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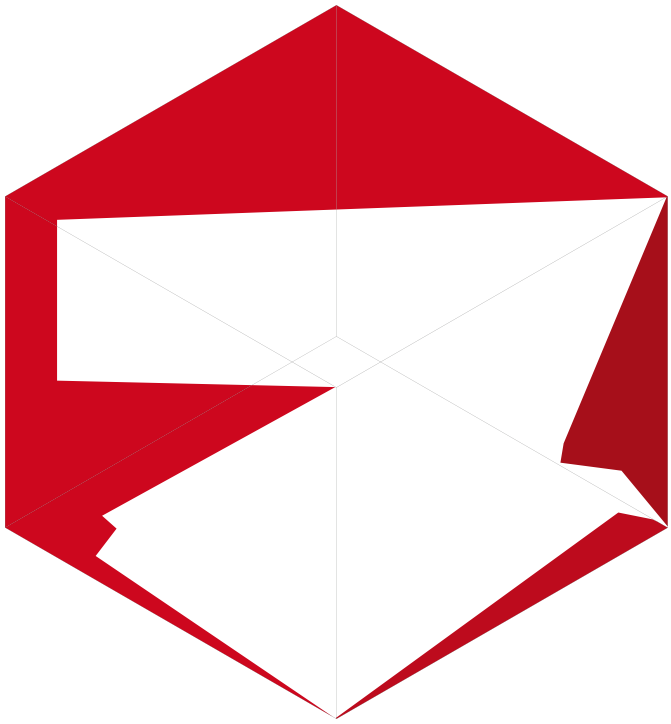

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Inside Making

Inhabiting Materials, Managing Environments

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Abstract: The article begins by considering architecture from the perspective of environmental management. The building is an organiser and enabler of what writers might alternately call environmental flows, material energies or immaterials: light, heat, sound, odour, humidity, and air movement. Although the primary function of the building is to alternately isolate, control, and replicate these flows, developing an appreciation of them is difficult within the context of architectural education, and their teaching is usually relegated to technical subjects. Instead, the article argues, construction projects as part of architectural design studios can be for learning not only about the materiality of building, but also about the environmental qualities resulting from the constructs. Three distinct architectural design studios—"Inhabiting Materials, Managing Environments," "Instruments + Environments," and "Sealight Pavilion"—are presented comparatively in terms of the interplay between materials and environmental flows, and the opportunities each offered for exploration and learning through the embodied act of construction.

Key Words: architecture, design, materiality, environmental design, making

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Inhabiting Materials, Managing Environments

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Introduction

Writing in 1968, architectural historian Reyner Banham begins *The Architecture of the Well-Tempered Environment* with a parable. As the cold of nightfall approaches, a nomadic tribe must make a decision regarding what to do with wood found in the forest. The tribe could either build a structure, such as a tent, or it could build a fire. The first option provides what Banham calls a "structural solution" to the problem of environmental comfort using the thermal resistance of material to slow the passage of heat, while creating an airtight seal between the indoor environment and the outdoor environment. The second option is what Banham calls the "power-operated solution," and overcomes cold with a large input of energy. While true nomads might opt for either option, civilisations, as Banham writes, have always tended towards the structural solution.[1] The structural solution is predicated on materials and their organisation and distribution in space, whereas the power-operated solution is dependent on immaterial energies and forces. With the drive towards a more energy-efficient, or ecologically-minded, built environment, the immaterial world of energies and forces is attaining an increasingly prominent position in the considerations of architects. Yet, when it comes to educating the architects of the future, learning about the importance of phenomena which can be physically-felt but not seen largely falls to technical subjects where they are conveyed through disembodied, analytic means. Such an approach risks trivialising the rich gamut of bodily sensation in the design and experience of the built environment. Rather than relegating important learning and valuing of such phenomena to technical subjects, construction projects in the university architectural design studio can play a central role in engaging future architects with the potential of designing with such phenomena, as a comparative discussion of three design studio projects lead by the author between 2008 and 2011 will reveal.

Architecture is an Armature of the Immaterial

As Banham's parable points out, building has always been concerned with issues of energy and comfort. In architecture's earliest surviving treatise, Vitruvius writes of the origin of architecture as being largely concerned with providing resistance to "the rain and the heat."[2] Echoing "Airs, Waters, Places" of the *Hippocratic Writings*, Vitruvius advocates the siting of buildings and cities in relation to favourable environmental flows of the winds and humours.[3] Spanish architect Luis Fernández-Galiano reminds us in *Fire and Memory* that architecture's origins, for Vitruvius, lay in its relation to environmental conditions.[4] Similarly, in *On Adam's House in Paradise*, Joseph Rykwert recalls Filarete's myth of the first act of architecture as having been linked to Adam's exile from Eden: in the rain that greeted Adam on departing the garden, he required shelter.[5] The fabric of our buildings manages their internal environments,

[1] Reyner Banham. *The Architecture of the Well-Tempered Environment*. 2nd ed. London: Architectural Press, 1984, 19.

[2] Pollio Vitruvius & Morris Hicky Morgan. *Vitruvius: The Ten Books on Architecture*. New York: Dover Publications, 1960, 39.

[3] Ibid. Hippocrates. "Airs, Waters, Places." *In Hippocratic Writings*, eds. G. E. R. Lloyd, John Chadwick and W. N. Mann, 148-69. Harmondsworth; New York: Penguin, 1978.

[4] Luis Fernández-Galiano. *Fire and Memory: On Architecture and Energy*. Cambridge, Mass.: MIT Press, 2000, 9-15.

[5] Joseph Rykwert. *On Adam's House in Paradise: The Idea of the Primitive Hut in Architectural History*. 2nd ed. Cambridge, Mass.: MIT Press, 1981, 118.

maintaining our spaces such that they are comfortable and convenient for the range of activities they house. As Fernández-Galiano writes, they may be actively heliotechnic—through a mechanised manipulation of the sun—or passively bioclimatic—adapting to natural ebbs and flows of energy.[6] Because we inhabit architecture, it is always surrounding us, conditioning us, texturing our existence and daily affairs. Our buildings are continuously, but inconspicuously, working, not only in resisting gravity, but in ensuring that indoor is kept controlled and distinct from *outdoor.* Because our buildings work ambiently, providing an atmosphere for our lives, they are not so much seen as felt. Although they are made by arranging materials in particular ways, one clear goal of our buildings is to provide for a level of environmental conditioning and control which would otherwise be unobtainable. Were environmental control unnecessary, we would have less need for buildings but we might not build at all. Again as Rykwert notes, Banister Fletcher begins his canonical text by stating that architecture "… must have had a simple origin in the primitive effort of mankind to provide protection against inclement weather…."[7] Such accounts find that architecture, then, at its core, has always been as concerned with the immateriality of forces, fields and flows as it has with materiality.[8]

Despite this, the immaterial aspects of our environment are somewhat foreign ground for the architect. Whether a space is too hot or too cold, too bright or too dark, too stuffy or too windy, too noisy or too quiet, or too humid or too dry, are precisely the aspects of space that most truly affect us, and are ultimately aspects which evade most of our abilities to represent and hence design. For all that architects may be following in the footsteps of Le Corbusier in providing neutralising walls and exact air indoors, the idea of engaging immaterial attributes for architectural effect, outside of lighting, perhaps, has not taken widespread hold.[9] Architect Lisa Heschong observed as much when, writing *Thermal Design in Architecture* in 1979, she called for architects to engage the design possibilities of appealing to the body's thermal sensors.[10]

The work of the architect happens mainly in the studio, where it progresses using scaled-down, and necessarily enfeebled models of conditions in the world. The Italian computer scientist Massimo Negrotti explains that the utility and power of models is that they are never complete in their relationship to reality. Rather they filter out aspects of reality in order to draw attention to others. The artificial flower, Negrotti writes, might look like a flower— it might be a visual and geometric model—but might not grow like one. If the aim of the artificial flower were to formally resemble a certain kind of flower, modelling its growth would be unnecessary. Were it to be necessary, a model of growth might take the form of a computer programme rather than silk.[11] As architects find themselves largely concerned with dimensional control of a building project, their models, such as floor plans, tend to emphasise those aspects. However, as both the concern for energy issues in the built environment and the need for integrated building solutions increase, driven by an awareness of the ecological crisis and of the advantages of Carpenter's work is founded on the relationship between light and glass, as demonstrated in his *Periscope Window* of 1997. In this work, a matrix of glass lenses sandwiched between layers of transparent and translucent glass manifests a projection of light and shadow. Weathers, uses considerations of thermodynamics to drive design decisions at the scales of installations, buildings and urban areas, as in the Amplification orchid gardens, or, more

[6] Fernández-Galiano. *Fire and Memory:* On Architecture and Energy, 100-26.

[7] Rykwert. *On Adam's House in Paradise: The Idea of the Primitive Hut in Architectural History*, 21.

[8] Jonathan Hill uses the term "immateriality" in the context of environmental forces and flows, and sensory perceptions, such as light, heat, scent, air movement, humidity, and sound. See, Jonathan Hill. *Immaterial Architecture*. 1st ed. London; New York: Routledge, 2006. Sean Lally uses the term "material energies" to describe the same phenomena. See, Sean Lally. *Energies: New Material Boundaries*. London: John Wiley & Sons, 2009.

[9] On exact air and neutralizing walls, see Le Corbusier. *The Radiant City; Elements of a Doctrine of Urbanism to Be Used as the Basis of Our Machine-Age Civilization*. New York: Orion Press, 1967.

[10] Lisa Heschong. *Thermal Delight in Architecture.* Cambridge, Mass.: MIT Press, 1979.

[11] Massimo Negrotti. "From the Artificial to the Art: A Short Introduction to a Theory and Its Applications." *Leonardo* 32, no. 3 (1999): 183-89.

energy efficiency, it is becoming imperative for architects to develop an appreciation of the opportunities afforded by the forces and energy flows of the natural world. Sean Lally, of recently the SHAGG and Wanderings installations, and the Undertow garden proposal, all of which produce immersive conditions through emitted sound, light, scents, and heat.[12] James Both direct washes of light, and pixelated light and inverted images through the lenses and projected on the translucent surface, result in a continuously changing effect. Like the compound eye of an insect, the Periscope Window amplifies the animate shadows cast by trees, ambient daylight conditions, and direct sunlight.[13] For the moment, such works are exceptional, relegated to relatively few architects, who seek to engage an expanded realm of bodily perception on the environment.

Although it is crucial that the education of the architect encompass an understanding and appreciation of not only the materials, but the immaterials of our environments, it presents challenges. Firstly, the everyday context of drawing and digital-modelling in architectural representation makes this difficult, as the ocular-centrism of these methods tend to reinforce what architect and theorist Juhani Pallasmaa calls "the hegemony of the eye."[14] In contrast to the extensive properties of matter, phenomena and attributes such as light, heat, humidity, air movement, scent and sound cannot be readily represented visually, making them difficult for the architect to consider when designing. Secondly, the immaterial phenomena are difficult to explore on their own, as they require form and matter as carriers. As a result, they have been largely relegated to specialised technical subjects, and ignored in architectural design. Although simulation tools, like Ecotect, have begun to bring aspects, such as illumination levels and thermal comfort to the attention of the architect, they are limited in that they reduce such phenomena to data and pattern. Disembodied, as in diagrams and tables characteristic of environmental design, they are devoid of meaning. Yet, physically felt, as Banham wrote, the immaterial qualities of our environments charge them with vitality, and their management are ultimately why architecture exists. Coming to understand immaterial phenomena is thus in lock-step with both developing an understanding of our own bodies and their sensations, and developing an appreciation of the natural world. Perhaps the only way of really coming to appreciate them is to design with them, at full scale, through corporeal experience, as a comparative discussion of three projects will illuminate.

Inhabiting Materials, Managing Environments: Material Meets Immaterial

Completed in June 2008, the design studio "Inhabiting Materials, Managing Environments" started from the perspective that making, even at a very small scale, would provide an opportunity to learn about the relationship between materials and immaterial environmental of bubblewrap, cardboard, reflective foil, hessian or Tyvek in conjunction with one of air movement, heat, humidity, light or sound. The materials chosen for the exploration all had important, yet undervalued links to architecture, serving as underlayments, interstitial layers, wrappings and temporary housings. Bubblewrap and cardboard, for example, are used for packaging of architectural items, but are also used as thermal insulation, as in phenomena, how they co- shape one another, and how they condition inhabitation. Teams of postgraduate students from the University of Melbourne each located their projects on a matrix, choosing to demonstrate the relationship between one material and one immaterial quality in a 3m cubic space (figure 1). The teams then built occupiable spaces which would demonstrate the interplay of one foil-faced bubble insulation, or as structural material, as in Shigeru Ban's various paper tube structures, including the Japan Pavilion for the 2000 World's Fair.

[12] See, for instance, Sean Lally & Jessica Young. *Softspace: From a Representation of Form to a Simulation of Space*. London; New York: Routledge, 2007; Lally, Energies: New Material Boundaries.

[13] Sandro Marpillero, James Carpenter & Kenneth Frampton. *James Carpenter: Environmental Refractions*. Basel: Birkhäuser, 2006.

[14] Juhani Pallasmaa. *The Eyes of the Skin: Architecture and the Senses.* Chichester; Hoboken, NJ: Wiley-Academy; John Wiley & Sons, 2005. Fernández-Galiano similarly calls this "the dictatorship of the eye." See, Fernández-Galiano, *Fire and Memory: On Architecture and Energy,* 4.

	tyvek	hessian	bubblewrap	cardboard	foil
heat					
humidity					
light					
sound					
air movement					

Figure 1. The matrix of material/immaterial possibilities for “Inhabiting Materials, Managing Environments.”

The non-woven polyolefin textile, Tyvek is used as a weather barrier within wall assemblies, but has also found uses in packaging and clothing. Woven, multi-layer polyethylene composite reflective foil is used as both sarking in roof installations, and a weather barrier within wall constructions for the management of moisture, heat and air. The woven textile hessian is used as a sacking material, but also as humidity control during concrete construction, and in sandbags for emergency measures and temporary structures.

Teams chose to work at the intersections of reflective foil and light, cardboard and sound, bubblewrap and humidity, hessian and heat, and Tyvek and air movement. For example, *9_31 (Archimedes)* was sited at the intersection of reflective foil and light, creating a layered, yet eerily flattened experience of a myriad of reflections captured in foil projected through a singular circle framed by the matte blue reverse side of the foil (figure 2).

Figure 2. *9_31 (Archimedes)* was sited at the intersection of reflective foil and light.

Skilfully employing the surface of cardboard as a sound reflector, and its corrugated web as a sound absorber, *Talking Walls* used a funnel-shaped module to create a pair of rooms for the exchange of secrets between individuals (figure 3). *Metaforest* challenged passers-by to enter a dense forest of treetrunks made of biodegradable bubblewrap, which emitted artificial fog and, as they decomposed, green liquid, akin to sap (figure 4).

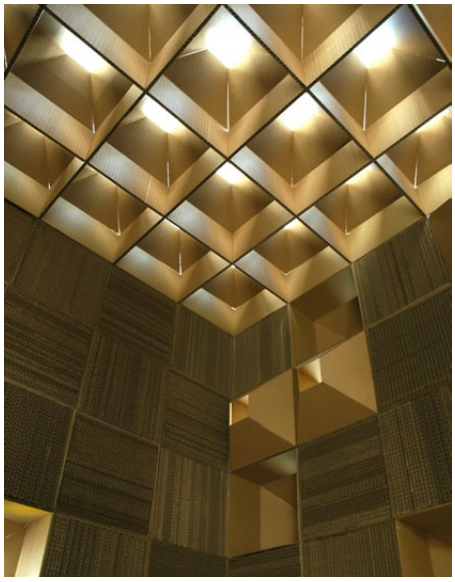

Figure 3. *Talking Walls* intersected cardboard with sound.

Figure 4. *Metaforest* considered bubblewrap and humidity.

The site for these investigations was an indoor, glass-enclosed pedestrian bridge over a major city centre street connecting two parts of a multi-storey shopping complex. The bridge served as the site for a 10-day long installation and experimentation period, and as the venue for both the final review of the work and the subsequent public exhibition, which lasted for two weeks. Highly trafficked, the bridge is a moment of experiential and psychic escape from commerce, when traversing from the department store, at the south end, into the shopping mall, at the north. Also, lifted above the street, the bridge offers a unique experience, not only in terms of daylight and spatial quality, but as a unique voyeuristic vantage point on the activity below. In return, the bridge is also visually permeable, offering the possibility of spectacle for the street below. Equipped with ample windows, artificial lighting, mechanical ventilation, and electrical outlets, the bridge not only offered its own environmental energies, but also offered the possibility of augmenting these electrically.

The sheet materials chosen for the project were all lightweight, inexpensive and easily worked. This enabled students to work without drawings, investigating the propensities of the material and designing through the process of building. Because they were lightweight, the materials were easily transported, stored and spatially arranged, without the need for engineered structural solutions. Because they were inexpensive, each of the materials was easily obtained, and replaced. Because they were easily worked, they did not require the need for specialised equipment or skills in material processes. While largely imposed by issues of budgets, timeframes, and resources, such factors contributed to the ethos of the project as one of experimentation and in-situ adjustment. Rather than developing from sketching, drawing and modelling onto full-scale pieces, the work developed through experiments at full-scale. Teams readily worked with the materials to examine how they reacted with not only fasteners and adhesives, but with heat, light, sound, moisture, and wind, as they worked with the environmental conditions of the site, and with powered alternatives.

For instance, while one group *(9_31 (Archimedes)* saw the project as an opportunity to work with changing ambient light conditions over the course of the day, another group (Tyvek and air movement) subjected materials to various heat treatments, while another (hessian and heat) used starches as stiffening, and still another *(Metaforest)* used a syringe to inject water into material cavities. Through designing with phenomena, the role of visual representations and models was diminished. Drawing did not drive the project so much as supplement it, as a medium of exchange for the discussion and recording of ideas. Design decisions flowed from embodied experiences—feeling heat and air movement, listening to sounds, seeing light, and experiencing the many aspects of humidity, from liquid water to evaporation to fog. The students built the projects through experience-based experimenting and designing, rather than designing first, then building foregone conclusions.

Instruments + Environments: Material as a Carrier of the Immaterial

The "Instruments + Environments" design studio, completed in June 2009, probed the relationship between sound and architecture by considering the relationship between housing the musical instrument and housing the human body. Two key developments conditioned the project's generation. The first was a chance meeting with Paul Davies of Arts Music, a luthier known for both his electroacoustic violins and his use of non-traditional materials, such as Australian hardwoods and recycled woods, in the making of string instruments.[15] The second was a conversation with the design and prototyping department of Visy, a local cardboard manufacturer, known for their innovations in expanding the use of cardboard, from designs for recyclable exhibition booths to recyclable shipping palettes.[16] They each proposed to engage students in independent *blue sky* rethinks of the wooden violin case and the cardboard environment. Each also proposed to engage the design studio in various ways: consulting on materials and processes, attending preliminary reviews of work, hosting excursions, and, in the case of Visy, fabricating the final works. The studio would then become a navigation between wood and cardboard, the bespoke and the mass-produced, the permanent and the degradable, the grown and the made, the instrument and the environment.

The "Instruments + Environments" studio then comprised a pair of interrelated, sequential projects: a handcrafted prototype for a wood violin case and an externally-fabricated cardboard environment. Teams of postgraduate students, again from the University of Melbourne, each designed and built a violin case in collaboration with the luthier over a six-week period in the architecture woodwork shop, taking into account a spectrum of issues related to its performance, from portability and protection, to display and image, to construction and fit. An embodiment of ideas of sound, music and performance, the wooden housing of the musical instrument served as a model for housing the human body with corrugated cardboard. Taking conceptual, formal, or procedural cues from the violin case, the teams then designed and constructed occupiable spaces over a further six weeks, situated in the same locale as "Inhabiting Materials, Managing Environments" (figure 5).

[15] Paul Davies of Arts Music, Melbourne.

[16] Visy, http://www.visy.com.au/

Figure 5. The “Instruments and Environments” exhibition was located in an indoor, glass-enclosed pedestrian bridge, which connected two parts of a multi-storey shopping complex.

With divergent starting points, the resulting environments each had equally manifestations. Given that the bridge is a space of transient habitation, one construction created two curved walls, which worked with parallax to create an optical play of layers. Another created a space which could only be entered by children within a diagrid structure and clad in a perforated, diaphanous cardboard skin. A third created a play of light with corbelled, prefabricated cardboard bricks. Finally, a fourth (*Aliosphere*) created an opportunity for seating within an introspective, spherical environment (figure 6).

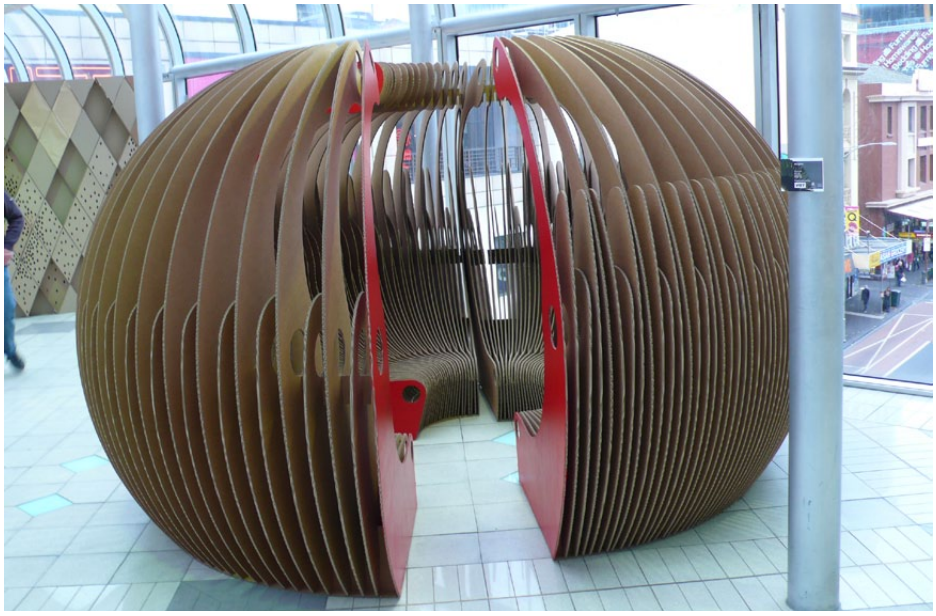

Figure 6. The *Aliosphere* provided an introspective seating environment in the bridge.

The processes of designing and constructing the violin case and the environment, and their interrelationship, were thus quite distinct. With the violin case, the woodwork shop became a *de facto* design studio, as students had only limited ideas prior to commencing making. Designing and making progressed simultaneously through a process of continual feedback. The works were conditioned by the processes available in the workshop, and the craftsmanship of the students. Inthe case of the environment, the final works were largely prefabricated (figure 6) . While this offered the students the advantages of access to larger sizes of material, and to the sophistication of automated, digitally-controlled flatbed cutters, this also meant that components were fabricated at a distance, and transported to the studio. As the production of samples and tests was subject to production schedules, this had the effect of reducing the possibility for an iterative approach to making and designing. This meant that although the material used in the environments was itself more easily worked, design decisions were made at a greater distance from the material and immaterial propensities than with the violin case. Relative to the instrument cases, the environments were developed primarily through drawing and modelling, much as a conventional architectural project with its established divisions of design and construction. Although the cardboard as a material was clearly more supple and plastic than the wood used in the violin cases, the material processes dictated a particular type of engagement with those materials on the part of the studio. Working in the architectural woodwork shop with wood encouraged an ethos of handcrafting. Working with outside fabrication, on the other hand, instilled the need to be imaginative in predicting possibilities in order to achieve a controlled, effective result. This contrast of the predictive necessity for engaging industrialised fabrication vis-à-vis the experimental potential of handcrafting became the hallmark of the studio.

Sealight Pavilion

Whereas “Instruments + Environments” and “Inhabiting Materials, Managing Environments” were both temporary installation projects, the *Sealight Pavilion* was constructed as a permanent addition to the waterfront of Melbourne in October 2011 (figure 7).

Figure 7. The *Sealight Pavilion* at the foot of Latrobe Street in Melbourne Docklands.

The *Sealight Pavilion* was designed and constructed by a team of twenty (mixed undergraduate and postgraduate) students from Monash University over a fourteen week period in collaboration with the Norwegian practice Rintala Eggertsson Architects and the international practice Grimshaw Architects, and with the support of the Victorian state government, who were the client for the project. The government also suggested that the site for the project be at the Melbourne Docklands, an area formerly known as Victoria Dock, which had served as the longtime port, but had fallen into disuse with the rise of containerisation and was in the midst of a conversion to a new life as an extension of the city centre.

Early studies illuminated the need to engage the bodily senses and natural phenomena of the site more fully than architecture in the area was otherwise doing. Initial site investigations by the students led each student to design a pair of machines: one to amplify light and one to amplify sound. Subsequent studies confirmed a disconnect between being at the dock and feeling the presence of the maritime history and marine environment. For a maritime area, water seemed remarkably absent in the experience of the place. For a place that had been the centre of Melbourne's exchange with the world, the traces of that history were conspicuously missing. The project then ought to itself work as an amplifier of the experience of natural phenomena, and would become a drawing card in the neighbourhood as one of the few places in which to experience the presence of the sea and sky.

Once the precise location was determined, the project developed through digital design techniques and physical models of increasing scale. Through this process, many options were tested for urban effect, experiential quality and constructibility. As it crystallised out of a narrowing series of competing options, the resulting *Sealight Pavilion* on one hand amplifies the natural phenomena of sea and sky, that are the most captivating amenities of Docklands, and on the other poses an alternative urbanism for the area, offering a counterpoint, in both scale and experience to the existing fabric. The Pavilion took form as two parts: a tower which dissolves as it climbs in height to frame the sky (figure 8), and a cantilever which dematerialises as it reaches out over the dock's edge to frame the sea (figure 9).

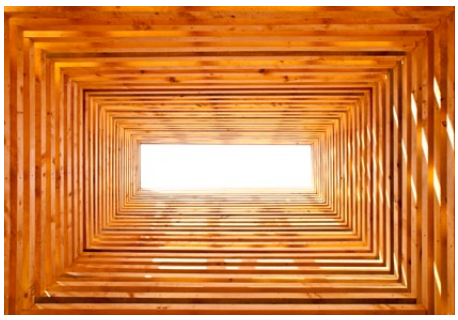

Figure 8. *The tower of the Sealight Pavilion narrows to frame the sky.*

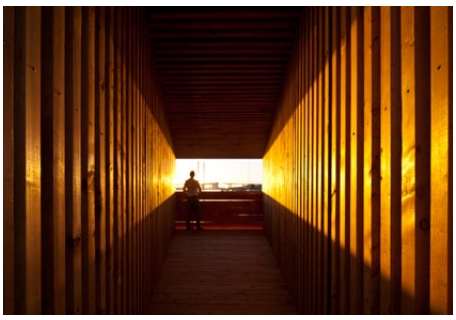

Figure 9. *The cantilever of the Sealight Pavilion reaches over the dock edge to frame the sea.*

The pavilions were constructed of reclaimed golden cypress, which is used locally as a windbreak. Sawn by a local artisan miller, the cypress will patina to a silver- grey, complementing the materiality of the dock.[17] Each of the two pavilions has a tapering inner volume which is geometrically distinct from the outer parallelepiped and opens wide to the horizon and narrow

[17] Susannah Hagan discusses the call for recycling of buildings in the following essay: Susannah Hagan. "The New and Renewed." *In Material Matters: Architecture and Material Practice*, ed. Katie Lloyd Thomas, 249-57. London; New York: Routledge, 2007. Of course, such interests are at the centre of William McDonough and Michael Braungart's work. See, William McDonough and Michael Braungart. Cradle to Cradle: *Remaking the Way We Make Things*. 1st ed. New York: North Point Press, 2002.

to the sky, so as to intensify the experience of both sky and sea. As the floor of the cantilever dissolves, the sight and sound of the water below and its reflections above become apprehensible. Likewise, as the lining of the tower cants inward, it serves to focus attention on the sky. The two pavilions align such that the evening summer sun shines through the openings of both to the street side. In this way, the pavilions serve to focus, and in this way amplify, the natural phenomena of Docklands (figure 10).

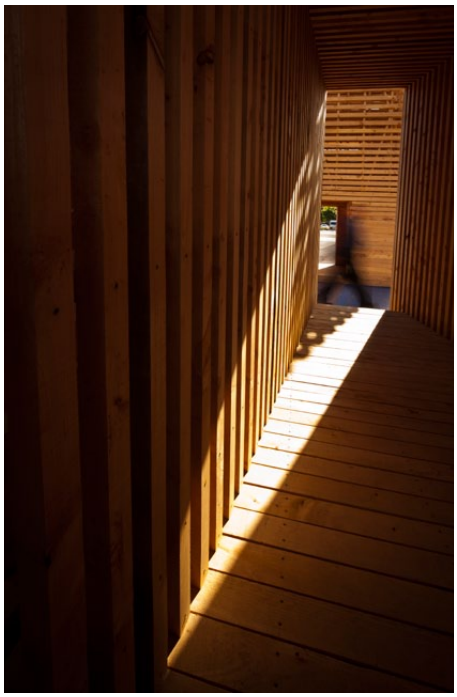

Figure 10. *The Sealight Pavilion intensifies the experience of light of Docklands.*

Making: Understanding of the Immaterial

While the *Sealight Pavilion* offered a very satisfying and meaningful opportunity for the work of students to contribute to the ongoing life of the city, and while "Instruments + Environments" offered an opportunity to engage a fabricator and external consultants, perhaps the project that most fostered an understanding and appreciation of the relationship between material and immaterial, and between the artefact and its environment, was "Inhabiting Materials, Managing Environments." In the case of "Instruments + Environments," the hope was that by engaging outside fabrication, the final environments would exhibit a higher degree of sophistication, afforded by the advanced fabrication possibilities of the manufacturer, such as large sheet sizes, large, flat-bed CNC cutters, and sheet optimisation software. Yet, this engagement with the greater technological sophistication of the external fabricator had the effect of reducing the capacity for the students to immerse themselves in the sophistication of the work. Similarly, in the case of the *Sealight Pavilion*, the approvals and engineering and the precise ordering of materials, in tandem with the cost and increased resistance and permanence of the materials, reduced the capacity to readily experiment. The intended permanence of the project meant that it was constructed of durable materials, and required permits prior to construction. Using custom-milled, reclaimed timber required the dimensions of all members to be established early on in the process. Because of the needs to communicate with the engineer, the materials supplier, and the regulatory agencies, drawings assumed a central role in the development of the design. This necessary separation between planning and execution

meant that while the project entailed first-person handcrafting on the part of the students, the making was largely preordained. In both "Instruments + Environments" and the *Sealight Pavilion*, the penalty paid by forfeiting designing from building and the direct interaction with both materials and immaterials was an increased need to predetermine the outcome, and a decreased potential for direct engagement with the immaterial qualities of our environments that are, precisely as Banham and others observed, at the basis of architecture.

Andrew Freear of Auburn University notes how engaging students in construction leads them into a greater consideration of the implications of the architectural drawing and its role in the shaping of our built world.[18] Through building, Freear finds architectural students learn the relationship between the line and its implications. Building gives meaning to lines, demonstrating them first- hand as surfaces, edges, intersections, lengths, and relationships that can be experienced with the body. They also learn that the line as drawn may have to adapt to take into account the possibilities of how materials actually behave. As the installation artist Richard Wilson writes: "Although one might have thought one's worked the idea out on paper and in maquettes, what one's really doing is mentally preparing oneself. Things never end up as first conceived."[19]

In the *Sealight Pavilion,* one of the greatest realisations of the students was that while their digital design tools led them to specify batten spacings of 0.5mm or less in precision, the possibility of realising such precision with the variability of wood was another matter, and they would have to adapt their thinking accordingly.

Architect Giuseppe Zambonini writes in "Notes for a Theory of Making in a Time of Necessity," a design process which emphasises the direct experience of material, akin to someone engaged in sculpture or the crafts, serves to "… focus attention on the essences of objects themselves—on an object's capacity to carry meaning embodied in its physical qualities, in its materiality."[20] However, in so-doing, the materials become carriers of the immaterial world of forces, flows and fluxes. This is precisely what Fernández-Galiano writes: "Architecture can be understood as a material organization that regulates and brings order to *energy* flows; and, simultaneously and inseparably, as an *energetic* organization that stabilizes and maintains *material* forms." [21]

In teaching through construction, gaining an appreciation of these flows of natural phenomena is as important as gaining proficiency with the materials themselves, as educator George Elvin notes,

> Design takes place on-site, where we feel the wind, see the way light falls, and experience the view through the columns to the open field. This takes us away from the once-removed world of the office to the site, and engages our body as well as our mind in the design process[22]

What "Inhabiting Materials, Managing Environments" reveals is that building is equally valuable as a means of instilling an awareness and appreciation of the role of immaterial phenomena in design and experience of the built environment. As a result of that studio, the students gained a profound sense of appreciation for the relationship between materials and immaterial phenomena in the built environment. When the students were asked to manifest the relationship between material and immaterial, they had to take stock of what was

[18] Andrew Freear. "Material Responsibility and the Work of Rural Studio." In *Material Matters: Architecture and Material Practice,* ed. Katie Lloyd Thomas, 237-48. London; New York: Routledge, 2007.

[19] Richard Wilson. "Re-Fabrications." In *Material Matters: Architecture and Material Practice*, ed. Katie Lloyd Thomas, 175-88. London; New York: Routledge, 2007, 182.

[20] Giuseppe Zambonini. "Notes for a Theory of Making in a Time of Necessity." *Perspecta* 24 (1988),17.

[21] Fernández-Galiano, *Fire and Memory:* On Architecture and Energy, 5.

[22] William J. Carpenter & Dan Hoffman. *Learning by Building: Design and Construction in Architectural Education.* New York: Van Nostrand Reinhold, 1997, 8.

available in the space in terms of light, sound, temperature, air movement and humidity. Inexpensive, lightweight, easily-manipulable sheet materials enabled a design process of direct experimentation, which allowed these explorations to play out. After exploring through the richness of material experimentation, they became all too aware of the limitations of representational methods regarding the material/immaterial relationship. Perhaps, most importantly, they gained an appreciation for the rich interplay between material and immaterial that makes our built environment truly complex, without necessarily having to resort to complex form-making.

Pallasmaa writes, "… architecture is primarily not about theory, technique or function, but about the world."[23] In the midst of the ecological crisis, there is greater awareness that our world is not only material, but also immaterial. In order to bring things into balance, it is imperative to value both. Architects need to do so. Moreover, a full architectural engagement with the body does not rest at material and form, but extends to forces and energies, as perceived in light, scent, thermal comfort, and sound. Making can be a way of engaging future architects more fully in both the materiality and immateriality of our world.

[23] Juhani Pallasmaa & Peter B. MacKeith. *Encounters: Architectural Essays.* Helsinki: Rakennustieto Oy, 2005, 174.

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