is seen as a problem and often vented directly to the exterior. In the dry air of winter, this is a waste of a resources if issue of local humidity is re-framed in the context of total environment. The high humidity of the bathroom can be classified as an asset to be relocated, but different operations need to be put in place and a different philosophy approached in terms of systems. The bathroom becomes a critical component in the assemblage 'moisture regulation' as a source material, a place to breathe.

What all the elements of the physical comfort lineage do, however, is remove a focus on conditioning a volume of space to instead refocus on the perception of individual comfort. It also considers various actions which engage in temperature and humidity in independent actions before considering the network effect of associated actions. Various paths of heat transmittal through an enclosure are considered, including conductive, convective and radiant transfers. The physical comfort lineage will be addressed in more detail by presenting the physical studies in section 4 of this paper.

4. Physical Studies

The intention of this paper is to examine the theoretical framework which gives rise to an alternative way of pursuing the idea of wall and enclosure,

building and dwelling. It is our belief, however, if that framework doesn't affect application or practice in some useful way, then it is irrelevant. In order to examine knowledge through application and the operation of the above discussion in praxis, a limited prototype was explored. The lineage chosen to be detailed was the human comfort line. This was chosen as it addresses the same concerns as dynamic insulation and hyper-insulated traditional walls: thermal transfer and relative humidity, and therefore would show evidence of difference in application more clearly. As a disclaimer, the purpose of the physical proposal and testing is to examine viability of the overall conceptual position, not to solve for all aspects of the framework. This is an initial foray into a field of study which, based on the findings from initial experiments and tested assertions, will lead to a larger and more involved project.

4.1 Prototyping

As stated above, the physical comfort lineage was chosen for the initial physical exploration of the concepts outlined in this paper. It needs to be stated that in this limited physical exploration, there are many conditions and influences that were not addressed in the limited study below, such as passive solar heat gain (referenced as a thermal battery in Figure 2), introduction of field based conditioning agents such as hot and cold water radiant and energy recovery systems. A set of parameters was extracted from the lineage conceptual framework in order to guide decision making. This set took into account a degree of adaptability which would be needed when several lineage would merge to act as an enclosure (for example, the social barrier lineage, light transmittal lineage, and physical comfort lineage would merge and share elements). Due to this, flexibility of material and redundant members were encouraged. The set of parameters represents the starting conditions as well as a set of biases.

These conditions can predetermine final outcomes and sometimes are problematic. In our case, these biases are critical to the pursuit of aspects of the project.

• Each operation and requirement of the enclosure is isolated into separate lines of inquiry, called here lineages.

• Materials solving particular lineages are chosen independent to any other factor besides what is listed in the other parameters. Parameters for materials focused on the greatest efficiency, flexibility, health and cost. There was no particular bias to a natural material rather than a fabricated material.

• Each independent layer is analysed in terms of effect on environment, cost,

health and energy.

• A field approach to delivery and effect systems is prioritized, stressing trickle effects rather than point source delivery.

• Air and water are not stopped from moving through the enclosure. They are considered to be assets rather than liabilities.

• All materials found orientated as a plane between inside and outside (lateral) must be permeable to air and moisture and should be continuous.

• A zero waste approach will be pursued in the assembly of the enclosure system. Any and all sheet material must be used completely, panels are designed to address standard dimensions of stock material.

• Rapid prototyping, shape grammar and digital fabrication techniques will reinforce and provide the tolerances needed for fabrication.

• In the case a lineage produces a layer of material, that layer will penetrate another layer nor be interrupted or penetrated in turn if not considered part of the design operation (i.e. mechanical fasteners are not allowed, thermal bridging is eliminated).

• The lineages will be reassembled in a network topography.

Two explorations into the physical comfort lineage were designed, in addition to a control test cell based on a standard wall assembly. The layers of the wall studies (test cells) were chosen individually based on the criteria addressed above and then introduced to each other through the associative structural system. The structural systems were developed through digital fabrication techniques of CNC milling and plaster printing.

4.1.1 Exploration 1

The first test cell (TC-1) included no thermal resistant material or insulation, something considered standard in any wall construction. Instead interior space was regulated with phase change (PCM), thermal reflective and hygroscopic layers as a primary strategy. Figure 4 presents a diagrammatic description of the association of layers into a test cell wall.

The entire test cell was clad in a blackout textile drapery liner, Roc-lon® Textralon-S™ (1). This material was used as a filter for UV and visible radiation, conforms to NFPA-701 standards, and acts as a sound isolator.

Temperature regulation was proposed to be accomplished by several different layers, rather than a single traditional type of insulation. Temptrol™

Innovative was used as a radiant barrier. In one location, it reflected heat back into the interior of the enclosed space (2+) as a winter condition. In another location, the reflective barrier stopped thermal transfer into the interior space as a summer strategy (2). The Textralon-S would retard the conduction of heat transfer across the proposed test cell. A complex n-paraffin developed by MicroTek (n-Octadecane) was chosen as the thermal battery layer (6). The phase change material would buffer extremes in temperature variations by absorbing and releasing energy at particular temperature points. This particular phase change product would work best in the test climate (Michigan, USA) as it has a 82.4°F melting point. A solution of n-paraffin was embedded in a light density fiberboard (LDF-PCM). Both the LDF and the 2+ layer of Temptrol Innovative were coated with Dow Corning® AllGuard Silicone Elastomeric Coating which acts as a hydrophobic layer. While AllGuard repels water, it allows for the passage of both air and moisture, making it a key layer in the system.

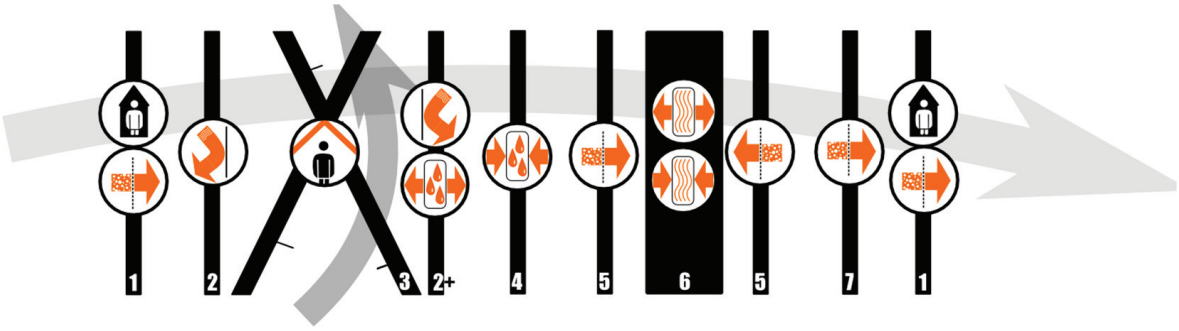


Figure 4: Test Cell 1 (TC-1) wall layer composition

The centre of TC-1(3) was designed to be a vapour and air chamber, acting as a reservoir for moisture and as a mixing chamber, thermo-tempering and buffer for air infiltration. The hydrophobic coating on the LDF-PCM composite controls access of moisture and eliminates undesirable interaction with the LDF-PCM. Marmot Earth Shield (4), an absorptive ground cover for tents, was chosen as the main moisture battery.

There are also several layers for air filtration. These include a fibreglass paper filter (5) treated with an AllGuard hydrophobic coating which acts as the PCM encasement material. The outer layer, Roc-lon® Textralon-S™ (1), holds a magnetic charge which causes it to act as a natural air filter. The final filtering layer is a fibreglass medium particle filter (7).

The vapour chamber (3) acts as the main structural spine of the test cell and was constructed from polyethylene plastic. The integrated cellular structure of the chamber was proposed to operate differently depending on outside temperature. In the summer months, it condenses and vaporizes moisture in an

effort to decrease the interior temperature, while in the winter, the chamber will maintain a insulating barrier between the two sides. The chamber panels are fabricated from a modified castellated beam pattern which is then folded and assembled for a gravity-based friction fit.

4.1.2 Exploration 2

Test Cell 2 (TC-2) proposed a series of interactive layers similar to TC-1, but with a few key differences. In this proposal, a thermal resistant layer was included within the first third of the assembly, orientated towards the exterior face. High performance fabrics, originally intended for the sport and outdoor market, have been utilized as core heat retention layers. In addition, the moisture batteries were brought out of the centre cavity to bond with the thermal storage batteries (PCM). This thermo/hydro bank was proposed to be the active element of the lineage and orientated to the interior volume. Figure 5 presents a diagrammatic description of the association of layers into a test cell wall.

As in TC-1, Temptrol™(3) was used as a radiant reflective layer. It is a low cost option which is also breathable and resistant to punctures or tears and performs at 95% reflectivity. There are some added benefits to the use of Temptrol™ besides the reflection of heat. It does not promote growth of fungi or bacteria, shields against electromagnetic and radio frequency interference, solar radiation, and is non-toxic and non-carcinogenic. The radiant reflective layer only faced outwards, in the summer orientation, in this proposal.

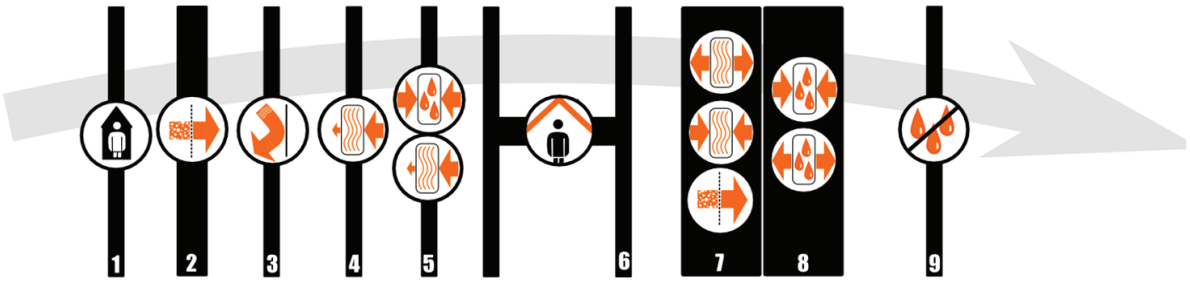


Figure 5: Test Cell 2 (TC-2) wall layer composition

The thermal resistance layers are made from Polartec® thermal fleece (4) and Under Armour®(5), both from the clothing and outdoors markets. The Under Armour®, in particular, acted as more than just a thermal regulatory layer as its wicking properties transferred moisture to the centre of the wall. The core of the wall was treated as an hygroscopic void which helped to regulate the internal air quality. It was created with polyethylene in a no-waste fabrication process through digital milling, which would allow for strength, air/moisture movement, and layer assembly.

The thermal battery layer (catch and release) was Microtek PCM (7), also found in TC-1. However, instead of the light density fibreboard, a standard

Armstrong ceiling tile(8) was used as the base material. This creates a very cost effective alternative while still being air and moisture permeable. The Armstrong tile also had the additional task of acting as moisture regulation, so in this case both the thermo- and hydro- were found in the same composite layer. The composite was completed with the addition of Allguard paint (9), a water repellent, but air and moisture permeable, paint. The Allguard was applied to the inside face of the Armstrong panel to protect against over-absorption of moisture.

Air filtration was performed by a fibreglass roll filter (2). The open structure allows for free passage of air and moisture while trapping larger unwanted particles. While a standard material in furnace HVAC systems, the inclusion within the wall addresses particular filtration needs. The outer exterior layer was constructed from Waverly® Solarium fabric (1), which is water repellent, UV resistant, tear resistant and flexible.

4.2 Testing and Observations

4.2.1 Mechanical/Scientific

There was a conscious decision not to approach testing of the lineages in an abstract way, such as calculating individual U-value or thermal resistance of the various elements in order to prove their operation. Network effect can cause unexpected and intensified results that are not apparent until real time action occurs. In this way, field conditions are more important than isolated laboratory testing. Rather than completing design and then spending months rigorously testing the final work, the testing was seen as part of the design process. This means that simple, quick but useful tests were needed to allow for feedback to affect adjustment of the next iteration. The influence is rapid prototyping.

There are issues that come along with such a position; many times there is a significant gap between design thought and scientific process. While architects have fundamental training in the scientific process and its methodology, the fluid nature of design can be counter to this process. Field testing as opposed to the laboratory are coupled with unavoidable last minute changes to designs prior to testing that invariably change outcomes and break rules. We do not see this as problematic, only opportunistic. We can take this stand because the results only guide our next iteration much like a studio design review. In the spirit of pragmatism the questions that concerned us were: How did it work? What did it do? Are you comfortable?

The difference in approach is one of the mechanic as opposed to the scientist. A case can be made for the validity of such an approach if it can quickly flag

areas of significance without a large investment of time and expense.

4.2.2 Testing Procedure and Results

Simple heat and humidity retention and decay tests were performed against a control to get initial feedback on the viability of the above approach. In order to consider the lineage based system as a valid approach to enclosure, the performance of the exploratory test cells needed to outperform a standard wall component, the control cell. The control cell was constructed of a standard wall for residential housing: 2x4 wood stud, 3 5/8" batt insulation, vapour barrier, exterior wall board, and drywall on the interior face.

External temperatures ranged between 47.5 and 50.44 degrees Fahrenheit (8.6°C to 10.24°C) and 49.82 relative humidity during the testing. Each of the test cells and the control cell where attached to the face of a test chamber. The test chamber was a 36" cube and constructed of R20 walls, floor and ceiling. Humidification and heat sources were present inside the chamber. The heat source was two 50 watt (171 BTU) electrical heating pads located on opposed walls. All source of infiltration were eliminated during the testing.

The first test was monitoring the the temperature retention under a constant low level heat source. Humidity was held at 70% in the chamber to create a significant differential between interior and exterior relative humidity levels. The heat source was activated for three hours, humidification was activated as needed during that time-frame in order to maintain the 70% level.

Figure 7 shows the gain in temperature for Test Cell 1, including monitoring the internal temperature of the wall. Probes were located in the structural core's air space (Figure 4, #3), at the PCM layer (Figure 4, #6), and at an interior location centred in the chamber but furthest away from the heat source. Figure 8 shows the same results for Test Cell 2. Probes were located at the structural core's air space (Figure 5, #6) and the PCM layer (Figure 5, #7). A sharp increase at the application of heat and sharp decline at the termination of the heat source is noted.

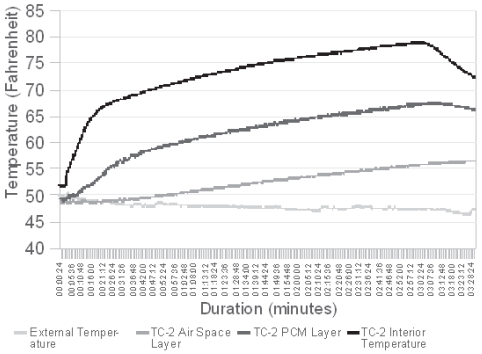


Figure 7: TC-1 Temperature

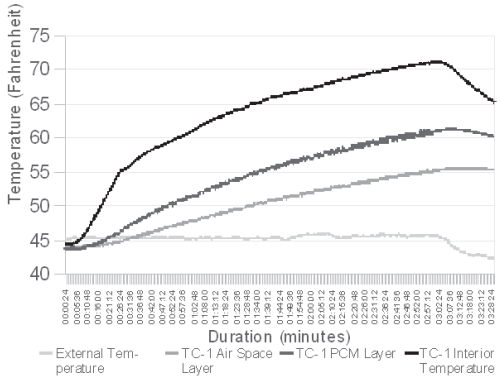


Figure 8: TC-2 Temperature

Decay tests were performed for both humidity (Figure 9) and temperature (Figure 10). The rate of decay was monitored for one hour after the termination of all heat and humidity sources. The control cell performed as expected in these tests, slowly losing both temperature and humidity to return to the exterior values. The test cells showed significant behavioural difference to the control cell in the humidity decay. Instead of returning to the exterior value of humidity, both TC-1 and TC-2 increased the humidity of the test chamber after any active source of moisture was eliminated. In temperature decay, both TC-1 and TC-2 lost heat at a faster rate than the control cell, and matched their rates of decline to each other (Figure 10).

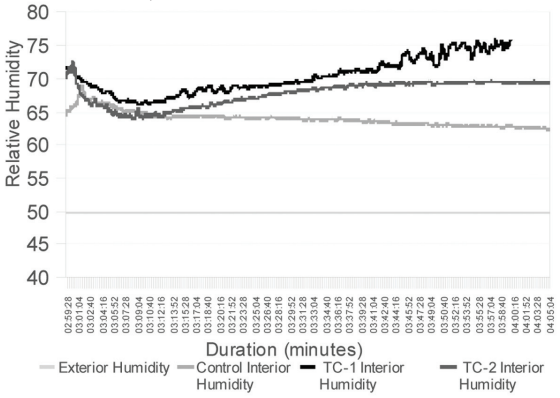


Figure 9: Humidity Decay

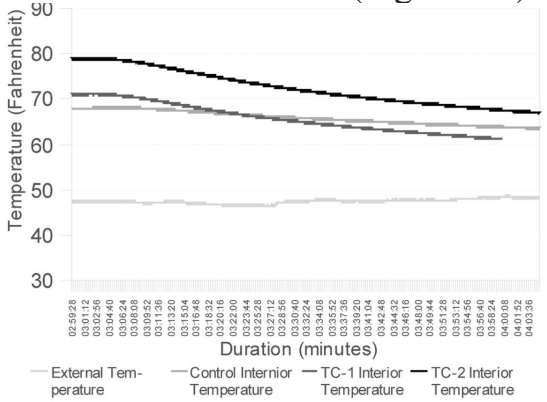


Figure 10: Temperature Decay

Figure 11 shows apparent or effective temperature calculated from wet and dry bulb temperatures. Apparent temperature (AT) takes into account the relationship between temperature and humidity (AT= 15 + 0.4 [Wet Bulb + Dry Bulb Temperature]) on the perception of comfort. TC-2 can be seen in Figure 11 to operate at a higher efficiency than either the control cell or TC-1. There is little significance between TC-1 and the control cell. This alone is interesting as while TC-1 contains no insulation or thermal isolation material, it performed at the same level as a typical fully insulated wall with 3-5/8" batt insulation.

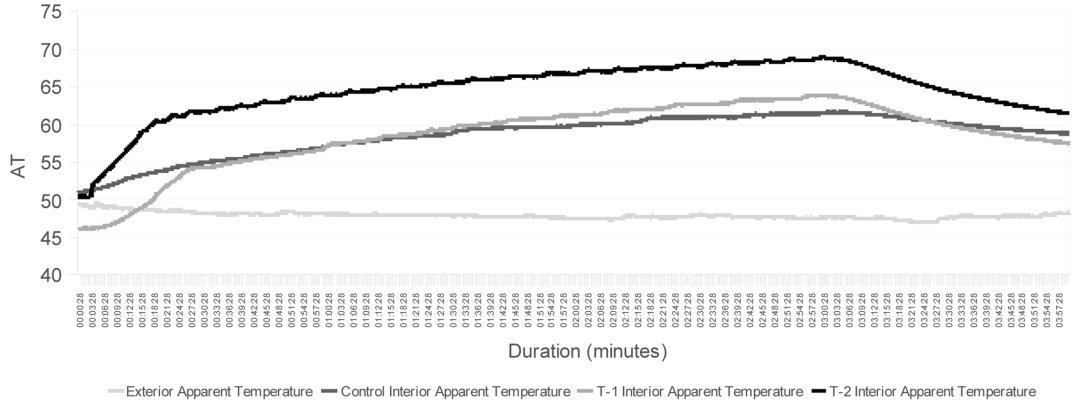


Figure 11: Apparent Temperature

4.2.3 Points of Interest

TC-2 performed at a level significantly above the control cell and TC-1. It was able to reach an interior temperature almost 10 degrees Fahrenheit (4.5°C) higher than either of the other cells. It will take further experimentations to determine whether this was the location of the air space, the addition of thermal resistance layer or some association between the layers.

There are two points of interest in the shape of the graph for TC-2 as well. These are the sharp incline representing heat gain which rose sharply for the first seventeen minutes from the point the heat source was activated, and the steep decay after the heat source was removed. The rapid increase of internal temperature from a constant source implies an effect occuring with the wall around 62 degrees Fahrenheit (16.6°C). This would not be the PCM layer as it would activate until around 82.4 degrees Fahrenheit (28°C). On the decay side, the reason for the drop-off is just as unclear. There is a possibility that both these events are due to the wall being, conceptually, a “powered” system. The lineage conceived enclosure had an active engagement with the environment and seemed to perform differently depending on input activity. This was expected.

Another point of difference between the control cell and the test cells was the interaction with the humidity source. One of the tests maintained a consistent humidity in the chamber of 70% RH. For the control cell it took a total of 60 minutes during 3 hours of testing to maintain that humidity. TC-1 needed 70 minutes of humidification while TC-2 needed 79 minutes. It is proposed that the presence of the humidity batteries was the reason behind the longer active humidification of the space. This would also allude to the reason behind the humidity increase once active power was removed, as seen in Figure 9.

Economically, there are several factors that stand out. The cost of the high performance fabrics was comparable with standard building batt insulation but has characteristics that can be exploited which are not present in the batt. A continuous surface can be maintained for greater efficiency, hygroscopic and moisture wicking capabilities are integrated into the characteristics of the fabrics, and they are a fraction of the depth of a standard batt. The polyethylene structure was also an interesting point. Through digital fabrication, a pattern was developed to allow the polyethylene to expand to four times its original dimensions in the X- and Y-axes, while increasing the Z-axis to the point of structural stability. At a square foot cost of $0.23 compared to $0.78 for standard wood framed wall, combined with the biological inertness, highlights a potential for further study. The phase change material had the highest cost and put the overall wall composites out TC-1 and TC-2 well beyond the total

of a standard wall in per foot costs. A more comprehensive analysis looking at cost savings due to decreased HVAC loads will need to be performed in order to judge the viability of maintaining a PCM layer.

There were proposed elements in the conceptual lineage when implemented in the test cells which could affect results in future studies. The addition of solar heat sinks could greatly affect both stored heat and the efficiency of eliminating conductive heat gain through the wall cavity. Moisture can also be wicked from areas of high concentration, exterior face of the wall in summer, to the hygroscopic layer. In addition, internal air pressure and air movement will have to be considered. As the venting of interior air is key to maintaining a positive flow through the volume of the wall, it was be important to consider how that air moves and is vented. It has been shown in previous experiments that dynamic walls can have a dramatic decrease in energy consumption of a building if there is a heat recovery system on the egress air (Etheridge, Zhang 1998). Beyond just pressure and infiltration, there is an effect on human comfort as apparent temperature is affected by air movement.

5. Conclusion

This paper detailed three stages of a systems approach to building design focused on the generic wall from theory through to application. There was an attempt as part of this inquiry, and a mandate from our research group, to maintain a strong relationship between theoretical thought and physical effects. In terms of the wall, there seems great potential in considering the wall as a diverse set of vectors, each with its own priorities and functions. There is the inability to disconnect our human existence from that of nature. In sustainability terms, seeing the wall as a continuation of the environment means that all aspects of the external condition is considered an assets rather than issues. While the final physical experiments, as a prototype application, were in many ways not robust, rigorous and extensive enough, they did raise many questions and set the stage for the next steps in a larger inquiry. Thinking of the wall in terms of a system allowed consideration of a multi-season, micro-climatic active design, rather than the normative static barrier and the isolation and re-association of the operational factors of a wall can be seen to provide some interesting results on an experimental level.

This project is still in the early stages. The intention is to continue this inquiry through physical experiments and irritative project cycles arriving at a module of enclosure which will represent all of the enclosure lineages. These will include dimensions beyond physical characteristics such as cost, embedded

energy, fabrication processes, social representation and psychological effect. The complexity of the systems approach leads us to continue a process of investigation through rapid prototyping and real-world physical testing.

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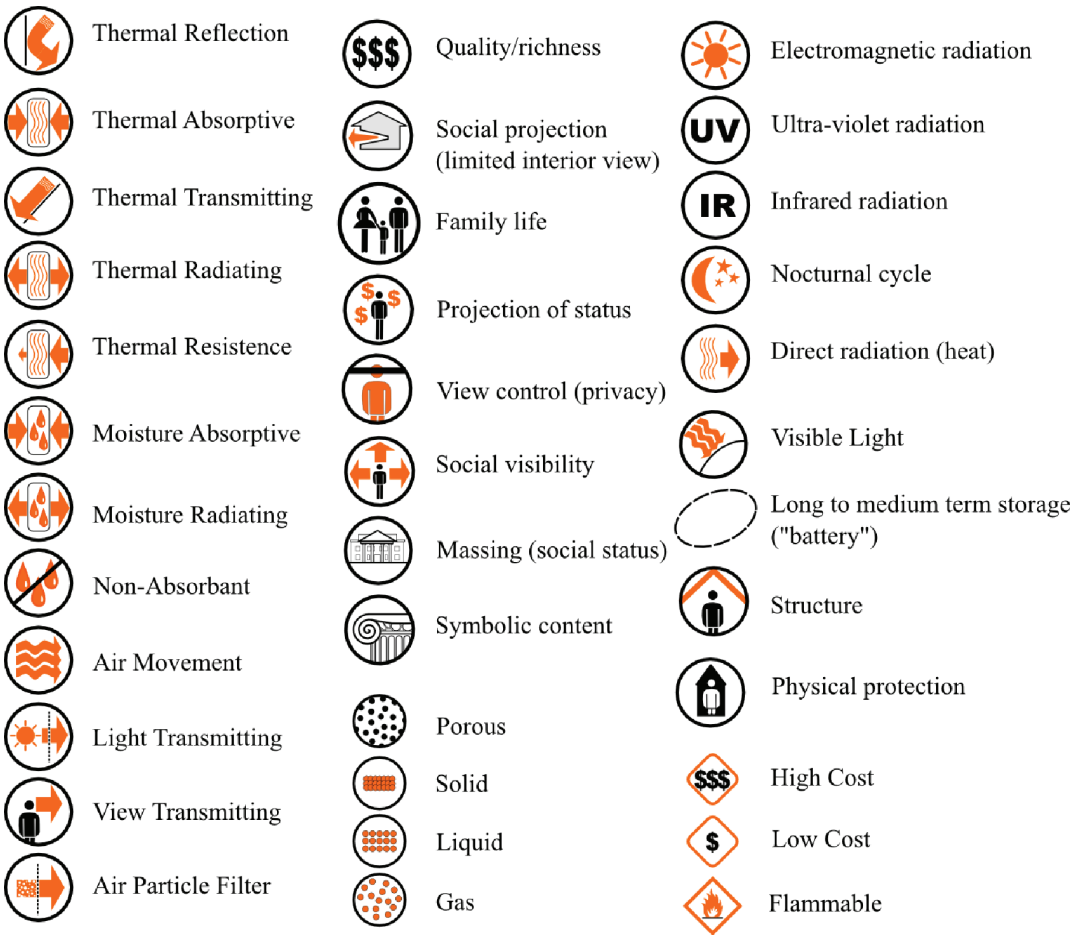
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Appendix A: Legend of Diagram Symbols



اعادة النظر في الاحتواء (الغلاف): السلالات

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الملخص:

الاطار النظري التقليدي لادراك الاحتواء الفراغي في المباني مبني على فكرة الفصل (separation) وهو التقاليد الغربية لادراك ما وراء الطبيعة (ميتافيزيقيا) على اساس الفصل بين الانسان والطبيعة. ولهذا الفصل جذوره في الاسلوب التقليدي لادراك العالم المادي هي اساس متضادات ثنائية (dualities). بالتالي تعرف معظم المسائل البيئية للمباني على اساس قضايا الفصل والعزل. وبالتالي نجد الحلول التقنية، المبنية على هذه الفلسفة، في دراسات المساكن المستدامة وعديمة الحاجة للطاقة (zero-energy) تتجه نحو الغلاف العازل تماما والفصل الكامل بين الداخل والخارج (super sealed box) . وهنا يمكن تقديم طرح مغاير اذا المبدأ الميتافيزيقي يمكن اعادة النظر فيه، وذلك ربما يؤدي الى مدخل بديل للتفكير في الحائط (الغلاف) بطريقة لم ندركها في السابق.

واعتمادا على هذه المنهجية يقترح البحث اطار نظري بديل للتفكير في البيئة وطرق البناء. يرتكز هذا البديل على اعتبار ان البعد بين ما نعتبره تقليديا "الداخل" و "الخارج" ليس كنظام فاصل أو عازل وانما نظام اتصال وتوفيق بين الداخل والخارج. وعليه تم تحديد العديد من العوامل المؤثرة والتي يمكن دراستها، مثل التحكم الحراري والتوازن في درجة الرطوبة والاحتواء من حيث النواحي الاجتماعية والرمزية وتوصيل الخدمات والاضاءة الطبيعية والابصار. وسيتم مناقشة العلاقات بين محاور عديدة للمسألة ومن ثم التركيز على محور واحد بالتفصيل.

وهذا البحث وضع بطريقة استكشافية، ونتيجة البحث هي ايجاد اطار نظري وفكري يمكن من القيام بالمزيد من البحوث بالاضافة الى هذه الدراسة المبدئية والمحدودة بمحور واحد للبحث من اجل التحقق من جدوى هذه المنهجية او التوجه. واهم ما في الامر في نهاية المطاف هو السؤال حول ما اذا كان مثل هذه البحوث تؤدي الى ايجابيات في مسائل الاستدامة من حيث البيئة والكلفة والصحة والطاقة.