

Lecture 3 – Estereostàtic (stereostatic: **solid** + **force** of weight without motion)



Welcome back to **Antoni Gaudí's Influence on the Contemporary Architecture of Barcelona and Bilbao.**

Housekeeping Items for New Students:

Muting everyone (background noise)

Questions > **Raise Hand & Chat questions to Erin (co-host).**

5 to 10 minute break & 10 to 15 minutes at end for **Q&A**

2x (Calvet chair)

Last week, **1898** same time Gaudí's finishing cast figures of the Nativity Façade. Started construction on **Casa Calvet (1898-1900)** influence of skeletons on chair, **bones as props/levers for body movement**, develops **natural compound curved form**.

Gaudí was turning toward **nature for inspiration on structure and design**. He studied the **growth and patterns** of flowers, seeds, grass reeds, but most of all the human skeleton, their **form both functional and aesthetic**.

He said, these natural forms made up of "**paraboloids, hyperboloids and helicoids**, constantly varying the incidence of the light, are rich in matrices themselves, which make ornamentation and even modeling unnecessary."

1x (Calvet stair)

Traditional Catalan method of brickwork vaulting (**Bóvedas Tabicadas**), artform in stairways, often supported by only one wall, the other side open to the center.

Complexity of such stairs required specialist stairway builders (**escaleristas**), who obtained the **curve for the staircase vaults by hanging a chain** from two ends and **then inverting** this form as a guide for laying the bricks to the arch profile.

Of these **ruled geometries**, one that he had studied in architectural school, was the **catenary curve: profile resulting from a cable hanging under its own weight (uniformly applied load)**, which five years earlier used for the **Vizcaya Bridge**, west of Bilbao (1893), suspension steel truss.

Leitmotif (recurrent theme): **Catenary Curve** Hanging freely under the forces of gravity acting evenly along arc, in a natural state of equilibrium rest.

[**Chaksam Bridge**, by Thangtong Gyalpo a Tibetan saint, south of Lhasa, Tibet, 1430 with planks hanging by ropes tied to chains suspended between towers; **Jacob's Creek Bridge**, by James Finley, near RT.819, Mount Pleasant, PA, 1801 first iron chain suspension bridge in U.S., suspended deck hang by trusses.; **Menai Bridge**, between islands of Anglesey and Wales, 1826 first modern suspension bridge.]

2x (Root bridge)

These suspension bridges are a modern development, with origins in primitive **living root bridges**, such as the **aerial roots of the banyan trees** in the East Khasi Hills of N.E. India, **intertwining and weaving roots from trees on opposite sides** of a stream, forming a **catenary curve**.

2x (arch graphs)

Similar to a **parabolic curve [RED]** which is derived from mathematics (quadratic function: polynomial variable is squared), whereas the **catenary [BLUE]** is derived from nature, the **pull of gravity** (hyperbolic cosine: sum of two exponential variables). [**Parabolic arch** produces the most thrust at base, can span the widest distance, **ideal for carrying uniformly distributed vertical loads**, whereas catenary arch is the ideal profile when only carrying its own weight. **Parabolic arch is wider at the base, to account for the loading in addition to its own weight**. However, the **catenary arch narrower at the base, has less lateral thrust, terminating the loads more vertically when it meets the ground plan**, avoiding buttressing.]

2x (catenary/Roman arches)

For Gaudí, this was significant, not just because it is from nature, but more importantly, because a free hanging cable naturally forms the profile exerted on by earth's gravity, so the **lines of thrust** (forces caused by the compression loads on the structure), follow the profile naturally, **internalizing the forces within a catenary structure, eliminating the need for an lateral buttressing** as in Gothic architecture based on pointed circular arches.

Most popular style of architecture with the young avant-garde architects was the **Gothic Revival**, led by theoretical writing/works of **Eugène Viollet-le-Duc**, **adapting structure and design in a rational manner.**

For Gaudí, “Gothic art is imperfect, only half resolved; it is a style created by the **compasses**, a formulaic industrial repetition. Its stability depends on constant propping up by the **buttresses**: it is a defective body held up on crutches. The proof that Gothic works are of **deficient plasticity** is that they produce their greatest **emotional effect** when they are mutilated, covered in ivy and lit by the moon.”

1x (original model)

The same year (**1898**) that he began construction on Casa Calvet and finishing up work on the Nativity Façade, Gaudí began a **new study of equilibrated structures, inspired by this catenary curve from nature.** Creating his greatest innovation, mechanical calculating machine, what he called **Estereostàtic model**, to develop a **new architectural form, whose structure works with Nature’s gravitation as the catenary curve did, but pushing further, into the dynamic, asymmetric, living structure of the human skeleton, with columns as bone props / levers.**

2x (reproduction model)

In a workshop on the site where the church was to be built, a wooden board was mounted on the ceiling, with the **floor plan drawn at 1:25 scale.** From this hung a system of **strings tied together representing the structural frame of pillars and arches, inverted by hanging upside down, so that the loading in a building that is naturally in compression has been also inverted to be in tension** in this hanging model, the **arches pulled on by gravity.**

3x (canvas bags)

From the arches, at the intersecting points where pillars would sit atop or below, would be tied a **small canvas bag filled with lead shots**, proportionate to the weight that would be applied to the arch by the pillar resting on it. The tensile stresses applied to the strings, automatically assumed by gravity alone the inverted form for the structure of the church, while **simultaneously determining the inclination angle of the pillars** based on the direction of the terminal thrusts. In this way, the structure was instantaneously calculated, **each adjustment to any element in the network would send a resulting trembling through the entire assembly, from top to**

bottom. The **whole affected by each point**, while at the same time **each point was affected by the whole**. Growing to **4 meters in height**, Gaudí worked on this model for more than a decade, perfecting the design, by readjusting the model **introducing or removing structural members in different locations**, creating new variations of the design to be weighed carefully in consideration of the implications on the construction, functional use of the space, mechanical, as well as aesthetics. Experimentation was a slow and methodical study, an exhaustive analysis working on the model until he was convinced that the design could not be improved any further.

1x (massing / inverted model)

10:35

Manifesto (public declaration): **stereo+static (solid + stationary weight force)**

A machine for calculating an **equilibrated structure**, where the building forces coincide within the structural form, **1. Architectural Form and Structural Engineering unified as one** and the whole structure balanced with the ground to which it is tied. **2. Loading forces coincide within profile of the structure, Inclined**, without division between lateral and vertical.

3. In pursuit of **Architectural Synthesis, where the distinction between supporting and supported elements dissolves**, this model evolved in an organic sequence of natural growth, **replacing traditional graphic-static mathematical calculations with an empirical making by the hands**. Not an instrument of the work, but a liberation of it. The model has become a hyperconnected world, yet all the materiality of the church it represents is absent, only the structural mechanics are in focus.

7x (graphic statics example)

Properties of the arch could be manipulated, the span or depth, to create a shallow Catalan vault for example. And, when pillars were located atop, **asymmetrically, the arch would be distorted and the adjoining pillar inclined**, reacting to the displaced loads. **Skeletal lever, prop coming to life, plasticity, animated, movement.**

Parti Pris (organizing concept): **Inclined Columns**

2x (interiors / exterior)

Once the skeletal framework was resolved, a skin of thin cloth was draped over, to study the form of the church. Then photographed inside and out, so that the details in the **wall fenestrations and furnishings could be drawn onto the photographic**

prints, watercolors applied to visualize the finished church in full polychromic effect. Set inside a makeshift hut, amongst the pines, it had become the most advanced architectural studio in the world.

[Alongside **Francesc Berenguer** making adjustments, the engineer **Eduardo Goetz Maurer** offering specialist advice, practical advice from sculptor **Joan Bertran**, builder **Augustín Massip**, carpenter **Munné**, and sculptor **Llorenç Matamala**)

7x (Inclined Column)

10:45

Colonia Güell Church stereo-static models (1898-1908) Space must be apprehended holistically in the manner of **angels who think in three dimensions**. Ordinary **man can only act on a plane of two dimensions**, so the calculating model enabled him to determine the **inclination angles of the supports naturally by gravity, leaning in multiple directions of three dimensional space**, a major advancement over traditional graphic statics calculations that could only be applied to a flat two dimensional sectional plane. Nature is not made of straight lines regularly spaced, it is complex, three dimensional and Gaudí was trying to model this with the Estereostàtic calculating machine.

7x (shallow vaults)

Traditional Catalan method of shallow brickwork vaulting (**Bóvedas Tabicadas**), when unevenly sized bays, creates unbalanced loads, resulting inclined support.

2x (graphic statics / colonnade)

Park Güell colonnade viaduct (1900-1903) graphic statics & inclined pillars.

10:50

(10 MINUTE BREAK)

11am

POLL: #10 Most intriguing about Stereo-Static model?

1m + 3x (exterior / interior)

Sagrada Familia bell towers (1904-1914)

8x (model /interiors)

forest of **tree-like columns (1922)** the trunk and branches of a tree, dividing into branches supporting the canopy vaults

8x (bridge)

Pasarela Zubizuri (Santiago Calatrava, 1997) a **tied arch** (arch ends tied together in tension by deck, **Fort Pitt Bridge** local example, 1959) footbridge across the Nervion River in Bilbao, bridge deck made of **translucent glass bricks**.

5x (airport)

Bilbao Airport (Santiago Calatrava, 2000) design closed for expansion, Exterior arrival cantilever.

5x (skyscraper)

00 Tower / Diagonal 00 (Emba Estudi Massip-Bosch arquitectes, 2011) Barcelona, corporate headquarters in Catalonia of Telefónica Group.

Concrete core with perimeter steel structure of two layers: an interior vertical structure of very slender H pillars (14x14 cm to 10x10cm at top) and an exterior **bracing lattice supporting the torsion and flexing stresses** from wind or earthquakes.

6x + 1m

Emmanuel Episcopal Church (Henry Hobson Richardson, 1886)

Richardson **ignored two venerable crutches of American church design—the spire and the transept**, nothing more than the **vividness of the brickwork** and the power of a severe **triangular gable set low** on an arched and battered base. Brickwork richer than any Richardson had designed before (“bake oven”), which shows his trust in the skilled Pittsburgh laborers who executed them. **Tapered apron Terra Firma**.

Experimented with **new structural material, laminated beams, spandrels & arches that failed from beams’ lateral thrust, exterior brick walls distended**. Built while he was building the Allegheny County Courthouse. Tiffany windows.

13x

Traces of Memory (Chiharu Shiota, 2013) Mattress Factory Installation

Japanese artist born in Osaka in 1972, studied art at the Kyoto Seika University.

“Memory of Books,” in the 2011 Venice Biennale.

Monumental yet delicate, poetic environments. Themes of **remembrance and oblivion, dreaming and sleeping, traces of the past and childhood and dealing with anxiety**. Shiota explores the **relationship between waking life and memories** through hauntingly beautiful installations that incorporate **everyday objects** like shoes, pianos and hospital beds **encased in webs of black yarn**, disorienting cocoons that reflect the artist’s **desire to ‘draw in the air’**.

POLL: #11 Which prefer: Model, Park, Sagrada, Calatrava, 00 Tower, Traces?

11:20

Q&A

11:30