Natrix, Barrier of Silence

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NATRIX, BARRIER OF SILENCE

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ABSTRACT: Schiphol requires a new sound barrier to reduce the noise nuisance in the neighbouring city Hoofddorp. A design is made using a water film as the sound barrier and air as the supporting medium. The 1800m pneumatic structure with a double skin has a strong and sustainable interaction with its function.

1 SUMMARY

Occupants of Hoofddorp in the Netherlands experienced for many years noise nuisance from the low frequent sound produced by planes during their start. In 2008 Airport Schiphol has written out an international design contest for a sound barrier.

Natrix symbolizes the particular Dutch relation between land and water. The noise barrier is a fluent arc of water carried by air referring to the supporting medium of airplanes. The barrier also houses world's centre of international developments in the field of water management and biotechnology, a combination of durable, energy-awareness and innovative thinking.

The 1800m long Natrix has the shape of a snake, built-up with an inner and outer skin pneumatically stressed and supported by pneumatic air arches. The inner membrane supports over the full area a thin layer of water that serves as mass necessary for the sound insulation. Also the water that is circulated in the skin, absorbs sun energy making the Natrix a large energy collector.

In section the round shape is a fluent external form with very restrictive turbulence and a high degree of laminar wind flow. This is of high importance located next to a runway.

The external ETFE skin is supported by a cable net with a varying grid pattern to change its absorbing frequency along the length of the runway according to the change of sound frequencies of an airplane during its take off.

The pneumatic build-up of the structure will result in an external membrane that will deform by wind loading, while the internal membrane hardly moves. The dynamic behaviour of the external membrane towards wind loading will result in low impact forces.

All parts are prefabricated and, because of the lightweight and flexible material, easily transported and erected within a short amount of time. After its lifetime it's quickly demolished, most parts can be reused and no soil pollution will remain.

Lighting the inner skin from within the cleft creates a 3-dimensional façade glowing at night, welcoming and saying goodbye to all travellers.

Keywords: lightweight structures, membrane structure, pneumatic structures, dynamics, sound barrier, water shield, Schiphol, Polderbaan.

2 INTRODUCTION

Below sea level, in the reclaimed land of the Haarlemmermeerpolder lies Schiphol Amsterdam Airport. Within this polder, Schiphol wants to develop an international hub of water management and sustainability. It should become one of the most innovative and sustainable airports in the world.

The most striking characteristic of this area will be a new sound barrier parallel to the Polder runway, one of the 5 runways of Schiphol. The barrier must present an innovative solution for the complex problem of ground noise in Hoofddorp-Noord produced by aircraft taking off from the runway. The aim of the project is to achieve a reduction in ground noise of at least 7 decibels.

The second best rewarded design called Natrix received an honourable mention. This design for the Barrier of silence is described in this paper.

Figure 1. 3D–visualization ground level.

Figure 2. 3D–visualization birds eye.

3 ARCHITECTURE

The Netherlands is a country of polders, a country that mainly lies under sea level. The runway so called ‘Polderbaan’ is located in the Haarlemmermeerpolder, 4m beneath sea level.

Natrix symbolizes this relation between country and water. It is a sound barrier created with a fluent arc of water, which sticks out far above the ground level and claims back the unevenness with the sea level. The arc of water is carried by air. This is a direct link to the basis of flying. The design shows a direct relation with its internal function; as a centre for research and development and exchanging knowledge in the field of water management and biotechnology.

In section the design is described by a fluent part of a circle, adapting in the polder area, despite its height of 20m.

The design was given the name Natrix; the international denomination for water-snake. This name refers not only to its form, and the use of water, but also to the materialization and the geometry of the skin. The pattern of the outer skin refers to the scales of the Natrix-snake.

The double skin, with a transparent external layer, creates both by day and night a particular three-dimensional depth in the design. By night this depth is once more reinforced by subtle illumination of the inner skin. The design is a landmark of Schiphol, for people who land and take off. It welcomes travellers who arrive and those who leave. It has not only been oriented for the view from ground level. Also from air it is a magnificent design, where travellers realize that The Netherlands lies to their feet.

Figure 3. 3D-visualization – section part.

Figure 4. Cross section.

4 FUNCTIONALITY

The function of its location and its shape is that of a sound barrier. The double skin, the cleft and the layer of water absorb the low frequent sound produced by planes. The sound absorption of the 28mm in diameter water tubes has been tested in the laboratory of Windesheim School in Zwolle. The total sound reduction of the barrier is 20dB for a frequency of 31,5 HZ. The water has second function is a medium to store and transport sun energy.

Figure 5. Testing the screen of water tubes in the sound lab

The 20m height and 1800m long building houses many other functions which all relate to a combination of sustainability, energy-awareness and innovative thinking. The internal floor area of about 30.000m² is used for an international centre for developments in the field of water management and biotechnology, meaning development and research in: groundwater flow, seepage, water storage, water quality and algae fuel. The building even provides the area for the production of algae and the storage of water.

5 STRUCTURE

The sound barrier has a skin of two structural layers. The inner skin consists of pneumatic air arches spacing 6m with in between PVC-coated polyester membrane. On top of the inner membrane water tubes with a diameter of 28mm are placed side by side. The outer skin exists from transparent foil called ETFE strengthened by a cable net and stabilized by an overpressure between the ETFE-foil and the PVC-coated polyester membrane. The two layers are fully disconnected from each other.

By the application of the two layers, a cleft is created that acts as an insulation layer. Also the overpressure is only between the outer and inner skin, meaning the inside area is not under overpressure and available for all functions.

Figure 6. Detail of double layered skin.

5.1 External skin

By the air pressure between the inner and outer skin the outer skin adopts the form of a circle. The maximum height of the top is always 20m above ground level. At the base the distance at the supporting points varies for architectural reasons between 60 and 70m.

The external ETFE-skin has been calculated on internal air pressure, wind and snow loading.

The internal air pressure has in normal situations (up to wind force 9 Beaufort scale) a value of 0.3 kN/m². The pressure is raised automatically in steps up to 0.6 kN/m², when the wind force is above this value. This way the construction is resistant against each wind force, and it limits the energy usage and extends the life span of the construction.

A diagonal network of thin steel cables supports the ETFE-skin. Because of the internal air-pressure the ETFE has a bubbly shape. By varying the pattern of the cable net and the internal air pressure the frequency of the ETFE skin can be influenced and optimized for absorbing sound-waves. Along the length of the runway the cable pattern is varied according to the change of sound frequencies of an airplane during his take off.

Figure 7. Frequency of ETFE module in the external skin as a function of internal air pressure and size.

Figure 8. Optimized change of pattern in the diagonal network.

The maximum deformation with an internal air pressure of 0.3 kN/m^2 and a wind force of 9 on the scale of Beaufort is 2.5m. The maximum deformation with an internal air pressure of 0.6 kN/m^2 and maximum wind force is approximately the same. The construction manages larger deformation, but it has been limited to 2,5m so that the external skin - with sufficient safety – never contacts the internal skin.

Most interesting in this design is that no matter how much the outer skin deflects the inner skin does hardly show any deformation. This is because the outer and inner skins are structurally not connected and deformation differences will be absorbed by air movement in the cleft. Studies at the Eindhoven University of Technology also showed that this influence is very limited. Because the people inside do not experience the deformation of the outer skin, there is no need for too low deformation limitations, resulting in a higher efficiency of material governed by strength.

Fluctuated wind acts on the outer skin. The outer skin deforms in a dynamic way. The larger the deformation the longer it takes to transfer the energy of a wind gust to the structure. The longer it takes, the lower the impact force. You can compare hitting your fist to a concrete wall (large negative acceleration, short transfer period of the energy, high force, more pain), and putting a pillow between it (lower negative acceleration, longer transfer period of the energy, lower force, less pain). Membrane structures have a higher deformation then concrete or steel structures, therefore a wind gust has less impact - meaning lower peak in the wind force in kN/m^2 , lower internal stresses and lower foundation loadings.

The round shape is a fluent external form which causes very restrictive turbulence and a high degree of laminar wind flow. This is of high importance located next to a runway. Also minimum turbulence means higher sound insulation.

Figure 9. Deformation of external skin loaded on wind loading.

Figure 10. Outer skin deforms because of wind loading, but inner skin hardly moves.

5.2 Internal skin

An arch is an optimum structural shape to support a permanent equal divided loading. Form finding must give a shape in which the line of compression is always nearby the centre of the section of the arch. This limits bending moments and therefore also the internal stresses. The design of the internal pneumatic air arches has been set up this way.

Because of the independent behaviour of the external and internal skin the varying external loading has very limited influence on the internal skin. The pneumatic arches therefore are mostly loaded with permanent equal divided loading: self weight, internal skin, the water tubes and the air pressure in the cleft. The water tubes give an equally divided loading of $2,43 \text{ kN/m}^2$.

The arches span the distance of 60 to 70m. To stabilize them the internal air pressure in an arch is much higher than the pressure between the outer and inner skin.

Beneath the arches no internal columns, stability cores or any other obstacles are located. This gives an enormous freedom in functionality and the internal layout.

When one pneumatic arch fails, the neighbouring arch will form the second line of support. When the inner PVC and / or the outer ETFE skin fails the pneumatic arches will support them.

5.3 Foundation

Because the skin has an admissible degree of flexibility and a dynamic reaction to external loading, it is capable of reducing peak loading and dividing them over a larger area. This limits the governing internal tensions but also forces on the foundation.

The external skin is always under tension because of the internal overpressure. The tension forces are taken anchored in a berm of ground. The internal skin is carried by the pneumatic arches. These arches always give a compression force to its foundation. Because of the relatively low forces no piling is needed.

6 BUILDING METHOD

During construction, Schiphol encounters minor inconvenience. No high cranes are needed. Assembling happens entirely from ground level, and lifted by inflating. After the earthwork is done, the whole design exists from prefabricated parts. The materials are light and flexible. Large surface areas can be transported and assembled, resulting in a short construction period.

Figure 11. Building method

7 SUSTAINABILITY

It is important that people justify their new developments towards nature. Sustainability is therefore an important aspect in the world of construction. The design has been examined in the field of sustainability from several disciplines.

Sun-energy is used in 5 ways: thermal energy, sunlight, PV-electricity, producing warm water of 70° and ground heating and cooling storage (GSHP). The design is able to provide energy in a durable manner for not only itself, but also its neighbouring buildings.

Figure 12. 5 ways the sun-energy is being used

Due to the efficient use of material (lightweight structure) its quantity is very limited. Only a few different types of materials are used, reducing the mix of raw materials.

The production of ETFE asks several times less energy than the production of glass. Both materials, PVC-coated polyester and ETFE, are for 100% recyclable and have a long life span. The ETFE surface is self-cleaning when rain drops on it.

The weight and the volume of ETFE is several times lower than that of glass, and it is less vulnerable. Because of this, much energy and time are saved on transport, assembly but also at future demolition.

8 REFERENCES

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