Introduction

This report will handle the Product, Process, and reflection of the graduation project designed in the LAB06 study of Architectural Engineering at the TU Delft. Important are the posed problem and the research questions. Further on, the method of solving these problem statement will be explained with text and pictures. The aim of this report is to create process and product information which can be used to prove design and engineering ideas. Another reason is the use of the research in my later career.

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Studio

Theme: Skins, Tension-Compression  
Design Mentor: Jan Engels  
Engineering Mentor: Tillmann Klein  
Title of the graduation project: Shell Structures, A study of the skin

Argumentation of choice of the studio, diversity you can look for at second hand bookshops. Inspiration can evolve from, just like all day live experiences and can be put into the E and A. The E is the technical part of me which I used to be normal for me at my HBO and TU Delft education. With Architecture a world opened to me, it is more then only a process. I wanted to learn more then only calculate the sound insulation of for example a façade. A well shaped process can result in innovation.
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1. **Product**

1.1 **Research area**

The definition of the problem must be clear, because in the further stage the design has to be made on an innovative level and the stated problem need to be solved. The Research area will be the starting point of elaborating the research questions:

The Skin of a shell structure is used a lot for roof structures, like domes and hypershells in de 60’s. Not very often the skin of the shell flows through the building and will create other transitions between interior and exterior. So the shell is not always a roof or only a thin enclosure. Skin and construction can be integrated or split up in a wider sense of perceiving the void. This means that area’s of the shell will be used for accommodation area’s, daylight transmission and walking lanes.

1.2 **Research questions**

When reading the problem statement, the most important questions arise. The context and the program are announcing themselves because they are leading in solving the stated questions.

Definition of a shell?

What kind of tension and compressive combinations are possible in shell structures?

In which way can the research area being used for the challenging principles of the design?

1.3 **Design Assignment**

The design assignment will be characterized by the technical and the architectural challenges. From the program and context of the building a shape will be designed. The challenge of the design will mean an appreciated building with a lot of qualities. A regular visitor of the designed object needs to understand some intentions of the designer of the building. An uninitiated must understand how the designed building is based on perceiving the skin of th shell.

1.4 **Goal**

The goal of the graduation project is in first to learn to combine the A(Architecture) and the E(Engineering) in an evenly balanced design. On the other side, it is important to present and write on an academic level. This means that efficient documentation and the presentation of the designed project need to be exciting and clear to understand. When the design is understandable developers are willing to work further with the designer and or researcher of this graduation project. Another intention of this graduation project is to document information, references and knowledge which can be used in my whole career.
2. **Process**

2.1 **Time span Research and Design**

The time span of the research and the design is based on a couple of steps in the process. The P1 to P5 are periods in the TU Delft schedule.

- **Research and design a shell structure**
  - Analyse research area
  - Define program and location
  - Design Principles and schemes
  - Research principles and schemes
  - Solutions
  - Design choice
  - Story
  - Final presentation

2.2 **Method description**

The method description, describes the techniques of the design process.

- **Research and design a shell structure**

  The first steps of exploring the theme - Shell structures - is realized by the design of a small pavilion - P1. Methods used are precedents, matrices and calculations.

- **Analyse research area**

  After this small design the problem field will be analyzed, with precedents and literature.

- **Define program and location**

  Another vital part of the P2 is the idea of a larger program and a location for the design. Methods which are being used are a location observation and collect inspiring photos.

- **Design Principles and schemes**

  This part is a creative process. By making models and make sketches, the design idea’s can be defined.

- **Research principles**

  This is the elaboration of the Problem area. In the section research, the research questions are being researched. By use of literature, matrices and calculations the design challenges must be proven.

- **Solutions**

  By research and designing, sketches and model making, solutions can be found. There are a couple of solutions in which a choice can be made.

- **Story**

  The solutions tell the story of the design and the research process.
3. **Research**

3.1 **Definition of a shell?**

The definition of a shell is split up in sub questions.

**What is the classic definition of a shell?**

The egg is probably one of the most familiar example of a shell. The skin is a monocoque structure. This means that the load bearing construction is formed by the shell, without any internal strengthening.

**How can a shell in my view be defined?**

In first, my interpretation is a very thin membrane. This will mean that the properties of a shell are the same referenced to a standard fabric membrane.

The question which arises is: are there differences?

A shell can transmit compression forces by use of filling material. This is a difference with traditional tent skins with arches, these have a woven skin without a filler. This results in a skin which only can transfer tension forces.

However, through the years a lot of combinations, with filler and woven fabric are developed. The first shell structures with a fabric are the dome with a woven skin of steel and concrete as a filler.

Concluding, a shell can be influenced by substructures. The discussion between how much it differs from a classic shell with all combinations of compression and tension elements in between will be researched in the next paragraphs.
3.2 What kind of tension and compressive combinations are possible in shell structures?

Analogies

Straight thin tension members are deformed by a compressive load or out of plane forces. This change in geometry can resist compressive loads. Conventional beams are formed enough to resist tension, compression and out of plane forces. In curved planes there are anticlastic forms and synclastic forms. The synclastic form can be found in shells, pressurized skins. Anticlastic forms are essential for not hardened skins, otherwise the skin cannot resist varying loads. An Egg shell can transmit evenly distributed forces very well. Because the very thin skin has curvature and pure membrane tension.

After the basics of the tension and compression forces, the next sub question evolves.

How can skins of shells being categorized?

The skins of the analyse are categorized by 4 themes. Each theme has examples of architects which were active on that theme. Beneath the four themes with a couple of architects and precedents are given:

**Monocoque skins**

Felix candela, Gaudi

**Hardened skins with sub structure**

Foster, Sydney Opera, Udson, Tie beam. Rolex Building, Sanaa

**Not hardened skins with sub structure**

ETFE cushions

Tent with arches, munchen, Frei Otto

**Pressurized skins**

Pneu, Cutty sark enclosure. Nicolas Grimshaw, Foster+Partners

Vacuum

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2 Müller, R., Zum Werk von Felix Candela: Die kunst der leichten Schalen (Köln 1992) 50.
Bini Shells

An example for monocoque skins are Bini Shells. Monocoque means that the skin is loadbearing without internal strengthening. Methods to make this shells is accomplished by a wood ribbed formwork or a pneumatic formingsystem. For getting other shapes, netmembranes of rebar are put in for internal strengthening of the skin. However internal strengthening is applied, but the skin acts as a loadbearing form with a monocoque expression.

Semimonocoque

Semimonocoque skins are defined by a skin which shares the load with a structure. An example is the Silvertop House designed by John Lautner. The roof is equipped with beams which in combination with the reinforced concrete skin bear the loads.

Forces

For the compression elements this means that the curvature of the shells are necessary to get the maximum out of the loadbearing capacity of the concrete. Just like Gaudi Explored the catenary of arches to get only pure compressive forces in the skin. For ‘spat’ tensional forces a tensional ring with rebar can be added or in the old fashioned way with mass of butresses.

For anticlastic curvature and tensional ring forces rebar will be added, because by anticlastic curvature the arch is ‘hanging’ and not standing and working as an arch.
**MONOCOQUE SKINS**

**Picture 7.** Forces in a dome.

**Picture 8.** Arch forces, catenary line
Shell structures. A study of the skin.

Picture 9. Cafe Los Manantiales monocoque, designed by Felix Candela.

Picture 10. Casa Batllo catenary, designed by Gaudi.

Picture 11. Exterior of Casa Batllo, designed by Gaudi.

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Hardened skins with sub structure are characterized by a sub structure which almost completely bear the load. The hardened skin is applied as a secondary load bearing structure. The sportpalace for the Olympic games in Mexico 1968 is designed by Enrique Castaneda, Antonio Peiri and engineered by Felix Candela. The segments are made of a Hyper Grid Shell [HP] with a triodetic truss system.

Sydney Opera House

The primary structure of the Sydney Opera House consists of triangulated prestressed concrete ribs, which are leaning against the arch unit: see Picture 16. Different segments can make the steep shell shape. When this basic sub structure is erected the hardened skin could be applied.
Picture 15. Six legged side shell arch unit

Picture 16. Triangular rib segments placed against legged side shell arch unit

Picture 17. Pattern of tiles.

Picture 18. Triangular hollow segments

Picture 19. Hard skin
Adaptibility & Flexibility

San Diego Convention Center
by Arthur Erickson, 1989.

The roof is covered with ETFE. This membrane covers a large area without structural elements. Translucent fabric is used for the bright public hall. The repetitive arrays of membranes allow for careful control of the scale of the overall system. This is a ridge-and-valley system.

Space under overhang is suitable for exposition. Fabric influences the lightflow. The modules are interesting, because of the adaptable and flexible structure.

Ridge and valley, Denver Airport

The longitudinal edge has a relatively small curvature. This is essential for the expandibility of the roof with the ridge and valley system.

A lower span profile reduces the climatic amount of air, wind load and skin area. However, by use of a lower profile there are higher stress which need more mass, such as buttresses, in case of this precedent.
NOT HARDENED SKINS WITH SUB STRUCTURE

Pressure and compression elements [San Diego Convention Centre].

Picture 25. Tension and compression elements of the exterior.

Picture 26. Tension and compression elements of the interior.

Picture 27. Tension and compression elements of the interior.
Shell structures, A study of the skin

Arch Structures - Research Laboratory

Arch structures can be put on hinges. The construction can be unfolded. Not hardened skins with arches can easily be expanded. The use of arches can reduce the tensile force needed for a stable structure in relation with suspended skins, like the San Diego Convention Center.

Suspended skins - Dynamic Earth

Dynamic Earth designed by Hopkins and is characterized by a suspended membrane. In the interior, a little amount of compression bars are needed. This could be an advantage for flexibility and slender posts.

Suspended skin - Art Centre New York

The skin of ‘the leaf’ is suspended by a tension ring and pulling portals on the outside of the triangular shape. The Roof can be seen as a dynamic enclosure. The floors with the columns are a rigid system.

Forces-consequences design

Long masts, arches, or other compression members are prone to buckling and require large and heavy cross sections in order to achieve adequate capacity. Another aspect of Arch structures and suspended skins is the curvature which is needed for lower stress levels. However a higher top means, increase in wind load, a larger skin area and a larger amount of air which needs to be warmed.

NOT HARDENED SKINS WITH SUB STRUCTURE
Pressure and compression elements

Picture 30. Dynamic earth, Hopkins

Picture 31. The Leaf - Kunstcentrum VS, Serge Schoemaker.

Picture 32. Dynamic earth, Hopkins

Picture 33. Principal of skin system.
Not hardend skins with sub structure

Insulated translucent membrane

Renewal of the suspended ceiling at the Olympic swimming facility in Munich, 2007

Acrylic glass skin is used for the outer membrane. A thermal envelope is needed with insulated suspended membrane ceilings.

Accomplished in 1972 for the Olympics by Frei Otto and Behnisch+Partner. The inner membrane is made of PVC-coated polyester fabric suspended by an exterior cable net.

A transverse bridge has been installed to make it possible to reach the second apex.

The Nadirs, taking care of up going loads, generated by the suspension of the skin.

11. Inner suspended membrane roof: structural layer polyester fabric, PVC coating translucent (the whiteness in the ceiling)
12. 2X35mm polyester insulating fleece, translucent with staggered seams, air flow, [with can stand temperatures above 100 degrees and foot traffic]
13. ETFE foil sealing layer, transparent.

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Pressure and compression elements.

The roof of the Olympic Swimming facility is suspended by two large compression masts [appexes]. The skin is split up in a watertight layer on top and an insulating layer beneath. The top layer of the skin is hung up by steel strings on the two appexes.
### NOT HARDENED SKINS WITH SUB STRUCTURE

<table>
<thead>
<tr>
<th>High point structures</th>
<th>Ridge and valley structures</th>
<th>Arch structures</th>
<th>Large pillow structures</th>
<th>Half structures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supported along lines</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Supported at points</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Picture 41.** Forms of not hardened skins
Energy membranes

<table>
<thead>
<tr>
<th>Material</th>
<th>J / g K</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>4.18</td>
</tr>
<tr>
<td>Aluminum</td>
<td>0.89</td>
</tr>
<tr>
<td>Brick</td>
<td>0.84</td>
</tr>
<tr>
<td>Concrete</td>
<td>0.88</td>
</tr>
<tr>
<td>Glass</td>
<td>0.7 - 0.8</td>
</tr>
<tr>
<td>Gypsum</td>
<td>1.09</td>
</tr>
<tr>
<td>Wood</td>
<td>0.42</td>
</tr>
<tr>
<td>Paraffin PCM</td>
<td>2.1</td>
</tr>
<tr>
<td>Salt Hydrate PCM</td>
<td>2.5</td>
</tr>
</tbody>
</table>

Flexible PV cells based on thin amorphous silicone. The PV cells can be applied to a structural membrane fabric.

Phase changing materials can improve the heat capacity of a membrane. The PCM also affects the translucency of the membrane.

Flexible PV cells.

Rotating umbrellas, Designed by Werner Sobek. Centrifugal forces opens the spokeless fabric umbrella.

Picture 42. Heat capacity of PCM and building materials at room temperature.

Picture 43. Affects on indoor temperature by use of a PCM/rubber coated membrane.

Picture 44. The phase change also affects the translucency of the membrane.

Picture 45. Rotating umbrellas.
PRESSURIZED SKINS

Fire and weight properties membrane

Watercube, Beijing, PTW architects

The structure of this swimming pool for the Olympic games 2008, is constructed with the geometry of soap bubbles. With this polyhedrons the three dimensional space is occupied in the most efficient way possible.¹

The ETFE (Teflon) used for the skin, weighs just 1% of glass and is a better thermal insulator. ETFE is translucent and flexible.² ETFE only melts, it does not burn. The fluoride is responsible for the reason ETFE won't burn.

Climate

Under the roof, the temperature gets 50 degrees on a warm day. The Double skin is ventilated in summer to get rid of the warm air. The building is split up in inflated zones, air is sended by sensors which measure the internal pressure of the cushions. Vans can be put on or off, with a covering range of 100,000 m² inflated ETFE cushions. With the daylight transmission, the lighting bill is reduced. The Greenhouse effect can be used in winter. The printed silver dots reflect sun radiation but let daylight in. The amount of printed dots is varied by the different sun radiation levels around the building. Three and four layered ETFE Cushions are used because of the need to have a lower thermal transmission. The rainwater is used to refill the swimming pools.

About 20% of the solar energy is trapped and is used for heating of the building and swimming pool. The roof can span more than 100 meter with a height of 7.20 meter. The polyhedra structure needs about 30 percent less steel than a conventional beam and column system. The cushions are used for entertainment by lighting them with LED’s.

4 Detail 2007-12.

Pressure and compression elements.

The polyhedra structure takes care of the more ‘conventional’ load transmission which are present in the steel as tension and compression forces. This can be seen as a spatial truss system, with pressure and tension tubes. Hower the skin is a special element, because the shape is synclastic. This achieved by an internal pressure in the ETFE cushions. The Skin of the ETFE is loaded onder tensional forces.
Light weight

**Eden Project, Grimshaw and partners**

The project consists of intersecting geodesic domes. The lightweight structure is necessary because the load bearing capacity of the soil is low. The botanical garden is used for trees and plants of three different climatic zones. Inflated air cushions are placed on a primary load bearing structure of steel. The overall weight of the construction is lower than that of the enclosed air.

![Diagram of Eden Project](image)

**Picture 51. Interior of Eden Project with the roof detail**
PRESSURIZED SKINS

Open/close

The skin consists of two layers, the outer layer with a hexagonal structure. The inner with a hexagonal and triangular construction. Only the openings in the outer skin are divided into triangulars.
Skin

Werner Sobek, Facade en vacuum structures, Vacuumized skin

Pressurized skins

Sensor controlled vacuum, because of transmitting external loads, such as wind

2 skins

Structural frame - Primary structure

Vacuum

-Teflon coated glass fibre - fabric
-Translucent insulation
-Stainless steel-net - I-beam
-Mechanical louvres
-Stainless steel-net - PVC coated polyester membrane

Translucent membrane

Translucent [Sobek]

Polyethylene has an light transmission coefficient of approximate 82%.

Picture 54. Vacuumized frame.

Picture 55. Vacuumized facade.

Picture 56. Licht transmission of different materials.

Picture 57. Licht transmission of different materials.
Vacuum realization

Vacuum storagebag

Vacuum in a storage can be created by putting an vacuum cleaner on the valve which opens. When the vacuum in the bag is higher than the power of the vacuum cleaner, the closing plate will drop and close of the valve.

Structural use

The examples on both pages, are more experimental and not always safe enough against fire protection and collapsing.

Thermal behavior

Conduction and convection is low, because of the vacuum there is an absence of air and this means no medium. Radiation reduction by silvering the glass, on the two internal faces. Radiant heat waves are reflected.¹

¹ Reflectixinc.com, 25-05-2011
Tensairity

The name tensairity is a combination of tension, air and integrity. The relationship with tensegrity - combination of cables and struts purely loaded in tension and compression - is made clear by the description that Tensairity is Tensegrity plus air.

Structural use

The tensairity consists of a compression member, tension member and when necessary a tension net. With this three structural elements, the pressure can be lowered because the tension can partially be carried by these three elements or with the same air pressure the tension and compression can be raised. This means a higher load possibility.

Picture 61. Exhibition Centre Villa Erba, Como Italy

Picture 62. Tensairity Element.

The tensairity consists of a compression member, tension member and when necessary a tension net. With this three structural elements, the pressure can be lowered because the tension can partially be carried by these three elements or with the same air pressure the tension and compression can be raised. This means a higher load possibility.

Picture 63. Section of a tensairity element.
PRESSURIZED SKINS

Imagine - Vacuumized bridge

The vacuumized bridge is filled with balls, which are vacuumized to get an arch shape. On the field of forces, the vacuum force must be higher than the tensional force created by loading the vacuumized bridge, otherwise the filling material will lose cohesion and collapse. There is a complete development stage needed for creating the bridge.

Picture 64. Development stage.

Picture 65. Mechanical equations based on vacuum pressure.
Deployable skin

This deployable bridge can erect by air pressure. It is a flexible construction, suitable for multiple purposes such as temporary bridges.

Deployable skin

**Bidirectional post tensioning of air inflated shell**

Post tensioned cables are placed on both sides of the membranes by an anticlastic shell shape. Single curved shells have post tensioned cables placed on the internal side of the curved shell.\(^1\)

The red dot direction tensions the upper cables. When the blue dot direction is being pulled, the cables in the bottom layer are tensioned.

The self erecting procedure of a single curved shell on the right figure shows the advantage of deployable skins, because the modular air cushions can be placed in an initial position.

Multi hypar modules. With one single module with a repeating array of modules can be adapted. Here by, a program can be made flexible and adaptable just like the Denver Airport membrane moduled roof.

\(^1\) Tarczewski, R. Textile composites and inflatable structures, 224
**PRESSURIZED SKINS**

Reinforced membrane

Frank Huijben, *Bending of a vacuumized beam with rebar*

The beam is filled with granulate. Picture 70 shows the load bearing behavior of a beam with varying vacuum pressure. A higher vacuum means according to this graph a higher load bearing capacity.

On Picture 72 rebar materials are applied ST[Steelmesh], PP[polypropyleen], TX[textile] and no rebar.

![Picture 70. Force-displacement diagram with varying vacuum pressure.](image)

![Picture 72. Force-displacement diagram with varying vacuum pressure and materials.](image)

Steelmesh can bear much higher loads than without any form of rebar. The cohesion of steelmesh to the granulate is better than the other rebar materials. This means a higher resistance against loading. This research of Frank Huijben focuses on vacuum molds and shaping of concrete forms with this knowledge.
**PRESSURIZED SKINS**

**Lighted membrane**

The Allianz Arena Munich is designed on visibility of the club colors by lighting the ETFE membrane. Visually the printing amount is varied on the skin, which can be seen through furniture from the exterior or interior.

![Lighted membrane](image1)

**Varied printing on ETFE skin - view through membrane**

Light box, with standard three-strip fluorescent light in conjunction with a perspex cover panel, which functions as a colour filter.

**OWL Enclosure**

This skin is completely inflatable by use of arches and radial tubes. The OWL enclosure could be used for a telescope enclosure.

![OWL Enclosure](image2)

Picture 73. Allianz Arena.

Picture 74. OWL enclosure.
3.3 In which way can the research area being used for the challenging principles of the design?

Design

- Walking area’s
- Accommodation area’s
- Zones (Skin and construction, thin or wide shell and openings)
- Interlocking

Engineering

- Material
- Climate[Building physics]
- Daylight
- Structural system

In the chapter Design and Engineering will this themes being elaborated. This chapter will give answer for the stated research question of this paragraph. After this chapter the conclusion and evaluation on the research area will be made.
4. **Design & Engineering**

**Brainstorm**

In first a program and a location is being explored, with it's possibilities. The first starting points are the Olympic Summer Games in Amsterdam 2028 and a functional description. The purpose of this starting point is to narrow the search area of creating a concept.

**Functional description**

The designed building is based on a program for the Olympic Summer Games in 2028. The theme of the program is communication. The function will inherit a press centre for receiving athletes and important delegates. Visitors can anchor their boats at the pier. It is a public communication place in the surrounding environment.

---

**Context(place), active pier**

![Picture 75. 1. Fine lines and massive objects](image1)

![Picture 76. 2. Walking line, movement](image2)

![Picture 77. 1. Design Area, NDSM werf in Amsterdam](image3)
In the form, architectonic expression and (possible) material elaboration of the program

Picture 78. Delicacy and massive

Picture 79. The object stays readable

Picture 80. Form activity

Picture 81. Form changeability

Picture 82. Iconic

Picture 83. Traditional system, innovative

Picture 84. Fine lines and massive objects
Use and experience value of the program

What is temporary and what’s not?

Program can be maintained on a longer timespan, just like the watercube. The appreciation and the quality of the program are leading in this.
Program

Study of the program. What does dit mean for my point of departure?

Compact version

• Organisation around the courtyard
• Low volumes, profile
• Differences in daylight

Long version

• Distances increase between functions
• Length of the pier will be complete used for daylight and view

Central version

• Strict division between the functions
• The central point is the guide.

Cluster version

• Functions can be reached in steps

Stacked version

• By stacking the building will be compact
Design Choice - Interpret, Solutions, Story

Program with functions

The next list of functions is required for a working press centre:

- Main Conference/press room
- Small Press conference room
- Foyer
- Meeting rooms
- Private offices [press workroom]
- Catering, food, restaurant, cafe
- Results Printing & Distribution
- Translation Area & Editing Area
- Press Chief’s Office & Press Operations Common area
- Rate Card reception Area
- Security room
- VIP Lounge
- Administration area
- Entrance Lobby
- VIP bar

The external facets on Picture 89 give a view on the activities around the press centre.

Picture 89. External facets of the press centre.
The visitor and media

In the year 2028, it is useful to compose a view of the visitor of that day. But how can you create that picture? What can be the interest then? Which type of visitor can be expected? It is very difficult to define a good picture of a visitor, but there are aspects which are important for the press centre:

- Urban population
- Revenue[Opbrengsten] from Broadcasting.
- Mondiale en olympische trends

In short this could influence the visitor on social media, live media and social trends, such as a growing urban population.

For instance in Athens 2004, it was allowed to spread digital video recordings by the internet for the first time.1 This is a development on the live media, which could be in 2028 of an even more sophisticated trend. Visitors at this moment would use tablets to communicate much quicker.

1 Olympisch vuur, NL Architects, 93.
## Features Main Press Centre & International Broadcast Centre, London 2012

This press centre will be used as a media hub which is used 24 hours a day. 20000 broadcasters, photographers and journalists will use this facility. Worldwide four billion people are reached by this press and broadcast centre.

<table>
<thead>
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<th></th>
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<td>55000</td>
</tr>
<tr>
<td>Persons</td>
<td>5600 Journalists</td>
<td>80000</td>
</tr>
<tr>
<td>20000, reporters, photographers, broadcasters and support staff</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Catering village</td>
<td>50000 meals every 24 hours</td>
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<tr>
<td>200m high street, hairdressing salon, post office, general store, bank, ATMs and a bar.</td>
<td></td>
<td></td>
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<tr>
<td>Environment</td>
<td>Green building standards in legacy include a 2,500sq m ‘brown roof’ of gravel and moss to encourage invertebrates. This matches an aim to collect 60 percent of non-drinking water across the Olympic Park, which can then be reused in a number of ways, such as for flushing toilets.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>State-of-the-art utilities, power and digital connectivity.</td>
<td></td>
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<tr>
<td>Print facility [MPC] next to Broadcast counterpart – the 55000 m² international Broadcast Centre [IBC]</td>
<td></td>
<td></td>
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<tr>
<td>After Olympic Games</td>
<td>Business space, potential for generating new employment opportunities</td>
<td></td>
</tr>
</tbody>
</table>

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Picture 93. IBC and MPC London 2012.

An aerial view showing the temporary elements of the IBC/MPC.


Picture 95. IBC and MPC London 2012.
Study Presscentre

Context

To activate the area of the pier with the press centre, the NDSM werf needs to accommodate functions. On Picture 97 this masterplan is elaborated.

Estimated scale

Inventarization of the MPC/IBC London 2012 presents a presscentre with a very large scale. This program is based on quantity. This will not be the aim of this press centre: it is an exclusive press centre. The quantity will be realized on another place. The expression of the press centre needs to be reminded in the urban environment.

Picture 96. Surrounding of the NDSM werf today.
Picture 97. Masterplan NDSM Werf at the olympic games 2028.
Design proces-zones

The point of departure for the program is the Central organisation, with stacking of functions and not to longitudinal design.

Reference for stacking and use of the shell as a landscape is Metropol Parasol in Sevilla. This raised plaza with an archaeology museum, acts as a sort of landscape with different zones, in the leveled program. The lower space can be used for concerts, and the higher landscape can be walked on with functions in the curved skin. The medium between this two zones are the tubes of the curved structure. In abstract their are bubbles placed in between the curved skins.

The Olympia Swimhalle however doesn’t have zones with an stacked curved landscape. The curves can only visible being experienced.

The Rolex Building in Lausanne designed by SANAA can physical being experienced. You can run under the curved floor of the building and run on and use this curved concrete floor.

So there are physical and visible zone, this will be an import topic in the design of the press centre.

Picture 100. Parasol Sevilla.
Three worlds or layers

The first idea’s started with a selection in special functions of the press centre. These are: the restaurant and cafe[visitors], press rooms, Restaurant and cafe[Offices].

With this knowledge a ‘party’ in the program needs to be designed. The idea to create three worlds evolved: the work world, the move world and the experience world. This is achieved by a vertical stacking of functions.

Special functions

- VIP Lounge
- Restaurant & cafe
- Main Press Room
- Press entrance lobby
- Rate card reception
- Admin area
- Security room
- Offices
- Translation & editing area
- Print facility
- Meeting room
- VIP lounge
- Press chief
- Multifunctionele ruimten

Picture 101. Special functions in the plans.

Picture 102. Section through the three worlds.

Picture 103. Special functions in a scheme.

Picture 104. Section through the idea.
Form search

The ‘party’ of the first ideas is being put in a 3D model. However it is only a form study. Concluding, this form doesn’t work for the press centre.

Picture 105. Formstudy, ‘party’
Web-weefsel

To get more design ideas, ingredients are searched in the field of webs. Each picture is described by an essence.

Picture 106. Sagging.

Picture 107. Multiple.

Picture 108. Contrast, light and dark.


Picture 110. Layered.

Picture 111. Thick and thin elements.
Precedents-layered

For examples of layered programs, a couple of buildings are given on the images beneath. The Sendai Multi Media Library designed by Toyo Ito consists of woven vertical traffic tubes. This can be seen as horizontal layering. The Tubes are the “filling” and the floor areas are the voids. This use of zones is horizontal. In the design this will be vertical. The Rolex building is an example of vertical zone transitions because you can run under the building and go up by use of the curved concrete floors. So the movement in zones is vertical.

The Mercedes Benz Museum is also an example of transition between zones. The exhibition floors run through the building as a vertical spiral. For the design process this will be kept in mind for designing zones in the press centre.
Webmodel

The section of the press centre tells the story. The web skins are all family of each other. However the middle shell is made more massive and can transfer compression. This is the move world. The experience world on top is made of multiple network skins and is loaded in tension. This skin is thinner and is visible lighter by more daylight and transparency. The work world is a hanger with only tension.

A model is being made to experience the study object.

Interlocking

The idea of interlocking evolved by drawing Picture 117. The idea of interlocking is that it is possible to move between one world to another world by passing through the skin of the enclosing world.
Picture 118. Study model. 3 worlds
**Space Age-theme**

The last model study, is based on the Space Age. The model looks like an ufo with 2 shells above eachother. However this is not the right research theme. The theme deals with the free and the restrained. This is too much restrained and too little freedom.
Program en routing

The program consist of 5 layers. There are 3 filled shells and 2 voids between these filled shells. The idea of filling shells is based on the principle of a standard building with floors. Each floor in this design is filled with bubbles with functions of the program. Depending on the scale of each function the skin bubbles more or less. Picture 127 shows the principle of ‘filling’ the floors.
Section

The get an design idea about the program. The functions are drawn in a section with ideas about routing, daylight position and layering and scale of the functions in the shells. The force of this design idea lies in the intersecting stairs and rooms. With the adding of bubbles the shells are vormed. The ‘gray’ space inbetween is designed and so can the world between it being created.

Picture 128. Drawing of the longitudinal section, with functions.
Plans

With the filling of the floors in the section. A plan can be drawn for the horizontal layering. The plans and the sections are leading in the realization of the curved shell skin.

Picture 129. The three worlds.

Picture 130. Functions in the 3 shells.
Free and Restrained

Another aspect is the relation between free and restrained. On Picture 132, the schemes of free and restrained options for the design are given. An important question is, which scheme approaches my dream the closest? The coloured scheme is chosen because the silhouette of the shells must be engraved in the memory of the person who sees the exterior. This means that the free must be dominant and the restrained inferior.

Picture 131. Googie pharmacy, John Lautner. Free and restrained

Picture 132. Choice in free and restrained.

Picture 134. Gulliver

Picture 136. The Jetsons

Picture 133. LA Airport
Structure

How is the relationship between free and restrained?

The 3 shells must express themselves freely. The load bearing system is restrained. Picture 139 shows that the restrained does not participate with the free. This is the starting point of designing the free and the restrained structure.

Picture 137. Silhouet exterior leading.

Picture 138. Fall over, columns participate in free form.

Picture 139. Shells, hover thorough thin "Small columns" which does not participate in free.

Picture 140. Stable, participate with free form.

Picture 141. Atomium Brussels.
Layered system

Two principles of the load bearing layered structure are drawn. The principle of choices is the scheme with the shell as secondary load bearing structure. The columns and floors are the primary load bearing structure.

\[
\text{Vloeren} \quad \text{Schaal primaire draagconstructie} \quad \text{Kolommen}
\]

\[
\text{Schaal secundaire draagconstructie, lichter, opener}
\]

\[
\text{Kolommen} \quad \text{Vloeren} \quad \text{Schaal secundaire draagconstructie}
\]
Design Models.

A couple of models are made to research the curvature in the skin by making: single, double and freeformed models. The freeformed model is the theme which is used for the designed press centre. By use of sections [profiles], the system lines can be determined. This is essential for creating the freeformed model and the orthogonal systems. The orthogonal system exists of floorheight, columnposition and floordimensions. On page 66 calculations are made of the floor dimension and the maximum span of a beam in the press centre. Finally a presentation impression is given on Picture 148.
Picture 144. Single curved model.
Picture 145. Freeformed model.
Picture 146. Freeformed model based on sections
Calculations

Global estimations

Floors Kanaalplaatsvloer

Span max = 10m. Height is 320mm, table vbi

Hoedligger THQ. Maximale moment, dwarskracht en deformation.

$q_{oad}[kN/m^2]$

$P_{budded deck} = 4,41 kN/m^2$

$P_{finishing} = 1,2 kN/m^2$

$P_{intermittent duty} = 1,75 kN/m^2$

$I_{center to center} = 10,0 m^2$.

$q_{oad}[kN/m^2]=10,0*(4,41+1,2+1,75)=73,6$

$M_{max}[kNm] = 1/8*q*l^2$

$M_{max}[kNm] = 1/8*73,6*9^2=745,2 kNm<1483 dus voldoet$

$V_{max}[kN] = 1/2*q*l$

$V_{max}[kN] = 1/2*73,6*12=441,6 kN<1050 dus voldoet$

$U_{max} = 0,004*l$

$U_{max}[mm] = 0,004*9=36mm$

$U_{pq}[mm] = (-5*73,6*9)/(384E1)$

$U_{pq}[mm] = (-5*73,6*9)/(384*2,1*10^6)=47mm>36 dus voldoet niet.$

Profiel opdikken onderzijde.

$U_{pq}[mm] = (-5*73,6*9)/(384*2,1*10^6)=47mm>36 dus voldoet niet.$

$I_{[m^4]} must be 0,0009 m^4$.

$I= Ae^2$

\[ \text{Picture 147. Beam and floor calculations.} \]
Picture 148. Final design, impression of the Press Centre.
5. Conclusion

The research area is split up in three main questions:

- Definition of a shell?

A shell is a monocoque structure. The loadbearing construction is formed by the shell, without any internal strenghtening. A shell can be influenced by substructures. The discussion between how much it differs from a classic shell is depended of all combinations of compression and tension elements in between.

- What kind of tension and compressive combinations are possible in shell structures?

By analysing precedents, the tension and compressive combinations of shell structures can be categorized in 4 themes:

  - Monoocoque skins
  - Hardened skins with sub structure
  - Not hardened skins with sub structure
  - Pressurized skins

- In which way can the research area being used for the challenging principles of the design?

Multiple shells in a layered floor system, creates a flow of the skin through the press centre. By use of two skin systems there become other transitions between interior and exterior. The spiral stairs makes interlocking connections between different zones in the press centre. The void can be perceived. Use of the curved skin in the interior, creates a variable distance between skin and construction. [floor and skin with a small distance can be integrated in one layer.

The research area will be present in the design by applying these facets.
6. Evaluation

The process of getting a bright picture of the research area, could be accomplished. It is possible to get more out of the interlocking concept by designing more holes in the skin and other transitions between zones. However the time span does not take care of more complexity. A further study on parametering the many variable distances between the floors, skin and construction, Could further optimize the voids, however the expression of the skin could negative being influenced. Finally the expression of the designed shells and the idea’s about the research area are realized by the design of the press centre for the Olympic Summer Games in Amsterdam 2028.
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