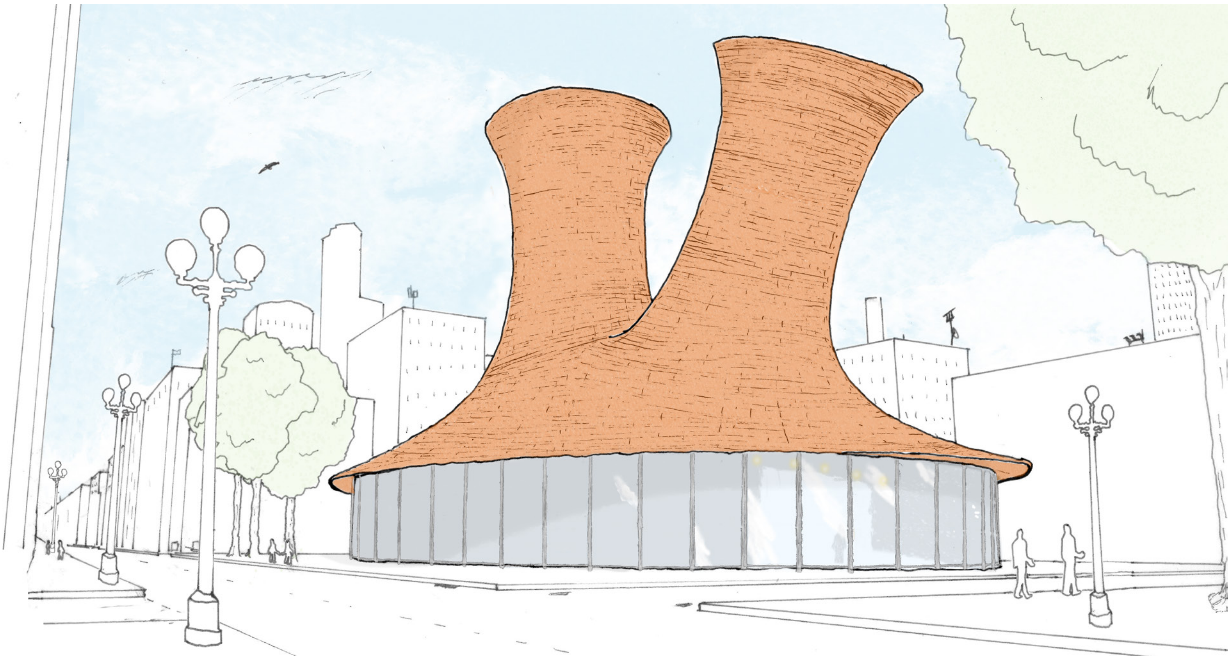


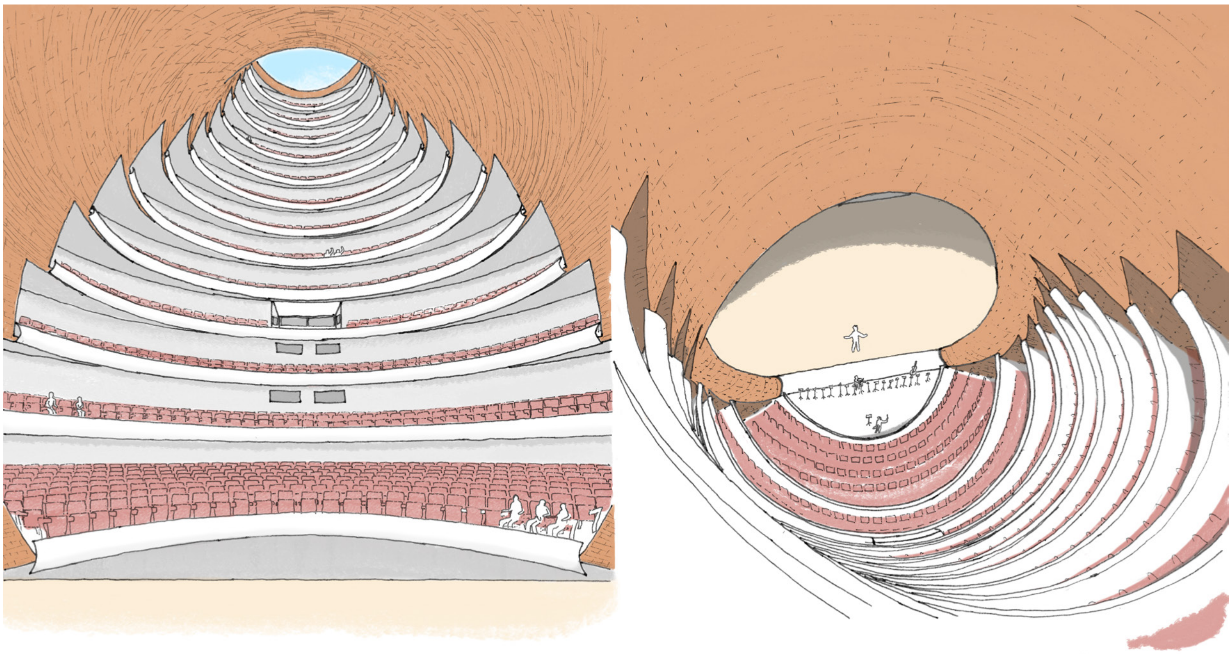
SEATTLE OPERA FACTORY

EXPERIENCING FORM AND PHENOMENON

Henry Wu

PROJECT PORTFOLIO

ACEX15 5.24



01 **Seattle Opera Factory**

	Academic project
part of	ASA Student Design Competition
at	Chalmers University of Technology
course	ACEX15 Bachelor's thesis
date	February–May 2024
with	Jonathan Samuelsson (architecture), Albin Esping (acoustics)
tools	fineliner, sketching paper, Rhino, Grasshopper, C#, Illustrator

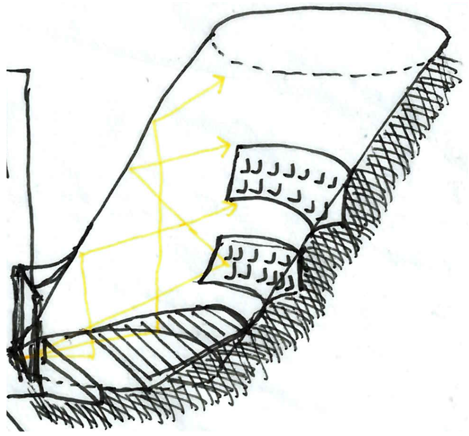
Purpose A university in Seattle wishes to build an opera and performance facility for its musical departments. The facility will be shared between the opera facilities and university education.

Concept To turn the opera hall into a long pipe. Using a similar principle to that of speaking tubes and trumpets, good acoustics will be achieved for the entire length of the pipe.

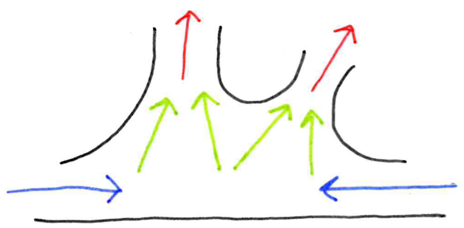
The pipe is accommodated through a tower protruding from the building. Another tower is added for the stage house (a standard feature in opera houses). The facility will then have two tall towers and the chimney effect will create a pleasant indoor climate through natural ventilation.

With brick in a billowing shell pre-stressed to compression with steel cables, the load-bearing structure is created with minimal use of a sustainable and durable material. The elements of the wall are separate from each other, which simplifies replacement, disassembling and reuse of materials.

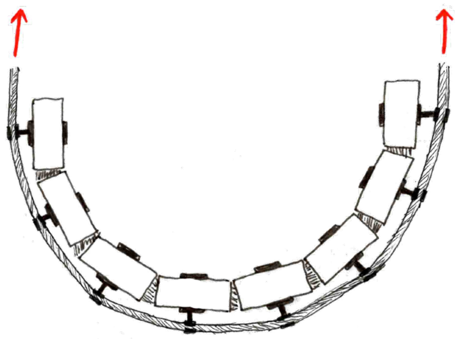
These three core concepts are combined to create an unprecedented opera experience: one where the



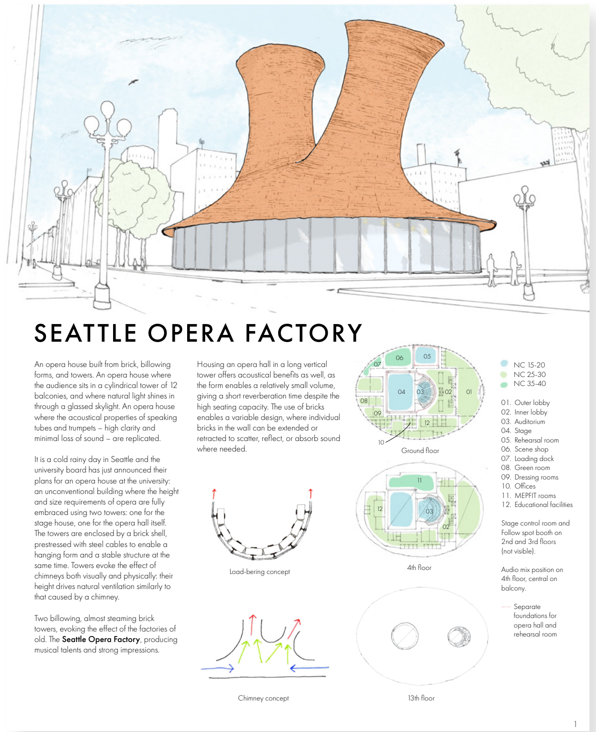
Pipe
Acoustical concept



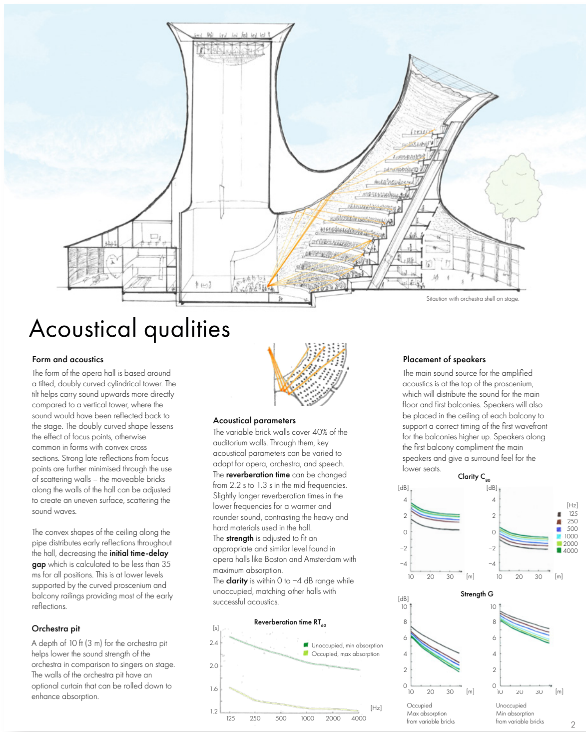
Towers
Climatic concept

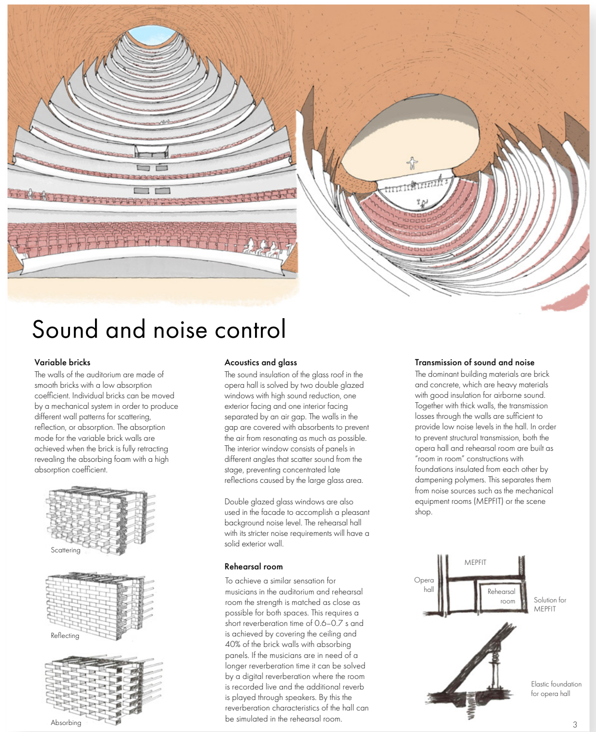


Brick shell
Load-bearing concept



The 3 posters presented for critique and sent to competition





Concept *cont.* audience sits in a tall tower with a skylight casting light down on them.

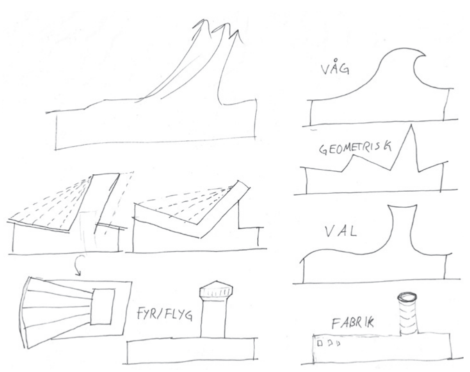
Process An iterative form-finding process was used in order to refine the concept and find good and uncompromising solutions to design problems. On the right page, all iterations on paper (as well as some digital) are shown.

(01) The pipe and tower concepts were originally separate ideas, which were combined into a single concept with two towers. Two form concepts were originally considered and elaborated upon – one with a continuously billowing shell, another with two straight towers. The idea with the shell was ultimately chosen as we found the form more interesting to work with.

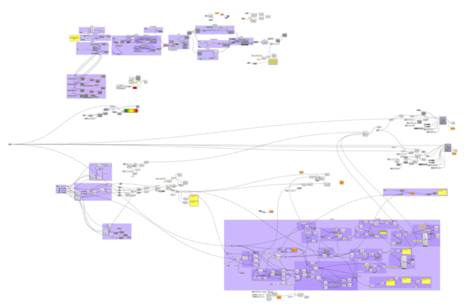
(02) Throughout the project, a mix of physical and digital tools have been used. Advanced 3D modelling and parametric design in Rhino and Grasshopper have been invaluable for form- and shape-finding, as well as for accurately modelling spaces in the building. The physical process with pen and paper have been equally invaluable for quickly testing and iterating new solutions.

(03) At one point, the area of the "base" had to be decreased in proportion to that of the towers. Form-finding by hand was used to find the best shape to accommodate this.

The project was done in a team of three – myself, my architecural team companion, and an acoustician who provided consultancy and acoustical calculations.



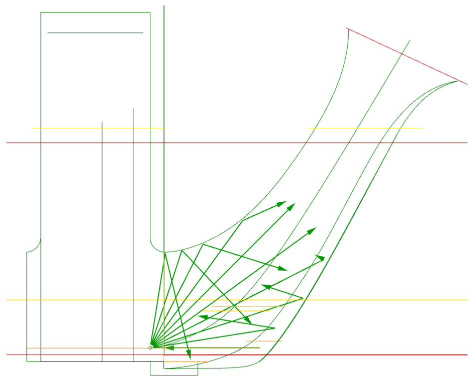
Original sketches for tower concept



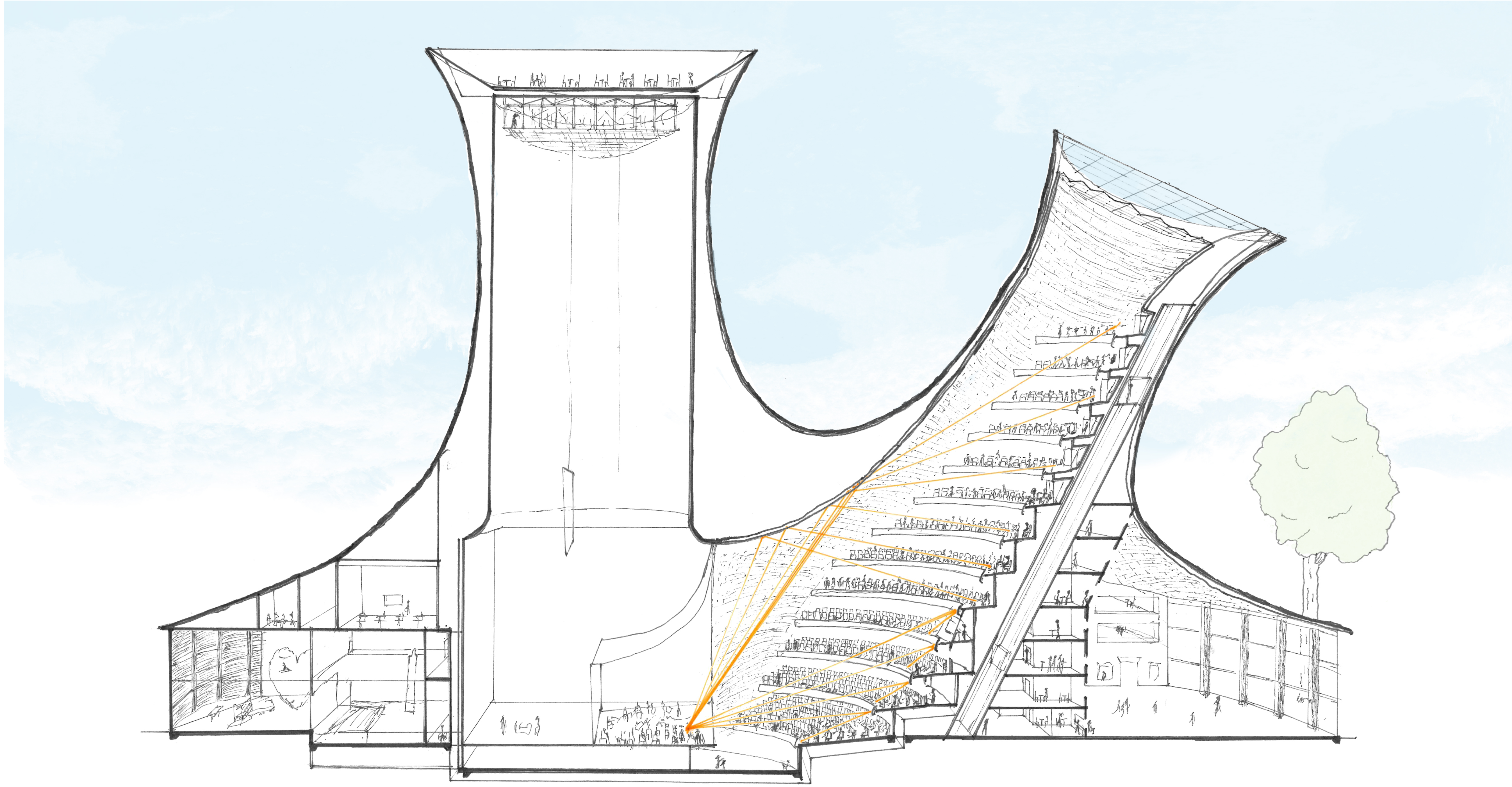
Project script in Grasshopper

```
if (reset || count > iters) {
  balls = new List<Ball>();
  for (int i = 0; i < vels.Count; i++)
  {
    balls.Add(new Ball(pts, vels[i], 0.25, 1));
  }

  boundaryCrvs = rectangle;
  ballPts = new DataTree<Point3d>();
  ballVels = new DataTree<Vector3d>();
  count = 0;
}

//Runs an iteration of the simulation
if (run && !reset) {

  //Corrects balls with "illegal" position (center is outside of rectangle)
  // for (int i = 0; i < balls.Count; i++)
  // {
  //   if (!balls[i].CenterIsInside(boundaryCrv)) {
  //     double t;
  //     boundaryCrv.ClosestPoint(balls[i].position, out t);
  //     Point3d ptOnCrv = boundaryCrv.PointAt(t);
  //     balls[i].MoveTo(ptOnCrv);
  //   }
  // }

  for (int i = 0; i < balls.Count; i++) {
    for (int j = 0; j < boundaryCrvs.Count; j++)
    {
      double distToCrv;
      double crvParam;
      if (balls[i].IsCollidingWith(boundaryCrvs[j], out distToCrv, out crvParam)) {
        Ball.Collide(balls[i], boundaryCrvs[j], crvParam);
      }
    }
  }
```

Script written in C# for acoustical raytracing



Resulting raytracing from script



This section drawing (approx. 1:400 [A4]) was done with a set of fineliners from a screenshot of a Rhino model. Colours and textures were then added in Photoshop by my architectural team companion.

The incline lift was a feature added late in the process, in order to solve the issue of access to an inclined tower. Perhaps an unconventional solution, but most things are unconventional in this building.

Result

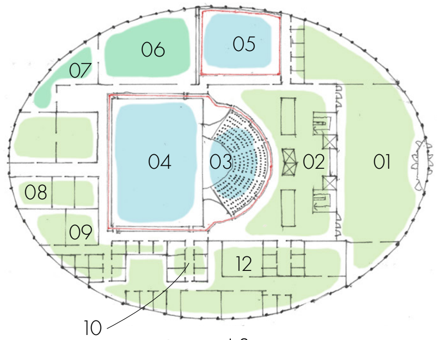
The opera stage and auditorium are centrally situated in the plan and is surrounded by performance and educational facilities. The auditorium itself is a tilted tower, thirteen storeys tall, with an incline lift providing access to the upper floors. As the stage, auditorium and rehearsal hall must be acoustically isolated from the surroundings, these rooms are constructed as "room in room" solutions with polymers and springs insulating them from surrounding rooms.

In the opera hall, the tilt of the tower helps carry sound upwards more directly compared to a vertical tower, where the sound would have been reflected back to the stage. The doubly curved shape lessens the effect of focus points, otherwise common in forms with convex cross sections. Strong late reflections from focus points are further minimised through the use of scattering walls.

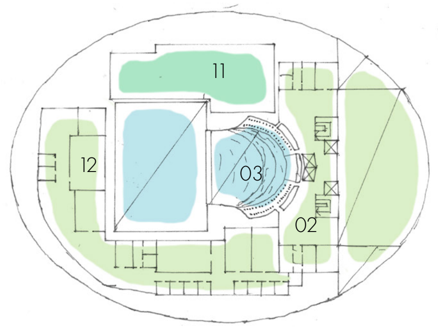
Convex shapes, such as the ceiling along the room, the balcony railings and the proscenium distribute early reflections throughout the hall. The result is that the initial time-delay gap can be decreased to less than 35 ms for all positions.

The walls of the auditorium are made of smooth bricks. Individual bricks in the wall can be moved by a mechanical system in order to produce different wall patterns for scattering, reflection or absorption. An absorbing foam inside the wall provides absorption when needed.

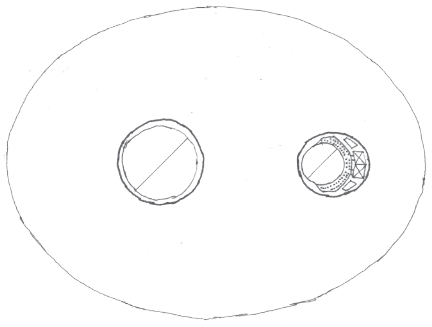
The variable wall means acoustical parameters – such as reverberation



Ground floor



4th floor

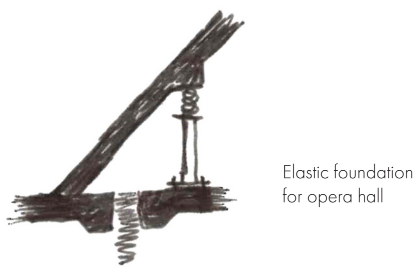

13th floor

Plan drawings, approx. 1:1 750 (A4)

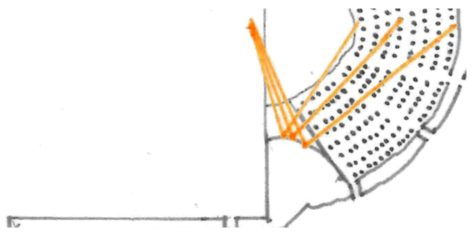
- NC 15-20
- NC 25-30
- NC 35-40

01. Outer lobby
02. Inner lobby
03. Auditorium
04. Stage
05. Rehearsal room
06. Scene shop
07. Loading dock
08. Green room
09. Dressing rooms
10. Offices
11. MEP rooms
12. Educational facilities

— Separate foundations for opera hall and rehearsal room



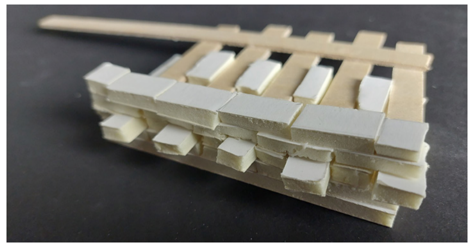
Insulating foundations for acoustically sensitive spaces



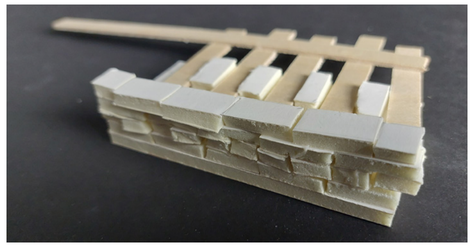
Early reflections: principle in plan (Early reflections in section on preceding page.)

Variable bricks model in different states

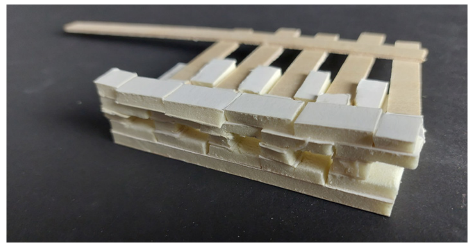
scattering



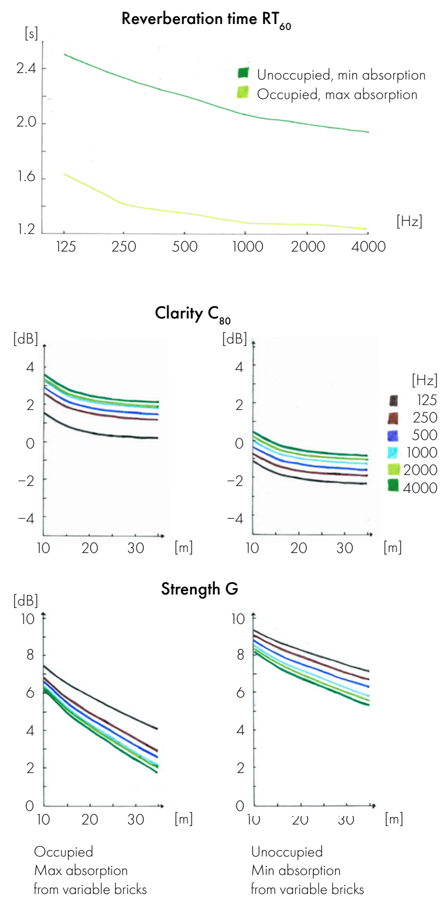
reflecting



absorbing



Acoustical graphs



Result *cont.*

time, clarity and sound strength – can be varied to accommodate many different types of performances, including both opera, orchestra and speech.

Instead of a solid wall, a skylight ends the auditorium tower, providing daylight to the hall. In order to reduce sound transmission, the skylight consists of two double-glazed windows separated by an air gap, lined with absorbing walls. The interior window consists of panels in different angles that scatter sound from the stage, preventing concentrated late reflections.

Reflections

Overall this is a project I am highly satisfied with, and I believe my team companion agrees with me here. The collaboration has been perhaps the best one in my academic career. During the work, we have mostly been in each other's company and have been able to quickly raise issues with each other. We have also not been afraid of criticising each other when needed.

This project has primarily been about form, phenomenon and the relationship between the two. For the most part, I think our project has been using form to control the phenomena – the pipe form controls acoustics, the tower form controls thermodynamics. But for the load-bearing structure, I think there is a more two-sided relationship between the form and the phenomenon. In order to even generate the continuously curving form we strived for, the proposed solution with the inverted shell was one of few alternatives (the other alternatives would have been a net or membrane, which are not stiff enough). If another solution had been

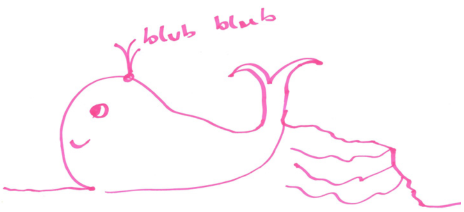
Reflections *cont.*

used, such as one where the towers are constructed separately from the rest of the structure, the resulting form would have been very different (see image).

This is the reason why the proposed load-bearing solution is so unconventional (or at least I can't find it in the bible of structural design, Heino Engel's *Tragsysteme*). It may also not be optimal from a durability viewpoint – how are you going to replace thousands of rusting steel cables in a building? But it is the only way I can think of that generates the form needed. An unconventional form might just require an unconventional structure.

As a final comment, I think what our project does best is providing a spectacular experience for the visitor – in a way, the building itself is an integral part of the opera experience. But is that what one wants out of an opera building? An argument could be made that many people would prefer an more invisibly elegant building, which amplifies the opera performance rather than distracting from it. I don't think there is a right answer to that question, but certainly our project has leaned hard on the spectacular path.

A quick model made from two sticks (for towers) and clay. The method results in a difference in form to the continuous shell in the final proposal.



The first iterations of the tower concept evoked the spout and tailfins of whales. (Sketch by a friend of ours)