Structure

Form, Beauty, Space

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Special thanks to my family and friends who supported me along the way, with extra special thanks to my girlfriend Janette for keeping me fed and connected to the outside world, and to my brother, Colin Dor-gan and Ronan O’Dea for helping me out in the final push.

Thanks to all the staff and students in the School of Architecture in the University of Limerick.
The objective of my thesis is to explore the various elements that make structure architecture. Through investigation into thinness, material, span, space and soundscape, I wish to create an architecture which can appeal to the senses and have value form many years to come. I propose to interrogate these qualities with the demanding programme of aircraft cargo and maintenance on the site of Shannon Airport, which is situated on the Shannon estuary and to find a unique solution to the current generic nature of the place.
Introduction

Structure – as architects and architecture students, we often say “post and beam, cantilever, bridge structure”, but we rarely stop and consider the sensorial effects that these structural elements have on the spaces they create. In our increasingly industrialized world, sometimes we forget the human that is at the heart of the grand picture, instead worshiping the gods of technology and manufacturing processes. This can lead to the situation Juhani Pallasmaa hopes to avoid, where “The current industrial mass production of visual imagery tends to alienate vision from emotional involvement and identification and turn imagery into a mesmerising flow without focus or participation.” 1 The pleasure one feels when we occupy certain spaces is something I hope to gain an understanding of, through an investigation of what a space is made of – namely, its structure. Odile Decq recognises the difficulty of designing for the modern human, noting that “architects face a challenge that is more complex than ever: the question of desire and pleasure.” 2

When I speak of structure, I am referring the region of architecture often handed over to the engineer and craftsman – something to hold up the concept that we as architects consider as the core of our buildings. We have lost the link between structure and architecture, failing to investigate its form and logic. We have also failed to understand any link that structure has to our senses beyond the single sense of sight. I hope to investigate the various elements of structure as architecture and its sensory and spatial reasoning, as much as is possible to pry into the haptic and sonic with words.

1: Juhani Pallasmaa, *The Eyes of the Skin*. Pg. 22
Structure is what a building is, at its very core. In the built environment, structure tends to last the longest of all. How often have we seen pictures of ruined towns with the skeletal remains of its frame still eking out an existence. Fashions come and go, as do tenants, sometimes forever, but the building skeleton bears the load of protector and supporter in all built civilizations throughout time. The issue of structure within the field of architecture is its separation from the realm of design, often being shipped out to structural engineers, who have their own view of what it should be, with few constraints outlined by the architect.

Corbusier’s Domino house concept, as described by Bjorn Sandaker, may well be one of the culprits for this lack of structural integration, because “The structure has virtually been emptied of any meaning except the purely technical. Architecture could now be seen as two autonomous systems, the purely structural and purely aesthetic.” For me, in this mode of thinking, the structure fails to be architecture; it exists solely as a frame upon which decoration can be hung.

I desire to avoid this form of thinking – I don’t want structure to be hidden, considered only as an engineering problem that supports my architecture. Obviously, the building should stand up, but architecture and structure should never be stood apart, for fear that the role of an architect would be delegated by market forces to that of a decorator, something perhaps already in motion.

We should be thinking of structure using the sets of definitions laid out by Sandaker, where he separates structural form into a conglomeration of global for and local form. Global form can generally be thought of as the overall building structure and local form being that of the material-nature of the material. This pure expression is an extremely honest way of constructing that requires its designer to experiment with the structure to their thinking even though their training, may be purely technical, mathematical or market oriented.

The situation of conceptual and structural disparity has become rife in the design world, where designing with a vague philosophical or aesthetical premise as our concept has become the norm. We can see examples of this in the buildings on our street, or those designed by vaunted architects. Take the example of Zaha Hadid’s London Aquatics centre for the 2012 Olympics. It is designed around the concept of water and its fluidity. Her company simply designs a shape, their perception of what a fluid would be if it were a building, and then sends it out to the façade engineering company Newtecnic, who design the structure that will hold it up. This building is a fashion item, a stylistically idealised building which conveys a concept by looking like that concept. Here, the global form is whatever will hold up that concept, but, as Paul Rudolph tells us “Sculpture is not architecture and architecture is not sculpture. Never.”

We should consider what that means for architecture as a profession. We become shape designers in the very lowest form of the word, one where we relinquish the control of materials and structure. Rafael Moneo puts it succinctly when he analyses the role of an architect “to be an architect traditionally implied being a builder; that is explaining to others how to build.” We need to have a mastery of how our entire building works so that each element of it is carefully considered for its impact on the people who experience it. This body of knowledge can begin with an understanding of materiality, similar to those architects of the past who were craftsmen with the material they chose.

Architects and engineers have stated in the past that materials wish to be used in a way that expresses their materiality, or the inherent nature of the material. This pure expression is an extremely honest way of constructing that requires its designer to experiment with the material’s physical and structural properties. Candela’s work is a true demonstration of the nature of concrete in the capacity of shell structures. In his work, the structure that concrete asks for is everything—the physical demonstration of a material stretched to its limit as the hyperbolic paraboloid.

There are many examples throughout the history of architecture where material properties are expressed through the structural form. Masonry, in particular, has had its material properties expressed in the arch, due to its mono-directional structural qualities, something

3: Bjørn Normann Sandaker, On span and space: exploring structures in architecture. Pg. 3
4: Bjørn Normann Sandaker, On span and space, Pg. 34
5: Paul Rudolph, Writings on Architecture, Pg. 101
6: Thomas Schropfer, Material Design: Informing Architecture by Materiality. Pg. 8
Antonio Gaudi took advantage of when designing the Basilica de Sagrada Familia, using catenary arches built of masonry. Louis Kahn was also someone who recognised the properties of masonry, going so far as to give it a personality and asking it questions such as “you must ask brick what it wants or what it can do. Brick will say, I like an arch.” This nature of materials in structure is one that is lost in cladding structures in another material. The cladding material will remove the honesty of structure within the building and prevent it expressing the truth of the concept behind the building. We face this difficulty in the world of high performance buildings today, where expression of material can become overwhelmed by the amount of regulations for thermal, acoustic and visual insulation. There is however some people still experimenting the idea of a material having an inherent form. One of the most prominent explorers of within this field is Shigeru Ban, who has experimented extensively with paper tubes, with impressive results. The innovation he brings to the structure, and the clear idea behind those structures help them to be nice spaces to be in.

However, masonry and paper tubes (as well as other materials) are mono directional, i.e., their very nature produces the form that they are assembled in. Both masonry and paper tubes have to be designed in compression. But we also have bi-directional materials, which can be designed in compression or tension, or both at the same time. These materials make up a large portion of the building supplies that we specify each day as architects.

With bi-directional materials, such as reinforced concrete, steel and timber, we face something of a conundrum as they don’t have the same structural issue that masonry has. They tend to be designed for economic reasons, using as little material as possible, sometimes expressing the lines of structural force explicitly. Pier Luigi Nervi describes it as the material asking to be moulded to the shape of the stress – achieving the maximum result with the minimum means. This stand-point is one held up by both engineers and the market forces behind building. This method is the most common way of achieving structure from materials.

The other method is Frank Lloyd Wright’s approach in Taliesin West, where some columns are three times the size they need to be. Not be cause a specialist was nervous, but because, as Paul Rudolph iterates, it creates a sense of security for us. “Wright’s interest in structure was, to a degree, a psychological one,” a view that I have begun to share since beginning research for this essay. This psychological effect is achieved through scale and materials and their imbued meaning.

Once we understand the importance of global structure, how do we approach it as architecture, when we know it has such an enormous effect on the space contained within and without it. In today’s abundance of building materials and proprietary systems do we go for pure expression of material, along the lines of Candela, or do we simply pander to the current technological awe, or can we create something that will last and be usable by as many as possible. A building that gives sensual pleasure.

Here is where we enter the realm of local structure, or the detail of the building. This local form is given by the very nature of making – a material’s light qualities, its texture, the joint details it requires and their measurement, as well as a whole host of other qualities. These are the very tangible, sensorial characteristics of materials and how they are used, and they help us understand the global form of a building, its more humanistic scale and its overall psychological effect. Every part of built fabric has local form which speaks volumes about its use.

One very evident example is in Felix Candela’s work with shell systems. In these shell structures, the only local form is that of the materiality of the concrete itself, or more to point, the surface that it was cast against. They are magnificent pieces, well suited to churches and stations as they give an impression of vastness, because of their uniformity of local form – this creates a space within which we feel awed, similar to the sensation of being next to skyscrapers. They seem to lack a scale and there is the notion of them continuing indefinitely. This is a situation where the local form and global form become so intertwined that they are experienced as one.

8: Thomas Schropfer, Material Design, Pg.25
9: Thomas Schropfer, Material Design, Pg.17
10: Bjørn Normann Sandaker, On span and space, Pg. 27
11: Paul Rudolph, Writings on Architecture, Pg. 137
12: Rudolph, Writings on Architecture, Pg. 136
Sensory understanding of structure

We can understand the term local structure to mean both detail and materiality. We have both the humanistic detail, where balustrade and door handles are curved to fit the hand, but we also have the industrial detail, such as the thickness of a pane of glass – six millimetres thick, because that is the thickness it goes to when coming out of the furnace, or the length of a steel girder, because it is impractical to make it any longer.

These details, human and industrial, and material properties are what makes up the spaces we inhabit. Local form is intrinsically linked with global form, for good and for bad, but it can speak to us in a way that global form finds difficult. We can touch, see and hear it. We can understand it sensually rather than the logical understanding we gain of global structure. The meanings of detail and materials are ever changing, to the point where “Steven Holl suggests that the incertitude of material meanings, far from being a liability, is one of architecture’s most powerful tools. He suggests that the potential of materials lies in their power to evoke rather than dictate meaning.” This changing in meanings allows our understanding of materials. It means that we can create a space with materials that we have been using for thousands of years, such as wood and steel, and come up with something unique each time, because of the change in perception of the materials used, going against Robert Venturi when he quotes Tim Colquhoun talking about material’s final form within the modern movement, saying “The essence of the functional doctrine of the modern movement was not that beauty or order or meaning were unnecessary, but that it could no longer be found in the deliberate search for final form.” For me, this view has become out-dated and narrows itself unnecessarily. It is testing for material form that makes structural experimentation so interesting, as it has the potential to create unique spaces that can lend themselves to certain uses.

We then also have the structural detailing of the building to consider as the moment where a building gains its humanistic scale. It is where local structural ideology meets the global structural form, creating something greater than the sum of both parts. Global forms can be similar, i.e. two a spanning trusses, but they can give entirely different images, depending on how they are joined. A seamless, welded truss hides

14: Tim Colquhoun’s comments in Robert Venturi, Denise Scott Brown, Steven Izenour. Learning from Las Vegas: The Forgotten Symbolism of Architectural Form. Pg. 133
its creation from view, except on close inspection, whereas a riveted truss, or traditionally crafted timber truss give us a completely different space due to its different mode of production. I find the addition of the humanistic touches in the built fabric are something to be cherished, as it gives the elements the feeling of having been worked, of having had a craftsman of some form work upon the building. We also get the feeling of the architect as a craftsman when we come across details that are exquisitely thought out. This tends to manifest itself particularly well at the junction between different elements, such as a window or door, where things are sized up according to an understanding of the people that will touch them. A true meshing of product design and architecture.

Only once we know about a building’s global form and local form can we begin to understand the effect it has on the space it creates within it and without it. If we fail to see and implement the changes to our design ideology, we shall end up finding the answer to the question that Winy Mass asks us: “How then are we to cope with an urban matter that cannot be considered entirely valuable?” It is huge waste of resources, both human and environmental to construct in this lost wax method, where we lose the form every time we copy it. When we consider a building to be something of value, we often repurpose it and use it as much as possible, for it is a space which is enjoyable to be within, something difficult, if not impossible, to do with poor quality buildings. Local and global form can be found, but “Architects must be more ingenious, inventive and imaginative in using material technologies. We should adopt a scavenger mentality, familiarizing ourselves with various modes of fabrication, both low- and high-tech,” accepting and experimenting with materials, both old and new, to investigate how they mesh with human senses, because the senses are how we interact with a space. Structure houses these spaces and therefore those sensations.

In architecture, when we consider the spaces that structure creates, we tend to fall back to the sense of sight, as it can be difficult to imagine how spaces are to hear and touch, even though these are senses directly linked to spatiality and materiality. We gain understanding of spaces when we see materials and volumes, because of the association we have with those characteristics, but we forget to reflect on that fact. Part of the problem we have with sound is how difficult it is to design for, as its principles are not as intuitive as those of light, and they very much depend on the activity within that space. It is something that we used to understand, but have perhaps left behind because the human scale, which is so important in sonic design, has been overwhelmed by the technological aspect of building.
Our sonic interaction with space

Because of the forgotten nature of sound within our buildings, we have to build from the ground up on our understanding of the sensory nature of sound within manmade structures. The world we live in and create is filled with sound; some of it is termed noise, some music and some speech. What we name it is determined by the place in which we experience it and whether it is pleasant or not. But since we are constantly surrounded by sound, we try to ignore it, even if it affects us subconsciously; reducing our productivity and raising our heart rate if that sound is noise, or boosting our work rate and relaxing us if it is soothing music, as described by Julian Treasure. He points out that at work, listening to natural sounds or classical music calms us by drowning out the noises in the background. There is no way of turning off our hearing, unlike sight, where we can close our eyes to block out undesirable scenes. He achieves this through headphones and birdsong, but I would hope we can create it through architecture.

This world that we live in is full of soundscapes produced by us, both the noise we make and the physical spaces that contain that sound. Some of it has to do with the velocities we use to move about within that environment, such as the high speed of air, rail and road travel – each of which has its own volume. We also have our vocal movement through a building, talking to one another as we walk down a hall, or in an office, as well as the various different sounds that our work and recreation cause, such as jackhammering or concerts. This large amount of varied sound can lead to a layering up of sound to create what Murray Schafer calls Lo-Fi soundscapes – places with low signal to noise ratios which are effectively areas of high sound pollution. The opposite of this is a Hi-Fi soundscape, one within which each sound is clear and well defined. This problem of sound pollution is unique to spaces of human use, for we alone create so many different sounds at such a volume.

Material selection in our soundscapes

To achieve this Hi-Fi soundscape, we must kill off the other sounds we create. This can be achieved through various acoustic treatments – baffles, bass traps and soft furnishings and by avoiding parallel walls or domes, as well as the dreaded acoustic tile, a treatment despised by Steer Eiler Rasmussen. This effectively kills the aural spatiality that we would associate with the scale, proportion and materiality of that space. Here is where we see the true link between the sense of touch and our hearing, for if a space is made of glass, steel and concrete, we expect it to respond to our voice in a certain way, but if it doesn’t, what then? The removal of the aural link that we associate with materials, leaving them with visual and haptic properties means that spaces look different and feel different to touch, but sound exactly the same, time and time again. Murray Schafer coined the term schitzophonia when referring to this dislocation of sound from source and materiality, or Juhani Pallasmaa’s blunter term “our ears have been blinded.” This schizophrenia is something we have all experienced, but probably not consciously noted, when we arrive in reception halls or hotel ballrooms. This association between sound and spatiality is such that acoustic anechoic chambers, where there is no reflection of sound, no outside sound and no material correlation, makes people feel nauseous and unbalanced. This is the extreme end of the spectrum when it comes to sound damping within a space.

Much of what has been investigated about sound in architecture relates to concert halls and performance spaces, which must perform or be useless. These projects tend to have an acoustic consultant who manages the intricacies within the performance hall. We are sorely lacking in investigation of the more mundane spaces that we spend most our time inhabiting. Many of the buildings we create in our lifetimes will not be concert halls, nor will they have the budget or time to experiment and investigate on spatial and auditory effects, up until we promote the importance of sound in architecture, and try to understand the inflections our spaces create for the activities contained within.

The promotion of a greater awareness of your surroundings and listening to your materials, consciously, can however lead to a state of sensory overload or burnout. Michael Pollan puts it well when he talks about...
the ritual of preparing food and being made aware of every nuance of its preparation. “This is not the way I want to eat every day. I like to be able to open a can of stock and I like to talk about politics, or the movies at the dinner table sometimes, instead of food”. Sometimes we just need to be able to relax, and with our senses jangling all the time this can be very difficult, because of the spaces we put ourselves in.

So in reality, whilst I preach against the acoustic tile on a sensory level, we must still exist in the real world, where every space has not been designed correctly for its use, and because sound is such a subjective phenomenon, diversity is key. We need to be made aware of our surroundings, but at the same time, we choose to stray away from them more and more, in order to achieve our own personal soundscape, which only we have control over. This idea was introduced to me by Murray Schafer, who, forty years ago, analysed the headphone phenomenon, where we wear headphones, because we cannot truly experience the auditory realm and use the crutch of technology to buffer our senses. It is becoming common in our society to wear headphones in public places to avoid interaction with people and their surroundings, perhaps as a direct result of the noise we (as a society) create outside the mundane, bringing character to the places we occupy. Likewise, the listener, and also the inverse is also true. This has been recognised like sight, spaces sound different to the ear depending on the mood of the listener, and also the inverse is also true. This has been recognised and was the subject of an investigative paper in Sweden, where they analysed the emotions various commuters and walkers felt when in different auditory environments, with fear and security being among the emotions.

This diversity of space, and its effects, is something that has always interested me, and has been championed in the past by Paul Rudolph, who tasks a whole nation with its pursuit, telling us that “the variety, scope and spiritual demands of a great country can only be met by emphasizing the honest differences in each situation, not resorting to a packaged architecture”. Rudolph seems to refer more to the materiality and scale in architecture, but I am referring specifically to the auditory atmospheres of different spaces and the journey between them. Thom Mayne is also a champion of this culture of differences, telling us how “architecture is understood as a series of intimate engagements, as something experienced haptically, by operating or moving through it, rather than via an intellectual or visual conceptualisation.”

I would hope that this series of differences can become something outside the mundane, bringing character to the places we occupy. However, anything we design will become mundane, so should we control the spaces or should we allow for experimentation by the users to adapt the varied soundscapes within our buildings to prevent them stagnating. Due to market forces, however, experimentation within architecture in the field of soundscapes is discouraged and any attempt tends to be covered up with acoustic tile. I would hope for something that does not limit itself by the sensations experienced within it, but allows for changes to be made to suit the user’s preference. This allowance for change has a lot to do with my interest in structure. I believe that, in today’s world, we need to design for the function in a minimum way, as the use of the structure may change many times in generations to come, as each set of users will have their own sensory parameters.

Any acoustic treatment, be it active (headphones, baffles, acoustic tile) or passive (walls, ceilings, facades), intentional or not, creates an atmosphere which gives an infection to the velocity it contains, sometimes creating voids of sound or walls of noise within and without it. What is truly interesting is the interaction between these spaces – the act of moving from noisy to quiet, from what was perceived to be silent to even more still, busy road to quiet alley. The simple act of taking off headphones when walking into a park is intensely refreshing and calming. This is because sound is not a continuous, dependable sense like sight, spaces sound different to the ear depending on the mood of the listener, and also the inverse is also true. This has been recognised and was the subject of an investigative paper in Sweden, where they analysed the emotions various commuters and walkers felt when in different auditory environments, with fear and security being among the emotions.

This is not the way I want to eat every day. I like to be able to open a can of stock and I like to talk about politics, or the movies at the dinner table sometimes, instead of food”.

Any acoustic treatment, be it active (headphones, baffles, acoustic tile)

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21: Michael Pollan. The Omnivore’s Dilemma: The search for a perfect meal in a fast-food world. Pg. 411
22: Murray Schafer, The Soundscape. Pg. 122
23: Julian Treasure, It’s not Sound Health in 8 Steps. Accessed December 05, 2011
25: Paul Rudolph, Robert A.M Stern, Writings on Architecture. Pg. 90
26: Bernard Tschumi and Irene Chang, The State of Architecture at the Beginning of the 21st Century. Pg. 41
Afterthoughts

I don’t think we have adapted to the industrial and market led world we live in-as sensory beings. They both assign universal values to the daily world we live in, but because of our individual nature, we see them differently no matter how standardized they are, due to our own personal understandings of materials. If we follow the route we have been following up to now, we could end up in the Generic City that Rem Koolhaas proposes27, but that soulless urban fabric is something we should strive to eradicate by using unique, sensory spaces. Architecture must be pleasant and enjoyable, if we remove that, we build prisons.

We can take some steps when designing for pleasure and desire, as well as needs. We must remember that

“‘good’ macroscopic form always depends on microscopic processes. Taken together, I believe these postulates constitute an adequate set of axioms not only for the architectural question of form and influence but also for the more problematic contemporary question of form.”28

This is true of the material form of our building and the overall encapsulation of our structures, as well as the soundscapes these spaces contain. Each space should be designed from the smallest element up, and

“Thus, just as in viewing a single leaf it is possible to reconstruct the entire plant, and in viewing an animal bone, the animal itself, it is also possible to deduce the members of an architecture from the view of an architectural profile. Similarly, the nature of the finished construction can be derived from an architectural member.”29

So, in short, we need to design with a structural idea firmly in our mind, understanding what that means, and balanced with the tempering elements of beauty, material and sensory pleasure of the spaces that are our interaction with the structure.

27: Rem Koolhaas, Bruce Mau and Office for Metropolitan Architecture, S,M,L,XL. Pg. 1262
29: Sandaker, On Span and Space. Pg. 34
As I discussed in my thesis essay, structure has an extensive role in architecture. The ideas of global and local form, as well as soundscapes, have formed the core of my physical investigations. I initially chose the site of Shannon airport for the appealing contrast of soundscapes it contained—the volume of planes taking off and the quiet of the estuary—but became intrigued by the generic nature of the place. It is a prime example of a place created by market forces, where government tax initiatives, political decisions and market led building forces have contrived to make generic places, devoid of any uniqueness or sensual interest.

I am attempting to counteract this continuing slide into the mundane through a new program of an air cargo terminal and aircraft maintenance hangars. Shannon has a history of various industrial functions, many of which have faded with time and leave behind their ruins as market forces and lifestyles change. My structures will be created to house certain functions, but will have the ability to transcend market forces by being adaptable to various functions and hopefully by becoming a valued addition to the landscape because of their beauty and efficiency. This elegance of structure has been something I have tried to create with my explorations through model making, in plaster, mesh and card. These models have demonstrated spans, spaces, thinness and gracefulness.

These structures have developed from sound explorations into diffusion and concentration, and material studies in plaster. The eventual form taken was that of a shell structure. Shells reached their peak popularity in the '50s and '60s and fell out of favour, despite being some of the most elegant and efficient structures, containing majestic spaces. Many of the spaces we experience are boring and generic, something that shell structures are not, due to the diversity of different spaces they create within them and the sense of flow they generate. A shell’s ability to span large distances and house large functions makes it ideal in an airport setting, as they allow various sizes of inhabitation. In addition to that, when a shell becomes a grid shell, natural lighting becomes available everywhere within, depending on the covering material. I hope to utilize these structures to rejuvenate the site, giving it a character which will be sympathetic with the vast natures of the estuary and airport, and their various qualities.

My structures will house the complex programs of air cargo and aircraft maintenance, allowing for expansion and contraction of program within them, as well as allowing an interaction between the airside and landside elements of an airport.
Fig. 4

Shannon topographical model - showing runway and important airport buildings
Fig. 5
Shannon satellite Photograph - Current state of the airport and seaplane dock
Fig. 6
Photograph of the condemned area of Shannon airport. These buildings are parts of the original terminal, including the disused control tower.
This is a section of my proposed site.

Fig. 7
Another angle of the condemned terminal, showing the flood protection berms to the right.
Fig. 8
Panoramic photograph of Shannon airport and seaplane dock, taken from the dock edge, showing the airport in the estuary landscape.

Fig. 9
Panorama showing the new control tower, part of the public terminal and some of the runway.
Material Investigations

Fig. 10
Plaster models that investigate various sound phenomena, such as whispering gallery echoes, diffusion and point reflection, whilst introducing the idea of span.
Fig. 11
Combining the elements of space, span, shell and soundscape to create elegant structures.
Fig. 12
Compressed version of the folded plate examining its geometry and light qualities.

Fig. 13
Self supporting hyperparabolic shapes which carry their load in compression only.
Fig. 14
Flexible structure inspired by previous investigations into shells, but made with flat planes and hinges.

Fig. 15
Reconfigurable structure, whose span is completely dependant on the angle of the support strut. The permeable quality of the plate allows for interesting light qualities.
Fig. 16
Sydney Opera House by Jorn Utzon - Studying the various elements of the shells that make up its structure and the platform they sit on.
Fig. 17
Plaster of paris self supporting catenary arch, exploring the very pure form of arch.

Fig. 18
Side supported free spanning shell. However, the solid shell type is difficult to light.
Fig. 19
Various models with permeable qualities that still obey the necessary geometry of a shell structure.
Fig. 20
Cargo flow (areas not to scale)

Fig. 21
Cargo flow through storage areas (areas not to scale)
**Cargo Terminal**

**Apron**
- Reconfigurable aircraft parking, including unloading backlog space - 60,000m²
- Shelter for Ground Access Vehicles

**Terminal - Total** - 20,000 - 25,000 m²
- Cargo areas
  - Covered load/unload platforms - raised by 0.6m with ramps
  - Ball bearing floor for incoming and outgoing cargo areas (Airside only)
  - Pallet and container store - Must be adjacent to sorting area
  - Heated warehouse with automated racking- 8,000 m³
  - Strong room - 200 m²
  - Cooler room with Blast chillers and racking- 2500 m²
  - Freezer room with blast chillers and racking - 1500 m²
  - Lockers and changing rooms for staff - 200 m²
  - Breakroom and canteen - 300 m²
  - Central sorting area - 1 m² per 8 containers per day - 2500 m² minimum
  - Rapid air transfer between air goods in and air goods out

- Maintainence - 1000 m²
  - Forklift maintainence
  - Pallet and Container repair
  - General workshop area for non specialised repairs
  - Tool Store
  - Gas store

- Office Space - 1 m² per 18 m² of warehouse space
  - Records
  - Cargo airline administration offices
  - Goods out - Air
  - Goods out - Road
  - Goods in - Air
  - Goods In - Road
  - Customs
  - Training area
  - Conference/meeting rooms

**Aircraft Maintainence**

**Apron**
- Configurable Aircraft parking - 15,000m²
- Sheltered parking for plane tugs

**Hangar - Total** - 17,000 m²
- Main hangar floor - 7650 m² per plane
- Parts storage - 2000 m²
- Engine workshop - 1600 m²
- Avionics workshop and testing - 800 m²
- Machine Shop - 1000 m²
- Paint shop - 1500 m²

**Offices** - 1000 m²
- Meeting Rooms
- Hangar Floor Manager
- Parts officer
- Training rooms
- Medical and safety
Fig. 22
Series of shell structures redefining an edge along the berm of the Shannon estuary.
Fig. 23
Roof plan of buildings - showing site context and arrangement with respect to the seaplane dock and existing buildings.
Fig. 24  
Exploded perspective view of building - showing supporting structure underneath and gridshell and covering above, with the flood defense berm on the right. The three shells in the foreground are to house the cargo terminal and the two in the background are aircraft hangars.
Fig. 25
Landscape perspective render - showing the relation of the buildings to the estuary and the scale of human activities within that landscape.
Fig. 26
Long sectional elevation of one shell - showing geometry of the roof, gridshell lattice and support structure, and their relationship to the flood protection berm on the left and the runway apron on the right.
Detailed ground floor plan showing one of the shells functioning as an aircraft maintenance hangar. The plane is one of the central determinants for the size of the structure. The ground floor contains functions such as metal workshops, parts storage, painting facilities, avionics diagnostics and engine overhaul workshops. These are made up from walls fifteen meters apart with lighter in-fill between them. Circulation happens on both sides of the functions, allowing the hangar floor to remain as clear as possible.
Fig. 28
Perspective view between two shells - Looking out towards the estuary from the pedestrian ramp that connects back to the passenger terminal. These ramps continue along the riverside edges of the buildings.
Fig. 29
Short detailed section through one of the hangar shells - showing construction details and a view of the functions that go on in the hangar, with a backdrop of a plane’s bulk in the background.
Fig. 30
Connection detail of where the laths meet the support structure. We see the glazing frame, tubular, torsion resistant steel section and the connection from lath to steel, as well as gutter and closing details.

Fig. 31
Connection between laths within the gridshell structure. There is a double layer of laths laid out flat, then the structure is then raised and the outer layer slips past the inner layer. The steel plates are bolted in place after this, and give the whole structure rigidity.
Fig. 32
External view along the airport facing side of the cargo hub shells - looking towards the pedestrian ramp which connects the waterside to the terminal and also covers the cargo container conveyor.
Fig. 33
Internal rendering of a shell - showing the pedestrian walkways and the space created inside, which are bright enough for many different types of use because of the mixture of translucent and opaque roof coverings.
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