

HEYDER ALIYEV CENTRE, Azerbaijan

Zaha Hadid Architects



Background

In 2013, the Heydar Aliyev Center opened to the public in Baku, the capital of Azerbaijan. The cultural center, designed by Zaha Hadid, has become the **primary building for the nation's cultural programs, aspiring instead to express the sensibilities of Azeri culture and the optimism of a nation that looks to the future.**

This report presents a case study of the project. It will include the background information, a synopsis of the architect's mastery of structural design. Also, some special elements of this building will be discussed in detail. And the structural design of the whole complex will be reviewed through diagrams and the simplified computer-based structural analysis.

The Heydar Aliyev Center

Since 1991, Azerbaijan has been working on modernizing and developing Baku's infrastructure and architecture in order to depart from its legacy of normative Soviet Modernism. The center is named for Heydar Aliyev, the leader of Soviet-era Azerbaijan from 1969 to 1982, and President of Azerbaijan from October 1993 to October 2003. The project is located in the center of the city. And it played an **extremely important role in the development of the city. It breaks from the rigid and often monumental Soviet architecture that is so prevalent in Baku.** More importantly, it is a **symbol of democratic philosophy thought.** Under the influence of the new Azerbaijan party and the Soviet Socialist Republic of Azerbaijan leader's political and economic reform, the center was also **designed to show the potential of the country's future cultural development, to encourage people to study the history, language, culture, national creed and spiritual values of their own country.**

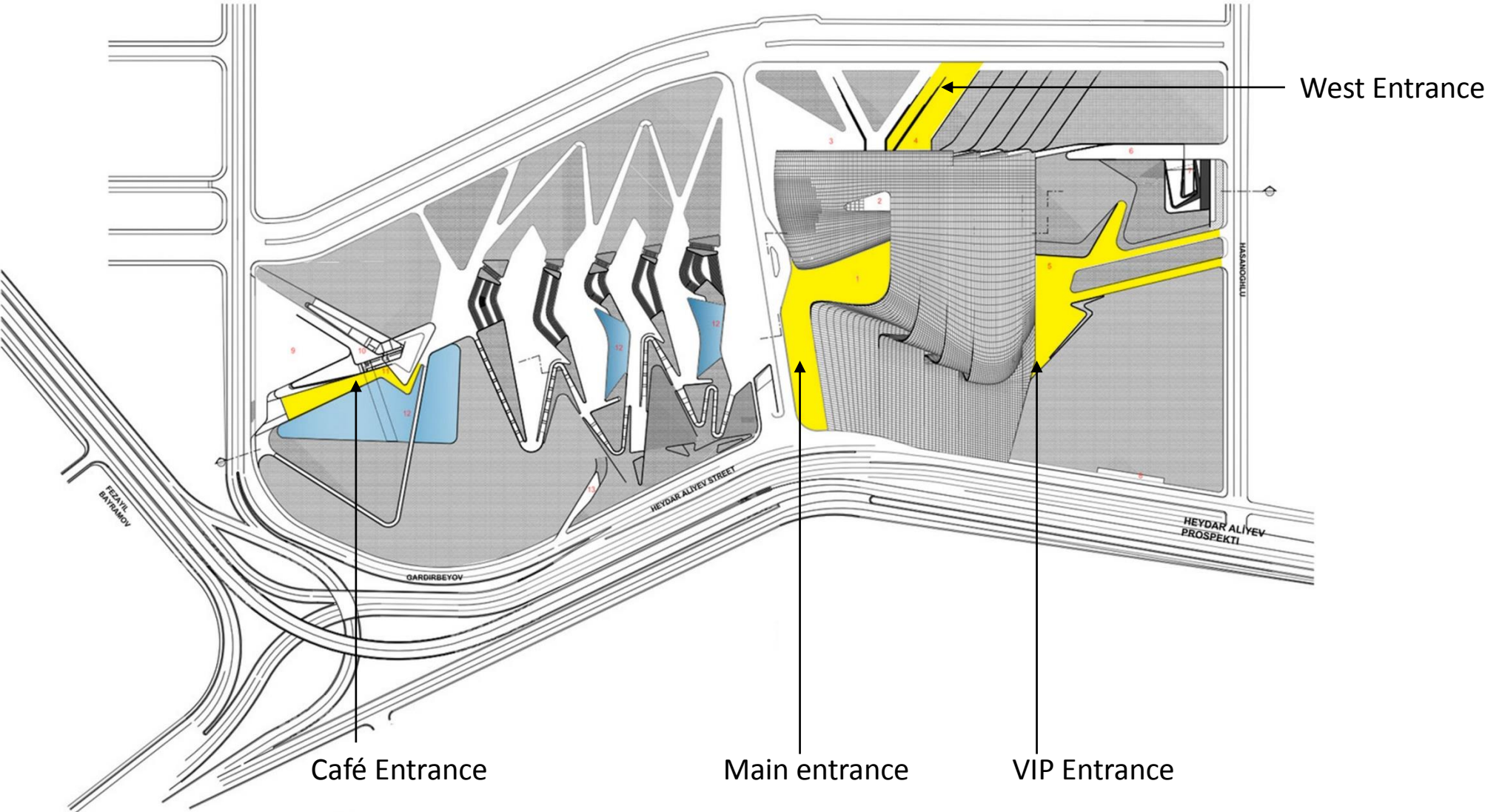


DESIGN CONCEPT

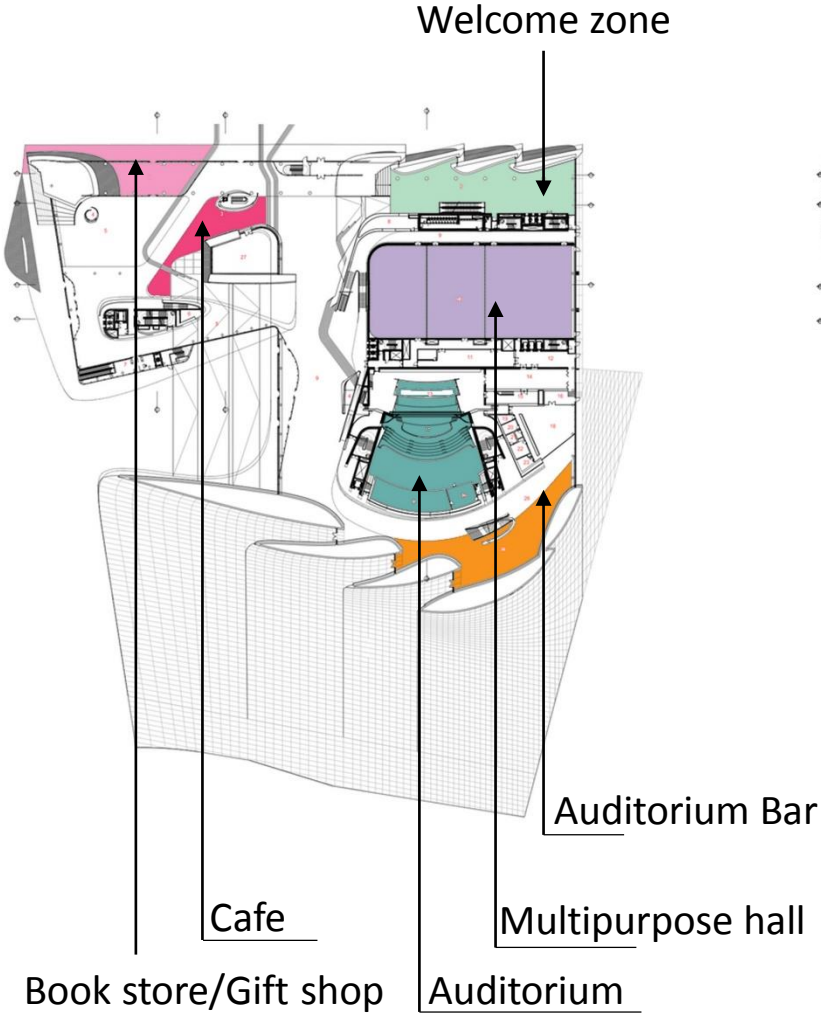
The design of the Heydar Aliyev Center establishes a continuous, fluid relationship between its surrounding plaza and the building's interior. The plaza, as the ground surface; accessible to all as part of Baku's urban fabric, rises to envelop an equally public interior space and define a sequence of event spaces dedicated to the collective celebration of contemporary and traditional Azeri culture. Elaborate formations such as undulations, bifurcations, folds, and inflections modify this plaza surface into an architectural landscape that performs a multitude of functions: welcoming, embracing, and directing visitors through different levels of the interior. With this gesture, the building blurs the conventional differentiation between architectural object and urban landscape, building envelope and urban plaza, figure and ground, interior and exterior.



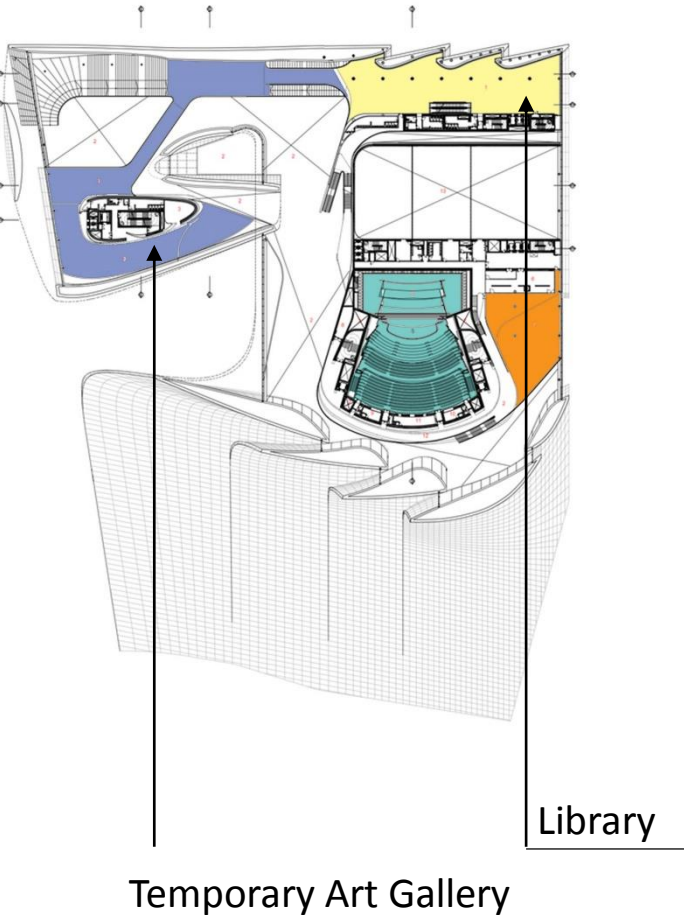
SITE PLAN



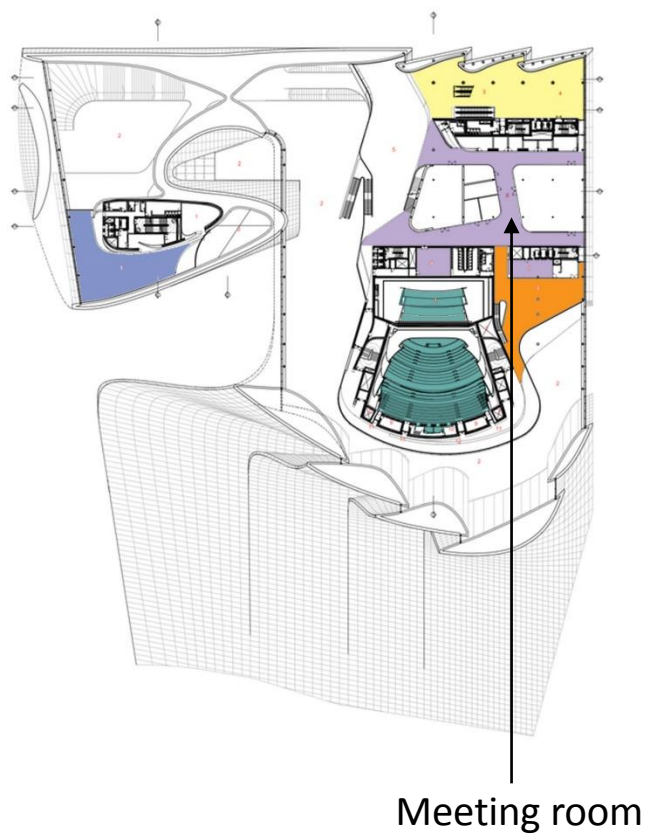
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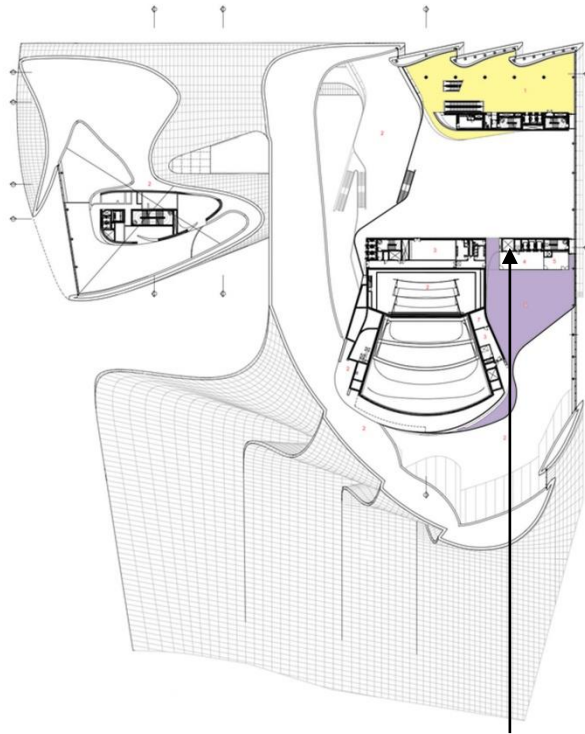
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LEVEL THREE

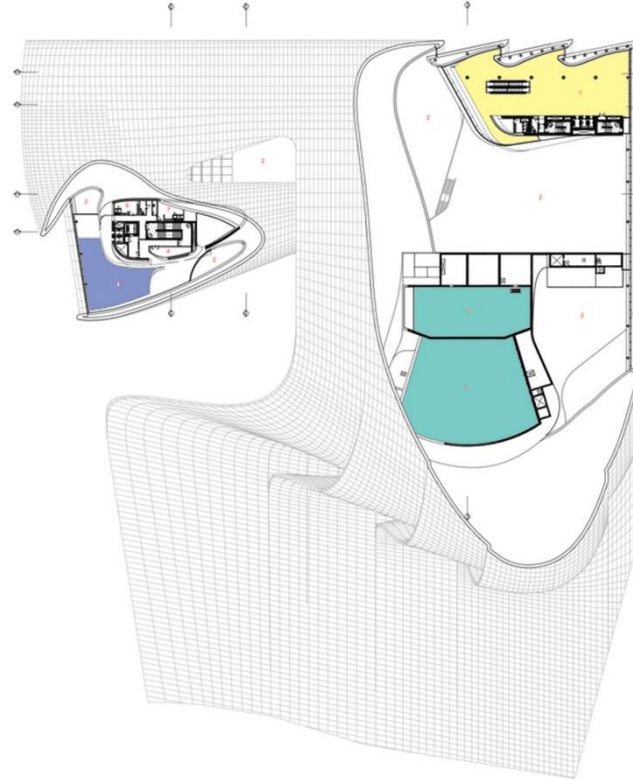


LEVEL FOUR

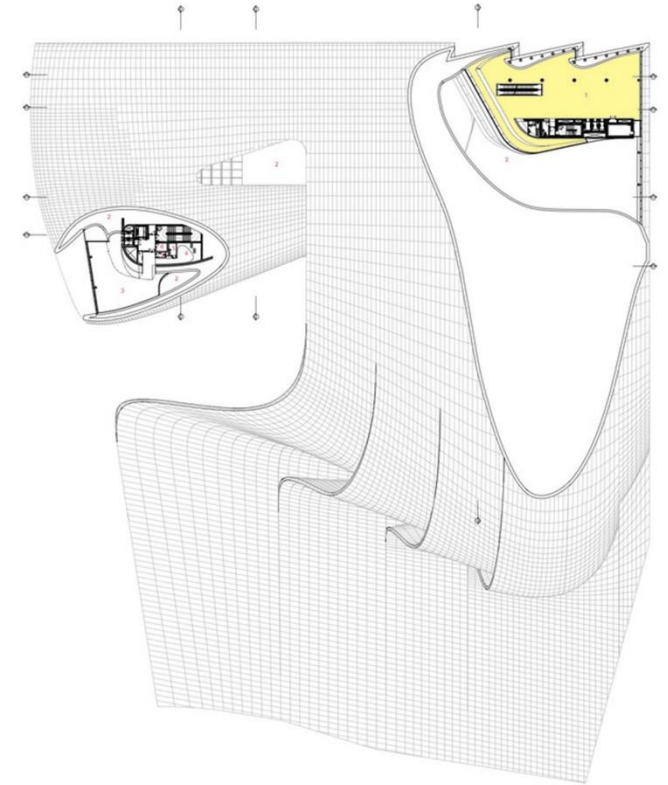


Administration

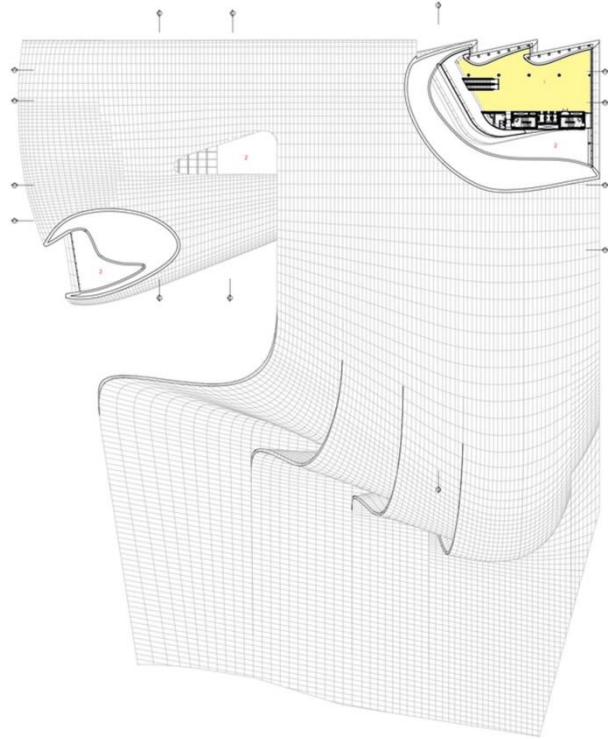
LEVEL FIVE



LEVEL SIX



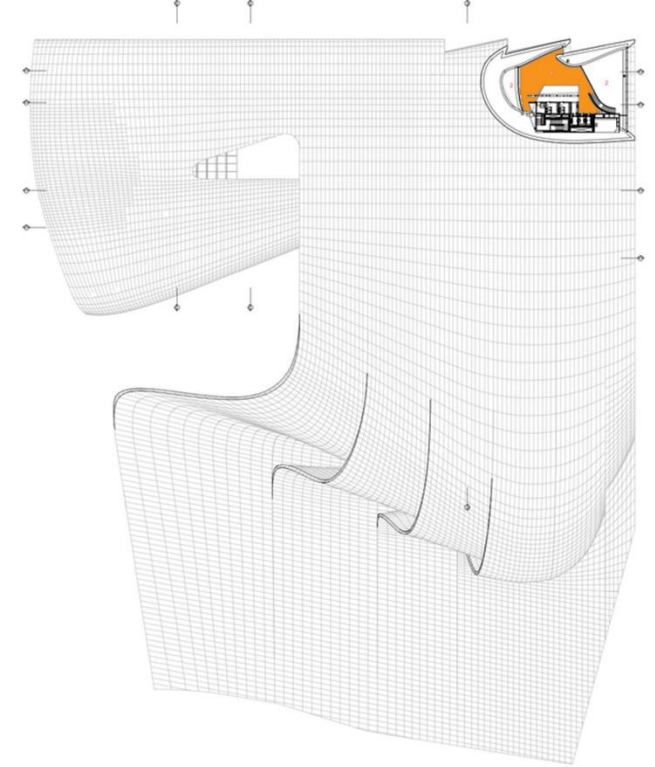
LEVEL SEVEN



LEVEL EIGHT



LEVEL NINE



Structural Features

Baku, which in old Farsi means 'where wind beats', is subject to high wind loads throughout the year, and as the city lies within a seismic zone, the project's structural engineers faced a multitude of challenges. The freeform structure of the project derives from the architectural design concept of modifying a single surface to adopt different functional requirements. The **aim was to create a large column-free space giving visitors the opportunity of experiencing the fluidity of the interior. To achieve this, vertical elements are absorbed by the envelope and curtain wall system. The Heydar Aliyev Centre consists of 2 structural systems: Space Frame and concrete with a single movement joint** (Figure 1 and 3 on the following page).

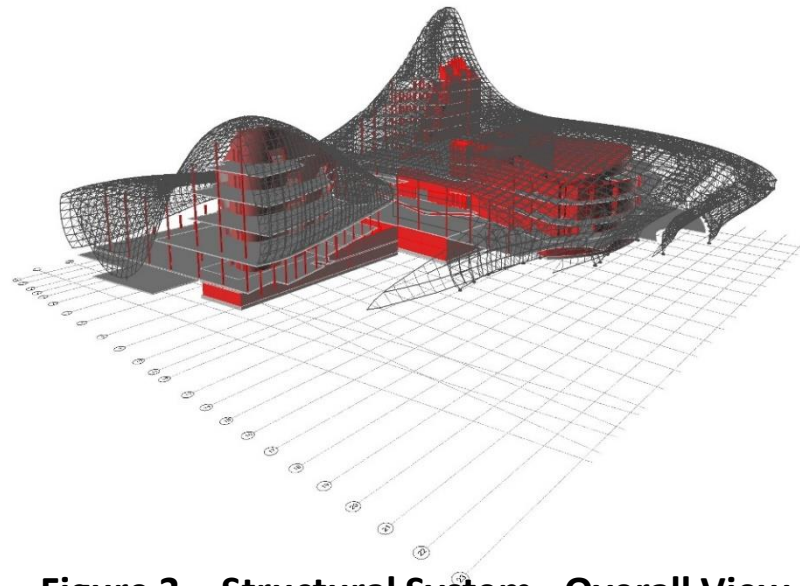


Figure 3. Structural System - Overall View

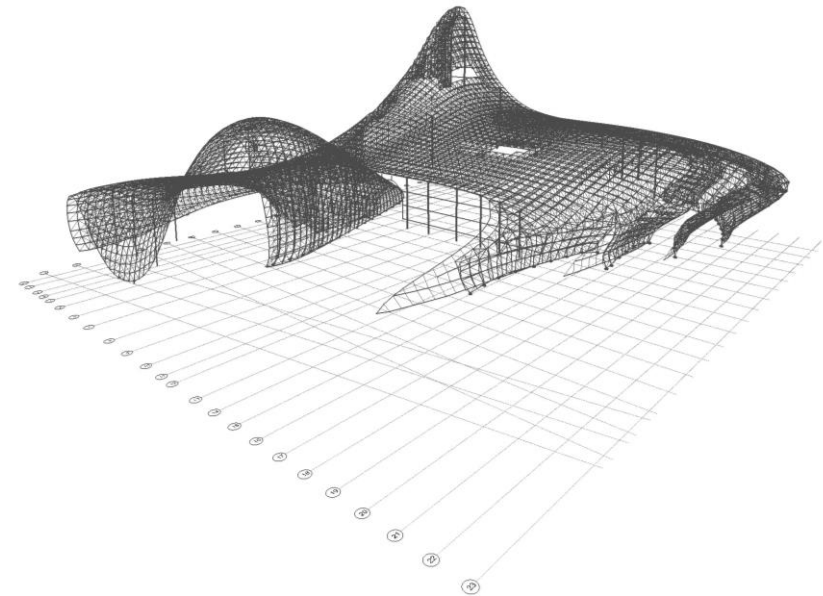


Figure 1. Structural System - Space Frame

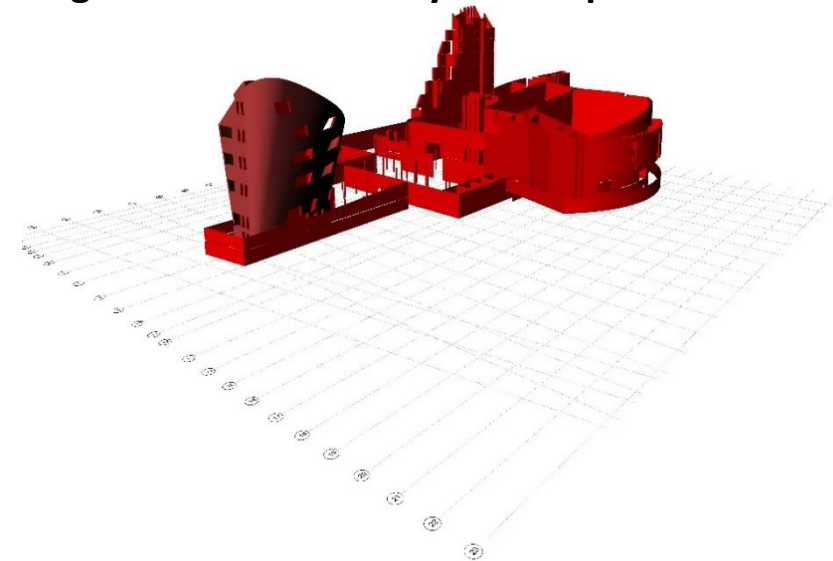
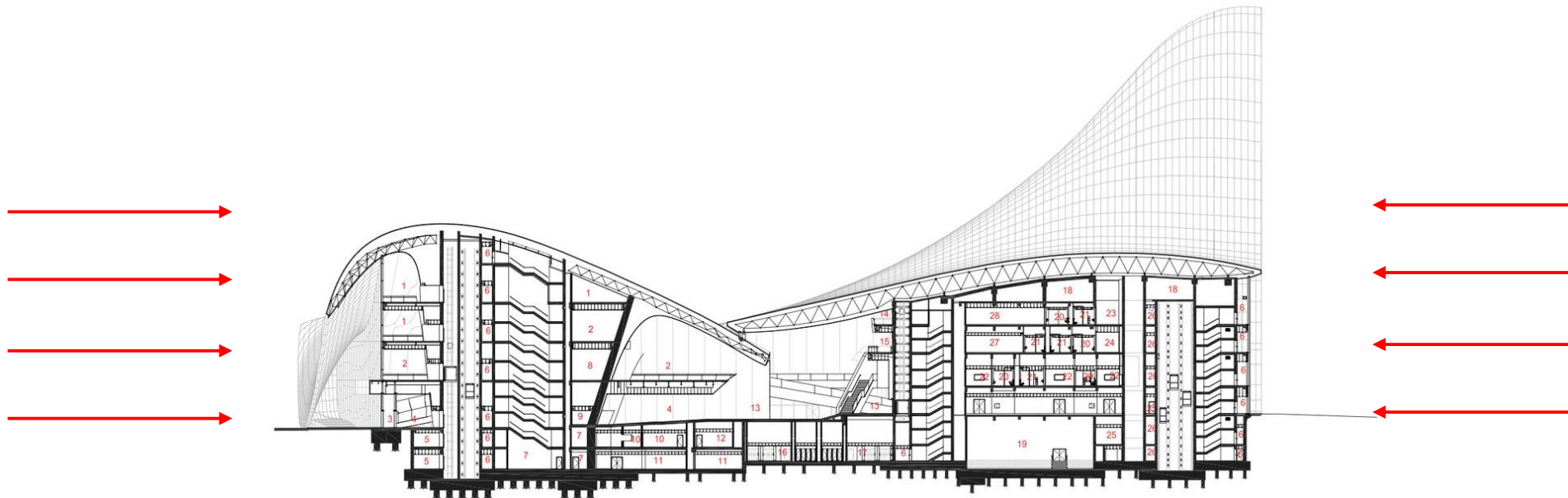
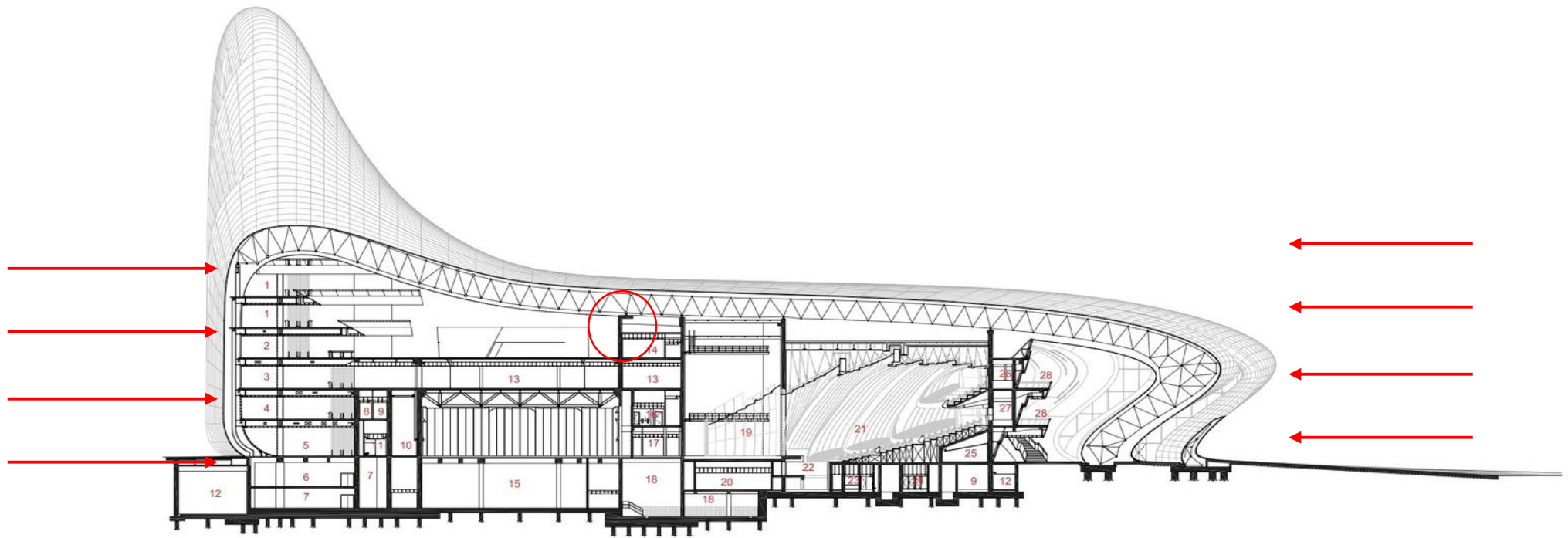


Figure 2. Structural System - Concrete Cores



Building Components and System

Space Frame

The space frame enables the construction of this free form structure while offering **significant savings** in time throughout the construction process. The surface geometry driven by the architecture, dictates the need to pursue unconventional structural solutions; the **introduction of curved 'boot columns' to achieve the inverse peel of the surface from the ground at the west, and the cantilever beams 'dovetails' tapering towards the free end, supporting building envelope at the east.** The substructure enables the incorporation of a **flexible relationship between the rigid structural grid of the space frame and the free- formed exterior cladding seams** which derive from complex geometry rationalization, architectural aesthetics and usage.

Concrete

Reinforced concrete is **mainly used to construct shear walls** as the partition to separate main spaces and to support the space frame. It also **used to construct the footing of the building.** As **Earthquakes** are one of the biggest threats to construction in Baku, the **building must be reinforced by massive 150-foot-long concrete piles buried below the Earth's surface** to withstand an earthquake measuring up to magnitude 7.0.





Special nodes

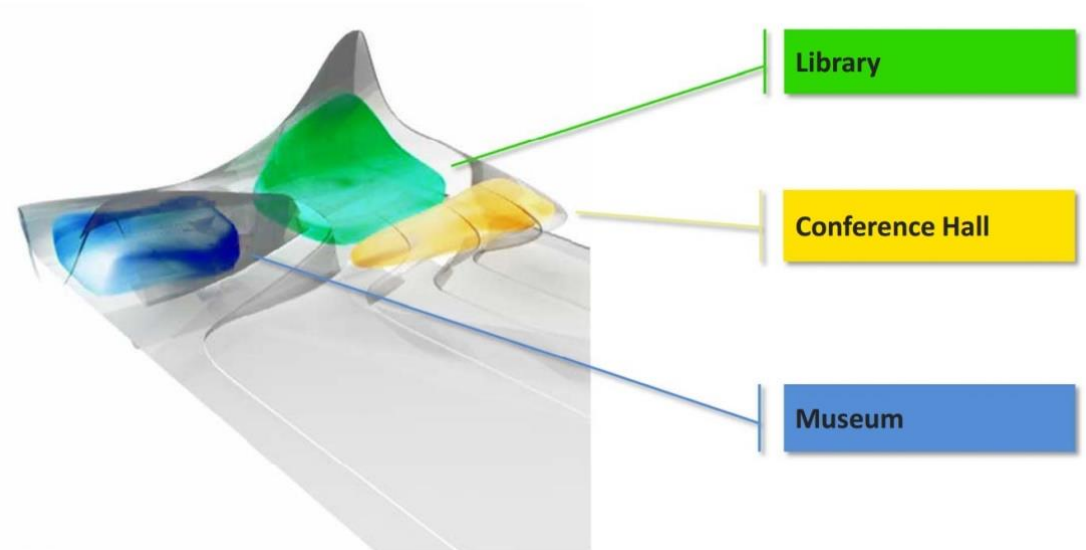
Due to the **large span of the space frame**, it is **connected to the reinforced concrete structure in addition to the support of the columns and directly to the foundation**, in order to maintain the stability of the structure as much as possible. **The method of maintaining stability is to extend the steel core beam from the reinforced concrete core tube, fix the vertical steel member to the joist, and connect the space frame to the joist.**



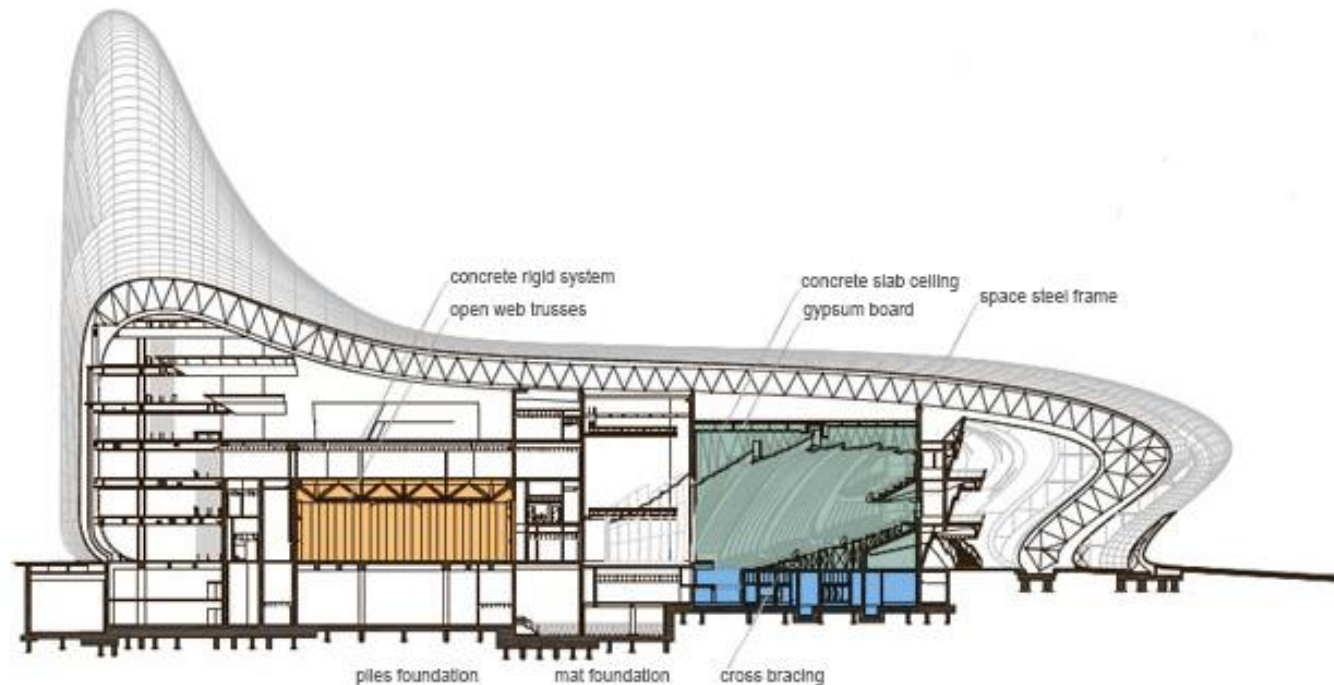
As shown in the figure, **the space frame will be subjected to a large bending moment**. In order to solve this problem and ensure structural stability, the structural engineer will **thicken the space grid here, from the other parts of the single layer into multi-layer**, to provide adequate bending resistance.

Interesting spaces in the structure

The continuous architecture contains three major programs, including the **museum, exhibition halls and convention center**, mainly composed by **rigid concrete structure grid free from external space frame with a single movement joint**. The three spaces are separated from each other and have their own entry and security areas. Also they share some common places under the continuous external skin. In order to make column free space, the certain wall and envelope serve as vertical elements.

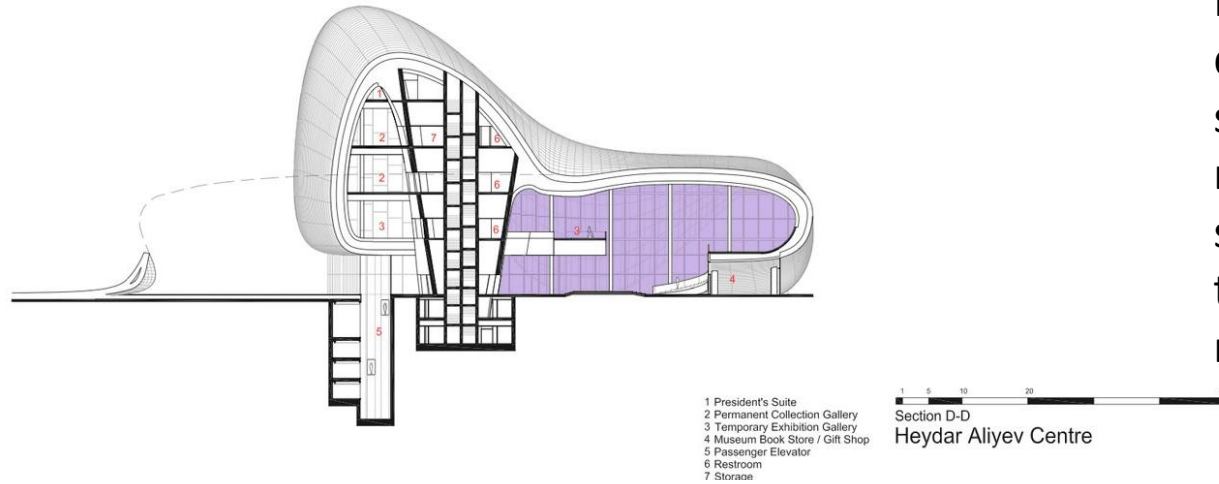


The **convention center** could be used for both convention and music performance with 1200 auditorium seats. **This section of 4 levels embraces 2 multifunctional conference halls, meeting rooms and the media center.** The auditorium is 18 meters height and spans approximately 28 meters supported by concrete shear wall around the space. To reach a large span, the **ceiling is constructed by two-way system and adopt steel space frame.** As for the **interial surface of ceiling, it is created by gypsum board supported by cables** to meet acoustical and lighting requirements. The first floor and second floor have a continuous large space and **transfer the self-weight to narrow reinforced concrete beams and columns at the base.** Then the loads are transferred to the pile foundation. Different sizes of cross bracing according to the height of seats are used to resist lateral force and stiffen structure. All information is shown in the **figure 4.**

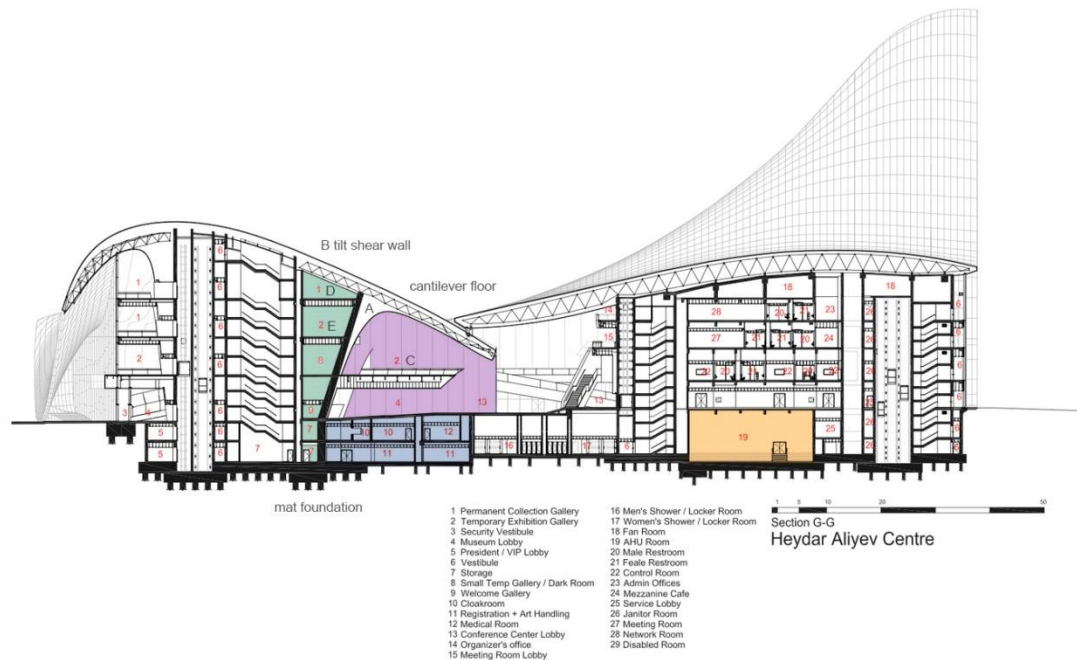


The multifunction hall is near the convention center which is divided into three smaller ones toward north in the garden. The hall spans about 27 meters with a height of 10.5 meters. **The ceiling of hall is constructed by steel open web trusses which have height of 2.2 meters, which is effective and could be used to resist deflections in a given size.** There are three meeting rooms with a concrete rigid system above the hall, which **transfer gravity loads to the concrete floor slab that is approximately 0.8 meter and trusses by columns and shear wall.** Then the hall transfers loads to slab, beams and columns at the basement which has a grid and patterns system through shear walls in the east, west and south.

The **museum** occupies 9 floors with exhibition halls, administrative office, restaurant and a cafeteria. It consists of a permanent gallery and a temporary exhibition gallery. **In the temporary gallery, a double-height space lobby is in the entrance with curve ceiling in the above. It has a very thin slab of 8-13mm thickness which covers the ceiling so they would have a very light self-weight transferring to the foundation.** The ceiling is made by steel trusses of nearly 1.5 meters height that support its self-weight as well, serving as a cantilever of 25 meters and transferring loads to the element B –the tilt shear wall with a wide of 1.4 meter. Then the **loads are carried by 3.1 meters thick mat foundation and 1.1 meter thick piles underground.** The element C is a cantilever floor that spans approximately 20.4 meters supported by the tilt shear wall. In order to reach the large span, the structure could be two-way concrete waffle slab with a height of nearly 2.2 meters. As for the basement, it is a grids patterns constructed by the concrete flat slab and columns.



In the **permanent collection gallery**, the space is divided by element B, the tilt shear wall. Element D spans nearly 9.8 meters while element E spans 8.2 meters measuring 1.2 meter depth. This beam in turn supports both dead loads and live loads from roof and the floor of exhibition and then transfer forces to the mat foundation.



The **library** is 8 stories seated in the north of site with a continuous exterior building skin in the façade. The AHU room is a large space that sits on a 1.2 meter **mat foundation** spanning 21.6 meters with a height of 9 meters. The 120-mm-thick reinforced concrete slab is supported by shear wall in four directions. The beam in turn supports the reinforced concrete slab every 3.5 meters by 0.8 meter depth. For the AHU room embeds in the finer grid, heavy girders are needed to carry more loads transferred from top elements like concrete columns, beams, slabs and trusses of the ceiling.

Wind load

Calculating wind load using the Generic formula: $F=A*P*C_d$

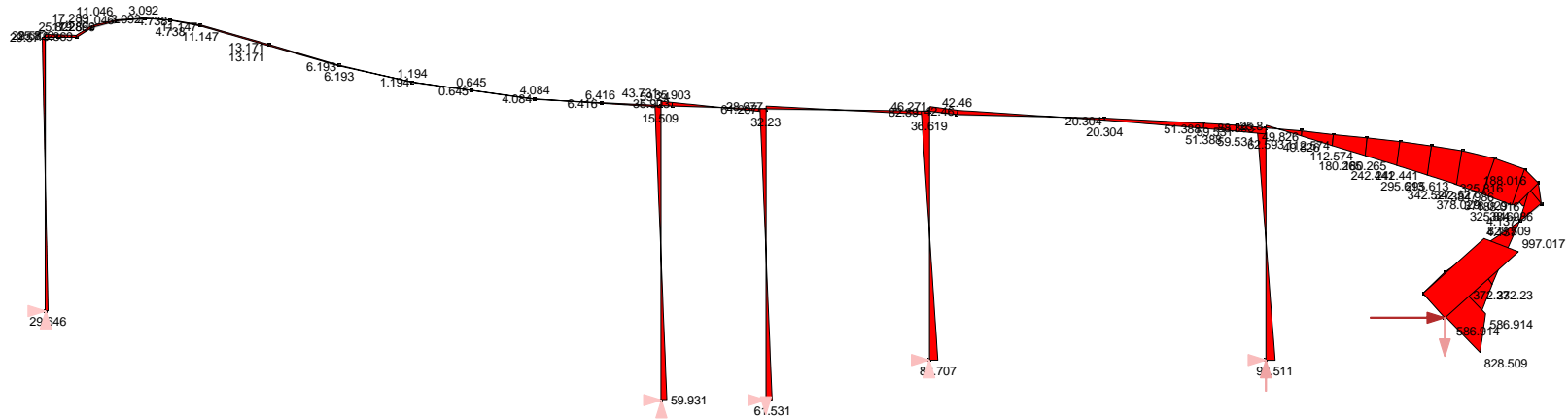
F is the wind load, A is the area exposed to wind direction, P is the pressure, C_d is a factor

The surface area of inner skin is 22,000 square meters, we estimate one sixths is exposed to the wind's direction, so A equals to 3666.7 square meters. P equals to 0.00256 multiplies the quadratic of V, which stands for local wind speed, and the number is 14mph. So we get P is 2.44 kilogram per square meters.

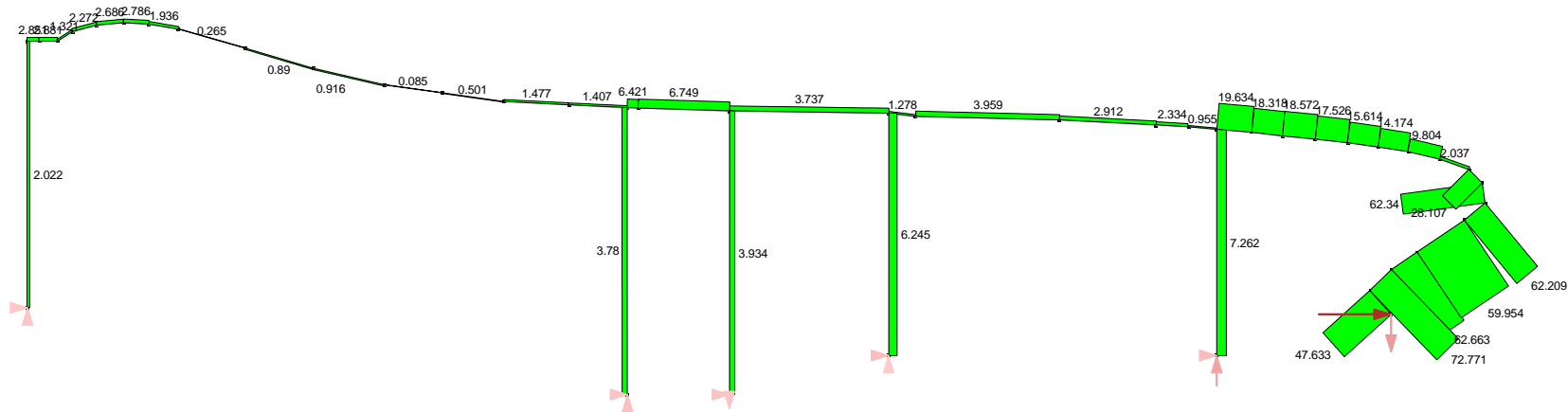
For a flat area, C_d is 1.4.

So we can calculate F is 3.72KN

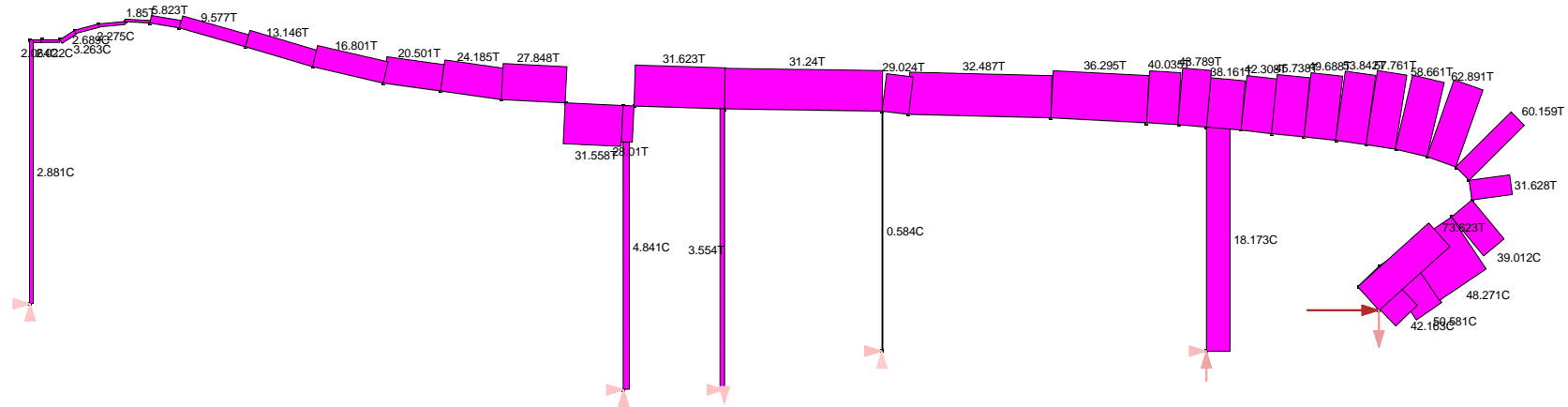
Moment Diagram under wind load



Shear diagram under wind load



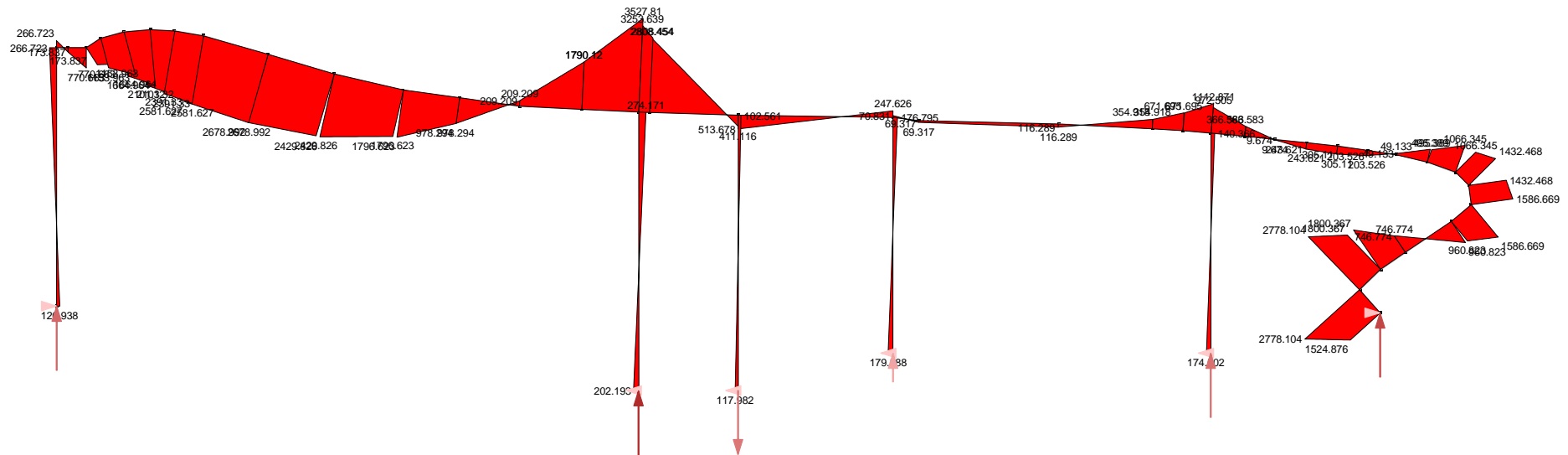
Member axial reactions under wind load



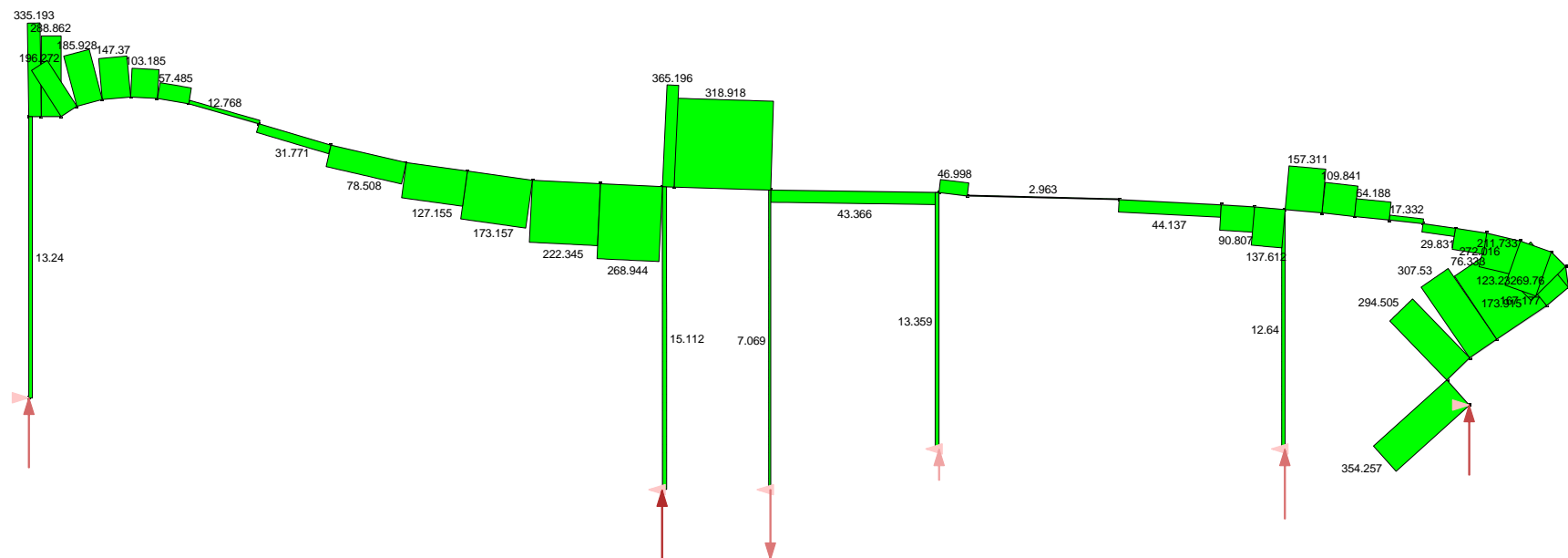
Gravity

- For gravity, The construction has been used 121,000 cube meters of reinforced concrete, 194,000tn formwork and 19,000tn mold steel. The density of reinforced concrete is 2400 kilogram per cube meters, so we can use 2400 to multiply 121,000 to get the weight of reinforced concrete, and the number is 290,400,000 kilogram.
- Since 1tn=907.2kg, and we already know it uses 194,000tn formwork and 19,000tn mold steel, we can convert it to kilogram. The weight of formwork is 175,996,800kg, while the weight of mold steel is 17,236,800kg.
- Adding these three number together, we can get the total weight is 483,633,600kg, or 4739609.28KN
- The total floor area is 101,801 square meters, so we use 4739609.28 divided by 101,801 to get 46.56 kN per square meters.

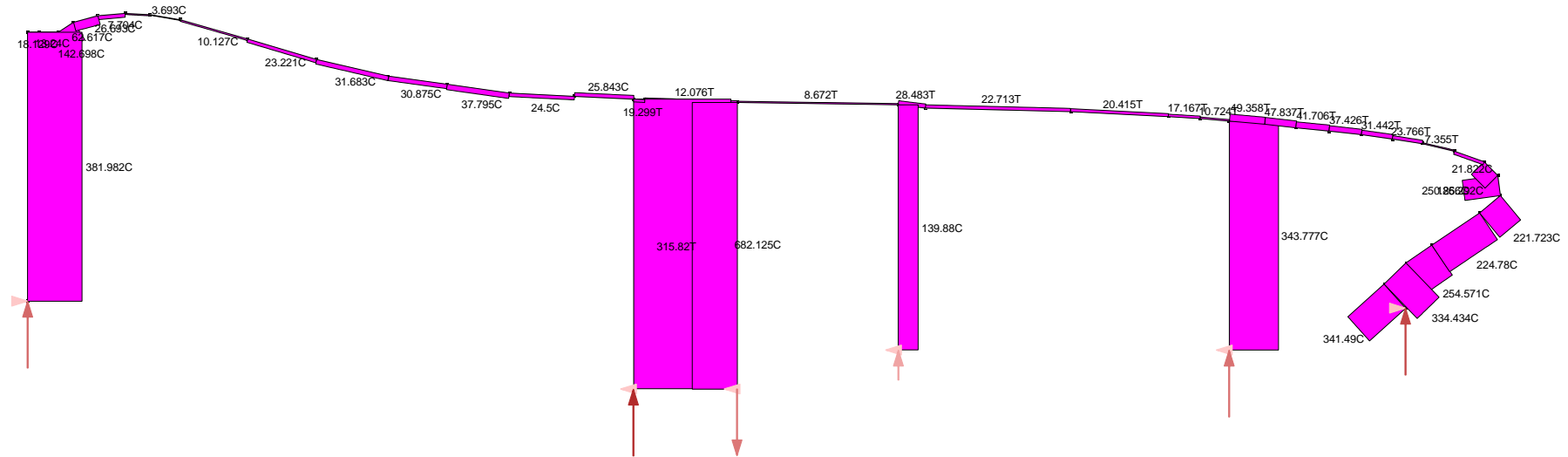
Moment diagram under gravity



Shear diagram under gravity



Member axial reactions under gravity



Summary

The design of the Heydar Aliyev Center establishes **a continuous, fluid relationship** between its surrounding plaza and the building's interior. This was achieved by using an ingenious and elegant structure system, which has **two collaborating systems**: a concrete structure combined with a space frame system. Because vertical structural elements are absorbed by the envelope and curtain wall system, **the large-scale column-free spaces** can allow the visitor to experience the fluidity of the interior.

Another important issue is the **building's skin**. To make the surface so continuous that it appears homogenous, a broad range of different functions, construction logics and technical systems were brought together and integrated into the building's envelope. It **makes the building appear homogenous** since different parts were covered and connected.

From this case, by analyzing the structural system and its relation with the exterior skin, we have seen how the structure design can better help the design concept come true.