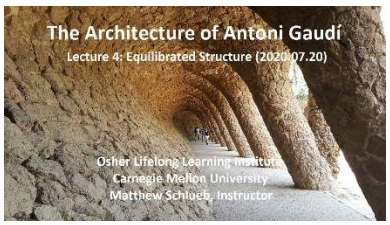
2020.07.20 Lecture Notes 3pm

Lecture 4 – Equilibrated Structure



Welcome to **The Architecture of Antoni Gaudí**.

Housekeeping Items for New Students:

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

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

Leitmotif: Equilibrated Structure

Last week explored **architectural form**, today discussing **Equilibrated Structure**,

a construct in a state of balance, natural form in harmony with weighted structure.

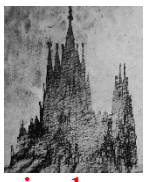
(Nativity Façade, Gaudí, 1892-1910)

After a decade studying natural skeletal structure for figures on **Nativity Façade**,

Gaudí embarked another decade study, applying skeleton to structure of buildings,

(ink drawing, Juan Rubió, 1915)

with **Sagrada Familia**, building form and massing reference **Montserrat**, mountain range enclosing Barcelona to the west, central to **Catalan faith** and their **identity**.



(watercolor wash, Gaudí)

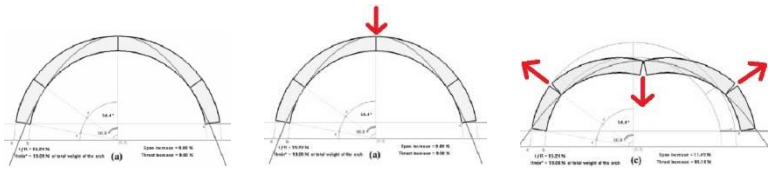
Myth believes rocks formed by geological explosion during crucifixion of Christ.

8th century, **Madonna statue (Patron Saint of Catalonia)** taken to Montserrat to protect her from the Arab Muslims invading the Iberian Peninsula.

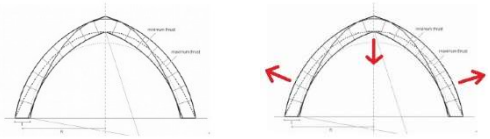

Long history of Catalan artists (**Picasso**, **Miró**, **Dalí**) paying homage in their work. Gaudí would take his building trades to Montserrat for Mass & dinner, to celebrate completion of projects.

(watercolor over photograph of model, Gaudí)

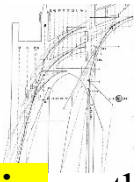
Developed **Estereostàtic model**, to design structure of **Colònia Güell Church**, using catenary curves supported with inclined columns, informing Sagrada Familia.



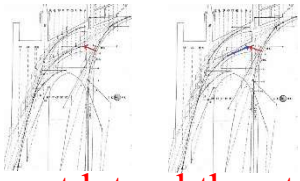
Traditional, **Roman arches** based on Euclidean geometry, circle considered perfect, resulted in lateral thrusts, tending to collapse if not supported on sides.



Gothic arches, popular in Gaudí's time, base on two paired circles, pointed arch, also resulted in lateral thrusts, the lines of compression imbalanced within legs.



Structures analyzed with **graphic-statics** mathematical calculations, using sectional drawings to determine compression forces, bending moments, moments of inertia… (imbalanced lines of compression, unstabilize the structure, thrusting outward)



Flying buttresses used to counteract lateral thrusts, stabilizing Gothic pointed arch.

For Gaudí, buttresses were crutches, holding up a dead skeleton crushed by weight, evidence for the imperfection and weakness of the organism.

"Gothic building becomes expressive only in a state of ruin, half-covered with weeds and ivy, and contemplated in moonlight or at dusk." (architecture hidden)



In **1874**, accepted into **School of Architecture in Barcelona**, sharing apartment with his brother (studying medicine), who published an article (**Bees, 1870**) promoting virtues of beekeeping, medicinal benefits of honey, describing methods worker bees use to build honeycombs, linked together by their legs, forming a chain hanging in the air, forming a parabolic arc by the natural forces of gravity.

Same year, joined the **Mataró Workers Cooperative**, received first commission (**Cotton Bleaching Facility, 1883**) and design his first parabolic structure.

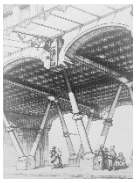
Parabolic arcs of short timers bolted end to end, as worker bees linked together.

Unlike Gothic arches, formed by the arc of a compass, the parabolic arc following a **catenary curve**, profile of a free-hanging chain shaped by gravity, naturally finds a state of rest, where the lines of thrust (compressive forces), **"vital energy"** are balanced within the arch, an **Equilibrated Structure**. Significantly, **inclined legs**, splay outward, responding naturally to the lateral thrusts, **continuous** parabolic line, vault of the arch and leg supports as a single inseparable entity.

"**Continuous forms are perfect forms**. The formal elements of a work must be welded together, **integrated**, and fused into **an ensemble**: they must also loose their individuality and thus contribute more to the **unity of the whole**. The discontinuity in Gothic is flagrant. They attempted to hide it with ornaments and thus turn the **attention away from those points not mechanically resolved**. They masked a conceptual deficiency with a visual element."

Honest expression of continuous, balanced, synthesis of architecture and structure.

"The tree is my master." Gaudí would say pointing to the **eucalyptus** in front of his **workshop**, located in pastor's house of **Sagrada Familia** (**1887-1912**). A tree develops according to an axis of forces that is the trajectory of its equilibrium, and the growth of its branches follows a helical line. Gaudí would observe that most trees are inclined, in trunk and branches, not perpendicular to the ground as in the columns of Roman or Gothic structures.



One of Gaudí's teachers at school, **Juan Martorell**, also a mentor that nominated him as architect for Sagrada Familia, was strongly influenced by the writings and works of **Viollet-le-Duc**, a French architect and proponent of Neo-Gothicism.

In one of his lectures published in **1863** (**Lecture 12**), Viollet-le-Duc stated "the use of rigid shafts or cast-iron columns as **oblique supports** is a means of which our builders have not yet thought, substituting oblique for vertical resistance is a principle in which a new architecture may be found."

In **1895**, Gaudí began construction on **Bodegas Güell** (Francesc Berenguer assisted) Steep inclined roof of Garraf stone, carried to the ground.

Parabolic volume, vertical Montserrat spire, extracted from the voided gable end.

Parabolic vault supported by inclined piers, in a single continuous material.

As with Gaudí's belief the expression of human figure is provided by the skeleton, he placed supreme importance on framework of a building:

"The **silhouette** of a monument is born out of its structure, everything has a positive reason, and if a line is repugnant to our **intuitions** it is not right; in tracing a line we **do not work solely by the power of rationality**."

The **parabolic structure** was the ideal construction solution, because it could outline and re-create an infinite space open to God. Incorporated into sacred architecture the **movement and life** of the ever-growing vegetal curve, guides the spirit in its development toward a culmination in God.

In the parabolic structure, Gaudí discovered a universal mystical symbolism, satisfying his vision of **architectural, structural, and spiritual coherence**.

Catalan artistry in brickwork, as **Güell's country estate's Dragon Gate (1884-85)**

In this gate, also suspended from a single support, **catenary curve hanging chain**.

In **1898**, after a decade of casting human figures in plaster for **Nativity Façade**, Gaudí designed the **chair for Casa Calvet**. Anatomical influence of skeletal bones in arms and legs of the chair.

Bones as props and levers for movement of the body, both aesthetic and functional, now this concept applied to the incline legs on back of chair, **implying movement**.

Tradional Catalan stairs supported one side, open in center, built by **escaleristas**, curve for staircase vaults by hanging a chain from supports, inverting as formwork.

3:35

(10 MINUTE BREAK)

3:45

Parti: Estereostàtic model

In same year as construction of Casa Calvet stair, began a new decade long study of **Equilibrated Structure** creating the **Estereostàtic model**, mechanical calculating machine, Gaudí's greatest innovation, for developing architectural form whose structure works with Nature's gravitation, as the catenary curve of parabolic arch, but further into asymmetric, three-dimensional, dynamic space, with living structure as of human skeleton with inclined, moving bones as props and levers.

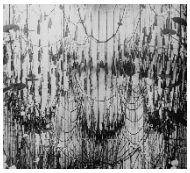
Colonia Güell was formed as a small industrial colony in **1890**, moving his textile factory out of Barcelona to rural countryside, away from the social ills of the city (alcohol, atheism, unionization). Equipped with most modern machine technology, and providing workers with housing, company store, entertainment, and church. The colony's emblem, references **worker bee honeycomb, as church floor plan**. In workshop erected on site, 1:25 scale floor plan on a board mounted on ceiling.

From this plan, hung system of strings knotted together representing structural frame of pillars and arches, hanging upside down, so compression loads are inverted into tension, pulled by gravity.

On arches, at intersecting points, where pillars would sit atop, small canvas bag filled with lead shots, proportionate to building weight applied to arch by pillar. Likewise, the pillars supporting the arch below, tied off at that point.

 **x 7**

Analyzed with **Graphic-Statics**, lines are drawn with inclination of the load path and length of line proportionate to the amount of load. **Adding two loads together**, determines the direction and amount of the resulting load.



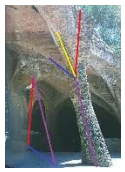
Estereostàtic model, by gravity alone, simultaneously determines the inclination angle of every structural member, **determining the direction of thrusts** based on the load amounts placed in weighted bags applied to the load points.

4 meters in height, Gaudí and his assistants (**Francesc Berenguer** making adjustments, engineer **Eduardo Goetz Maurer** offering specialist advice, practical fabrication advice from builder **Augustín Massip**, sculptors **Llorenç Matamala** and **Joan Bertran**, and carpenter **Munné**) **empirically worked out the design** of the church, by the hands, without mathematical calculations. Each adjustment of weight amount in a bag or repositioning a knot location, resulted in trembling through entire assembly, the whole affected by each point, while each point was affected by the whole, automatically and instantaneously calculated, the model a hyperconnected world, all materiality absent to focus on structural mechanics.

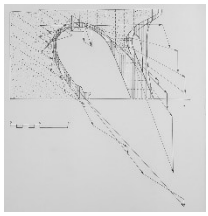
Totally empirical method to study three-dimensional form and space, Gaudí said, "being very **intellectually lazy**, I have **rejected the procedures outlined in books**. You have asked me about certain details (of this drawing). I can't tell you anything more at the moment, as I don't know any more myself."
To colleagues, it seemed Gaudí would put into effect each day, what Virgin Mary had revealed to him the night before. But, he **sought perfection through slow and methodical study**, exhaustive analysis of models until he was convinced the design could not be improved any further. 25 versions of Palau Güell façade; Sagrada Familia crypt piers 4 years, lanterns 14 years, nave 10 years; Estereostàtic 10 years.

4pm



Colònia Güell Crypt construction began in **1908**. Estereostàtic model went beyond two-dimensional sectional plane of graphic-statics drawing.

Manifesto: Park Güell Colonnade Viaduct (1900-03)

Classical verticality of columns in **Hypostyle Hall (1906-09)** > inclined trees.


Sagrada Família Bell Towers (1904-14)


Sagrada Família Columns & Vaults (1922)

With **Sagrada Familia nave**, **inclined columns**, **catenary branches and vaults**, **gravitational thrusts balanced** within an **Equilibrated Structure**, **honest expression** of **continuous synthesis** of **architecture and structure**, **skeletal bones of props and levers, achieving a Living Architecture.**

4:15

Q&A