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Design and Analysis of Various Type of Volumetric Modular Steel Structure and Connections

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Abstract –Within the scope of this report, modular steel structures have been designed in four different geometric shapes, and their structural static and dynamic analyses have been conducted. Each presented structure is designed with distinct geometric shapes and properties. The structures presented in the report resemble conventional buildings but are conceived and modeled with an optimistic perspective, entirely factory-finished volumetric modular structures, and are free from human factors.

The connections between modules in this report, weren't made patented steel connections from other companies. Instead, two different connection elements that eliminate the use of bolts and welding on-site have been designed to facilitate the assembly between modules. Local buckling, load-carrying capacity, and stress analyses of these connections have also been performed, with deformation values being kept below the specified limits. Some analyses were carried out manually, while others were performed using software such as SAP2000, IDEA Statica, SolidWorks, and Fusion. Architectural drawings, plans, and manufacturing details were created using Revit (2021) and Fusion. Renders were produced using Twinmotion, and architectural and engineering sheets were generated using Photoshop (2021). Other supplementary components were created using AutoCAD, Excel, and Word.

Based on the obtained results, a cost analysis was conducted to determine the cost advantages of the optimal design. In addition to costs, comparisons were made and presented regarding weight and feasibility among the structures. The study aimed to explore the various forms in which factory-finished volumetric modular structures could be realized and understand their behavior under static and dynamic loads with different connections. The collected data and findings have been shared.

Keywords – Volumetric Modular Steel Building, Modular Steel Structure Connection

I. INTRODUCTION

Steel, due to its reusability and strength, is a highly suitable material for structural purposes. When designed modularly, its appeal is further enhanced. This leads us to modular steel structures. Fully finished volumetric modular steel structures are a type of construction based on the concept of producing everything within a room's framework, interior and exterior facades, MEP equipment, and even furniture in a factory setting, achieving up to 90-95% completion. With advancing technology and techniques, these structures are rapidly entering the price-performance range, bringing numerous innovations and conveniences with them. They emerge as a sustainable type of construction, further bolstering their attractiveness due to their potential for long-term reusability.

In volumetric modular steel structures, structural steel elements are often selected in the form of box profiles. This choice is favorable in terms of both strength and applicability. One of the greatest advantages of these structures is their ability to expedite construction timelines, sometimes reducing them to a few weeks or even a few days. With such short construction periods, human errors are minimized, ensuring high levels of occupational safety. Dust and noise levels are significantly reduced, and vulnerability to adverse site conditions diminishes considerably. Reduced material transportation costs and a consistent material flow to the site minimize disruptions caused by urban traffic.

Modules can be connected to each other using various connection elements. This choice depends on factors like cost, feasibility, aesthetics, and requirements. Many construction engineering and architectural companies have their own patented connection elements. Notable examples include "Vector Bloc" and "Candle-Loc," both of which are patented connection products. Although the fundamental principles are similar, each connection has its specific strength and durability limits. **[29]**

Aside from the differences in connections, the volumetric modular steel structures, such as the frame, walls, and ceiling, can vary from one structure to another. Walls are typically composite and are often constructed using Light Gauge Steel (LGS). Additionally, mineral wool insulation is commonly used for fire protection, and gypsum board and paint are applied for interior finishes. Similarly, floors and ceilings are chosen and applied in a composite manner. Since modules are delivered to the site in a finished state, MEP (Mechanical, Electrical, Plumbing) designs are prepared in advance. Rooms with specific needs, such as bathrooms and kitchens, have their ceiling and floor heights determined and implemented accordingly. Ventilation openings are designed. In most cases, MDF or plywood is mounted on secondary beams in the flooring, and laminate or ceramic tiles are applied based on the module's intended use. Plumbing, electrical wiring, and other installations are completed within these composite elements in the factory, with thorough testing. Due to transportation considerations via trucks and ships, modules are generally designed to fit within the average road width in terms of maximum width and length. This ensures both comfort during transportation and ease of handling. **[8]**

The interactions between modules are examined along with the chosen connection elements, and their responses are measured. If the site is distant, transporting modules by sea is often the most advantageous and cost-effective method. Similar to other aspects, the method of foundation connection can vary from manufacturer to manufacturer. Different connections can be used as long as functionality and necessary strength values are met.

One of the most critical considerations in volumetric modular steel structures is the connection method and the connection element. Especially in multi-story buildings, the structure must function as a cohesive whole, necessitating careful attention. While frictional forces might be sufficient for a small, low-rise structure, they are insufficient for tall buildings. **[26]**

II. CLASSIC VOLUMETRIC MODULAR STEEL CONSTRUCTION

The designed classic modular structure has been conceived to be manufactured in a factory with minimal human error, meeting all structural and aesthetic requirements and intended to be assembled on-site. It consists of 3 floors, 12 apartments, and a total of 48+3 modules. Columns and beams are made of rectangular box profiles with a cross-section of 16x12x10, composed of S235-grade steel. The Module Rail, a square-section custom-made element that connects modules both above and below, is made from S235-grade steel with a cross-section of 10x10 when assembled. Additionally, there are Module Pins and Module Connectors that both connect modules to each other and pass through the inside of the box profiles to establish connections with lower modules. Corner joints of the modules are welded using electric resistance corner welding E4320, following the TS EN 10219 standard. Figure 1 depicts the structures in rooms and total building finish state.

To facilitate the stacking of modules and ensure their connection both horizontally and vertically, a Module Rail connection element has been designed. This connection element also serves as a secondary beam. The modules have a Module Pin connection element that passes through the interior of the box profile columns, ensuring their connection to each other. When multiple modules intersect at a point, they are connected to each other using the Module Connector connection element. The Module Pin connection element has been designed and implemented with the concept of utilizing the tensile strength of steel effectively within the modules. Figure 2 illustrate the use of steel and wood structures together.

The calculations have been carried out both manually (Fig.3.) and using software tools such as Sap2000, Idea StatiCa, SolidWorks, Fusion, and Revit in accordance with the relevant regulations. The required strength values have been achieved with the specified cross-sections. Dokuz Eylül University Faculty of Engineering Building has been used as a reference for the project location and seismic calculations. There are a total of 5 different modules.

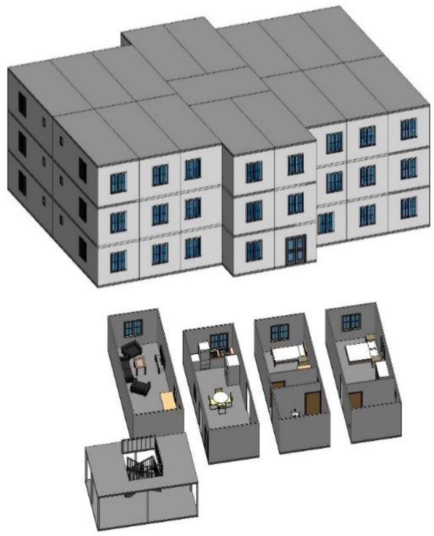

Fig. 1. 3 Perspective view of a 3-story modular structure, staircase module, and 4 room modules

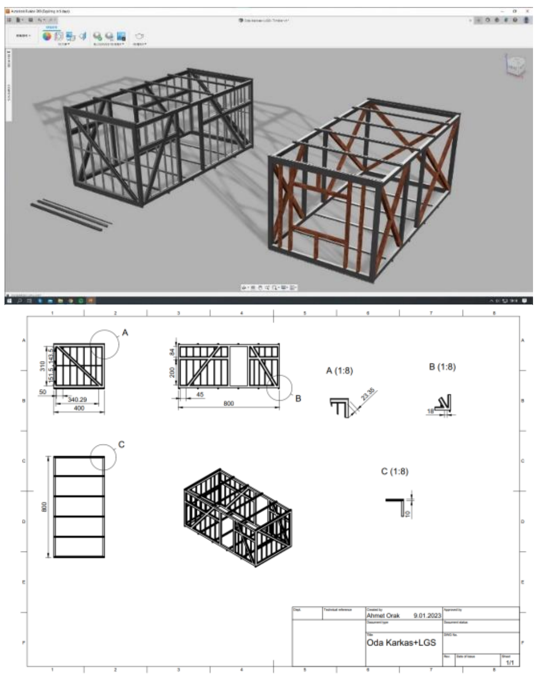

Fig. 2. Examples of module frames composed of different structural elements and module manufacturing detail

The walls will be assembled and applied according to the material details. The wall thickness is 12 cm in each module. Shear force and moment values for module corner joint analyses were obtained using Sap2000 that we can see in Fig. 4. (From Revit to IDEA StatiCa using BIM) (Eurocode EN1992-1991(2005)). Quantity and cost table illustrated in Table 1.

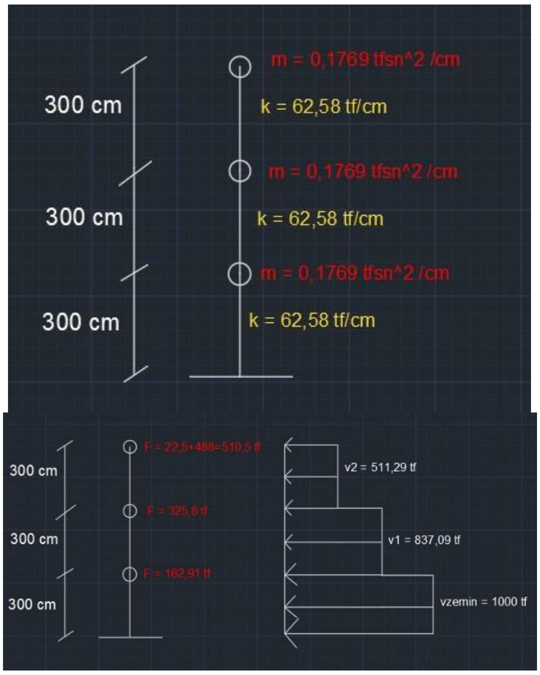

Fig. 3. Calculation model for equivalent seismic load

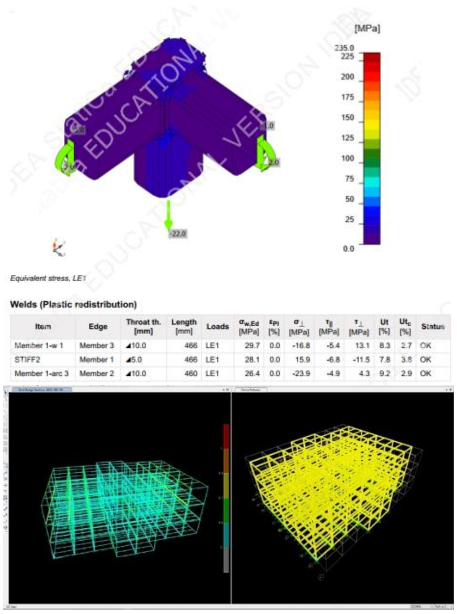

Fig. 4. Module corner joint analysis stress results, Sap2000 "Design Check" control

Table 1. Quantity and Cost

	Kolon - RHS160*120*10	Kiriş - RHS160*120*10	Tali kiriş - SS10*10 Modül Ray	Modül Şiş ve Modül Bağlayıc
Adet	288 adet	480 adet	576 adet	288 adet
Toplam Ağırlık	35,424 ton	78,72 ton	34,784 ton	9,68 ton
Birim Uzunluk	3 metre	4 (384 adet) -3 (96 adet)metre	3 metre	3 metre
Toplam Uzunluk	864 metre	1824 metre	1632 metre	864 metre
Birim Fiyat (m. Başına)	433 lira (iskontolu)	433 lira (iskontolu)	1300lira (tahmini)	250 lira (tahmini)
Toplam fiyat	374112 lira	789792 lira	2246400 lira	216000 lira

III. GREAT PRIZM OF LIFE MODULAR BUILDING

The Great Prizm of Life primarily serves as housing, but it is also designed to be adaptable for purposes such as hotels, hospitals, etc., as needed, or desired. It is the result of intelligent designs that are self-sufficient and can function on their own. Figure 5 visually explains the perspective views of project. The project takes inspiration from concepts like the food pyramid, the triangle of life, and pyramids. It offers an innovative perspective to address pressing issues such as global warming, deforestation, and resource depletion, which are strongly relevant to today's ecosystem. In the project, the Kir tree, Pasakılıcı, and Devetabanı plants will be used due to their significant oxygen production and visual characteristics.

The modules are connected to each other in various ways, resembling a staggered brickwork pattern, using only the Module Rail. This design aims to demonstrate that sustainable modular structures can transform into different conventional structures, highlighting the feasibility of the concept. **[26]**

The location of the project was deliberately chosen as Cape Town (Mother City). Given the recent severe water scarcity experienced by the city, resulting in the felling of trees for water conservation, The Prizm of Life presents an absolute solution for sustaining life. It achieves this by addressing both indoor water needs for toilets and flushing, as well as outdoor plant/tree water requirements on the building and landscaping. Rainwater is directed to modular water reservoirs installed beneath the parking area, effectively utilizing the water that falls on the structure. The design also incorporates solar panels above the parking area to power water pumps, building lighting, shared utilities, and even some of the household electrical needs. **[12]**

Fig. 5. Building perspective views

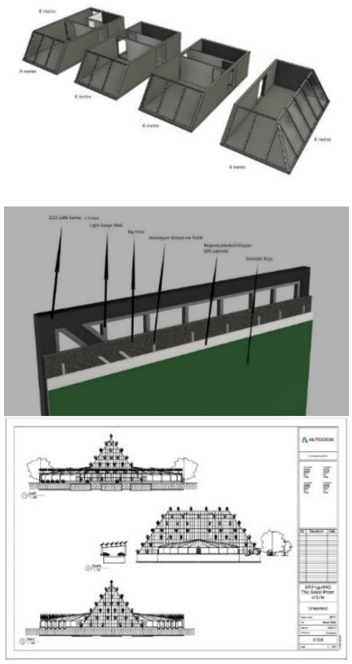

Fig. 6. Room modules perspective view, wall interior structure and layers, building views

Each apartment is composed of 4 or 5 smart room modules and accordion-style elements called "Kordeon." Each room module includes its own framework, fire safety measures, MEP (Mechanical, Electrical, Plumbing) design, a system for watering plants at the window without the water being visible as it travels through the interior of the steel frame, furniture, and ventilation system (Fig. 6.). There's a 60 cm space (false ceiling) on the ceiling of each module, through which the ventilation system circulates, ensuring fresh air exchange by moving through each module corner to corner on each floor.

The accordion-like structure, called "Kordeon," is made of ETFE material, columns, and beams. ETFE is a polymer plastic that is transparent like glass, yet lightweight and highly durable. It consists of two layers filled with air, offering high light transmission while providing insulation against heat. Similar to an accordion, it can be opened and closed from one side to the other. Inside the Kordeon structure, there are play areas, a gym, a game room, and cafeteria spaces designed for both children and adults.

ETFE panels are used for the walls and roof, providing a transparent and lightweight enclosure. ETFE, or Ethylene Tetrafluoroethylene, is a fluorine-based plastic that offers excellent light transmission and insulation properties. It consists of two or more layers of ETFE film that are inflated to create a pillow-like structure. This construction allows for efficient use of natural light while maintaining a comfortable indoor environment. ETFE is also known for its self-cleaning properties due to its non-stick surface.

Furthermore, the Kordeon structure can be easily opened and closed, offering flexibility in its use. It houses playgrounds, sports facilities, game rooms, and a cafeteria, catering to both children and adults. Notably, the Kordeon can be detached and reassembled next to another structure, serving a different purpose as needed.

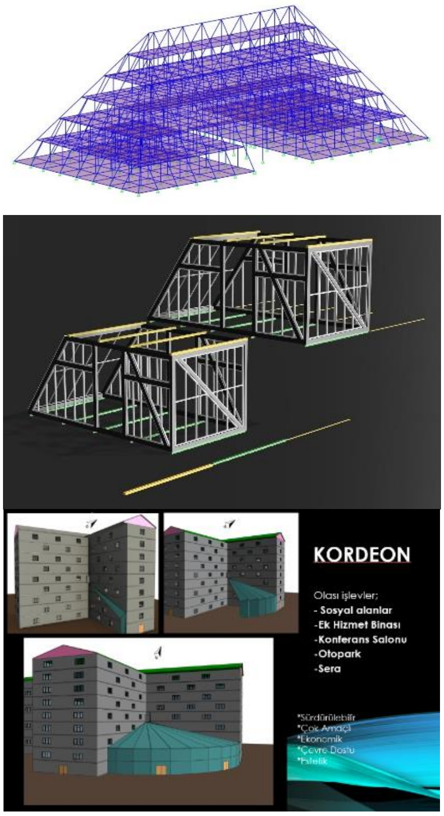

Fig. 7. Sap2000 model, 2 modules with Modul Ray connection, Kordeon promotion poster

The project emphasizes the advantages of steel. The project consists of a total of 42 apartments and 158 modules in a building with a ground floor and 5 upper floors. Each module is individually designed to include all necessary features and preferences and is manufactured and assembled in the factory before being transported to the site. **[10]** The Module Rail was designed to optimize construction and reduce human errors on the construction site, enabling the completion of the building within a few days. Therefore, no bolts or welding will be used. The assembly of the modules will resemble a staggered brickwork pattern, and details have been provided. The socially-oriented design of the Kordeon structure also features beams and columns made of S235-grade steel. The Kordeon structure is supported by a 3-layer ETFE material filled with air. Low-E insulated glass with EPS insulation has been used for the exterior windows, providing thermal insulation.

In the calculations, the entire structure was first modeled and analyzed in the SAP2000 program that we can see in Fig. 8. Then, a module-based approach was taken, and the analysis of each module was conducted based on the static and dynamic loads affecting them. Additionally, the Kordeon structure, which serves as a social space, was modeled in SAP2000 and analyzed under static and dynamic loads. The connections were analyzed using the IDEA StatiCa program. The connections of the factory-produced framework (S235) are welded (E4320), and the stress, deflection, and load-bearing capacities of corner joints were analyzed. **[7]** Figure 7 is created with Sap2000, Fusion and Revit programs.

The Modul Ray connection element, aimed at eliminating the use of welding and bolts on-site and minimizing manufacturing errors and construction time, was modeled in Fusion and solved in SolidWorks. The design was initially sketched and analyzed with estimated thicknesses before optimization. After optimization based on section properties, a smart design was achieved that could safely carry the same loads as the initial design with half the section size. For simulation purposes, a sample of 2 rooms and Modul Ray connections was drawn in Fusion. The frames of the modules and Modul Ray are designed using S235 steel grade, including Light Gauge Steel (LGS). The suitability and sufficiency of corner joints and sections (RHS 16012010 mm box profile) were determined under transported loads. **[18]**

Rainwater collection channels have been designed to allow rainwater from the external glass facades and the ETFE coverings of the Kordeon structure to flow down to the ground and be collected. These channels direct the water to modular water reservoirs placed beneath the floor of the parking area, with three tanks totaling 350 cubic meters. The project area is set in Cape Town, where the average annual rainfall is 52 millimeters. When multiplied by the total collection area of 3000 square meters, this corresponds to an average annual water volume of 1800 cubic meters that can be collected. The water collected will be utilized for various purposes within the project.

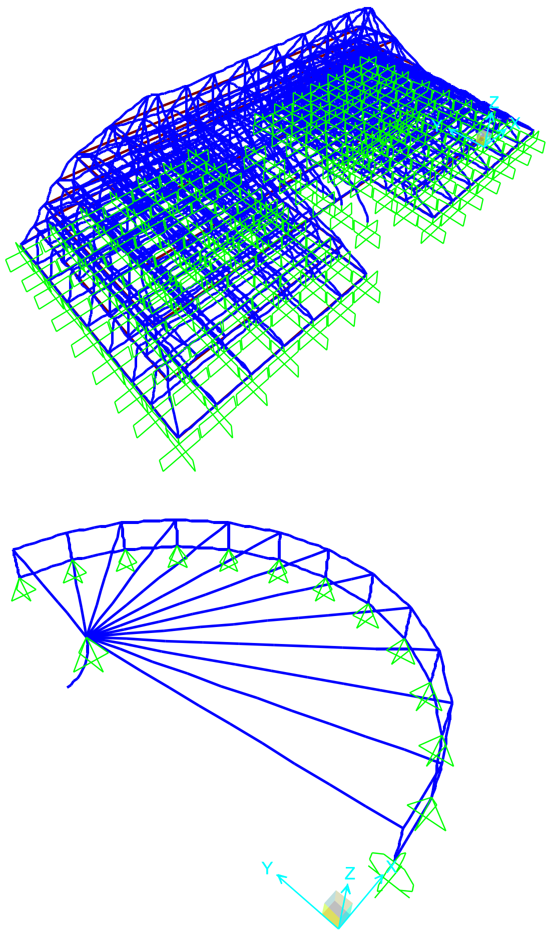

Fig. 8. Deformation of main structure and Kordeon under loads

Water consumption calculations have been made based on the tree diameters. The water needs for the trees (106 trees) on the main structure (Prizm) and the trees in the landscaped areas will amount to an average of 800 cubic meters per year. The remaining 1000 cubic meters of water will be pumped into the modules for use in toilets and flushing. The water intended for the trees on the main structure will pass through the interior of the steel frames (16012210 section) on the exterior facade. The inner parts of the box profiles that carry water will be coated with a plastic layer to protect the water from the steel. **[15]**

Solar panels (96 panels, 390*289 cm each) placed on top of the parking area's flooring will convert sunlight into electrical energy throughout the year. This energy will be used for water pumps, building lighting, and common electrical expenses of the building. **[28]**

Metal plates have been designed to encase the trunks of the trees in planters placed within the modules. These plates prevent the scattering of mud and dust during heavy winds and rain.

The ground of the project site is classified as Class B, and a continuous foundation has been designed. The connection between the foundation and the modules will also be achieved using the Modul Ray system. The connection between Modul Ray and the foundation will be established using chemical anchor bolts. **[21]**

IV. MODULAR PIZZA BUILDING

Structurally, this building, which shares the cross-sections of classic rectangular columns and beams as well as those of our "The Prizm of Life" project, has been developed to demonstrate that in modular steel structures, beyond structures with sharp-edged, straight-section elements, it is also possible to create volumetric modular structures with oval or circular profiles. Here Figure 9. Illustrates non-sharp edged and circular modular building and room modules.

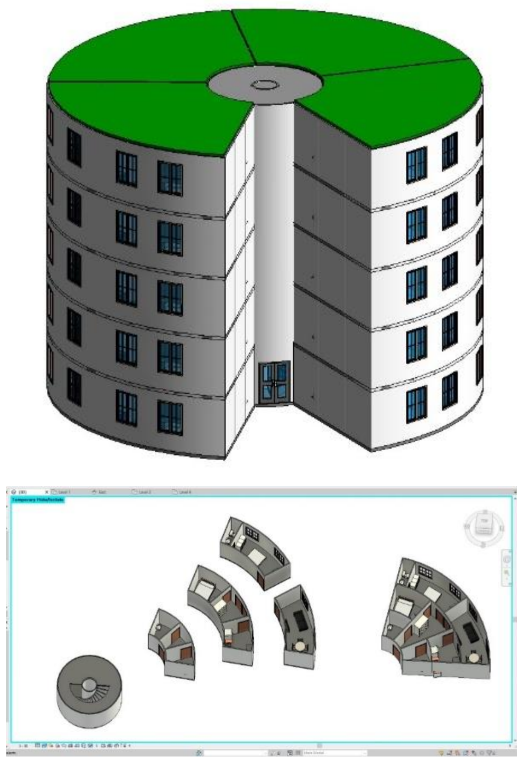

Fig. 9. Building perspective view, stair module, 4 types of room modules and a apartments formed by these

There are 4 apartments on each floor, and each apartment consists of 4 different modules. The building is designed with 5 floors and will serve a total of 20 apartments. The disadvantage of this modular structure lies in the increased cost due to the custom-made circular beams. The total cost of structural elements is expected to be 2-2.5 times higher compared to regular modular structures.

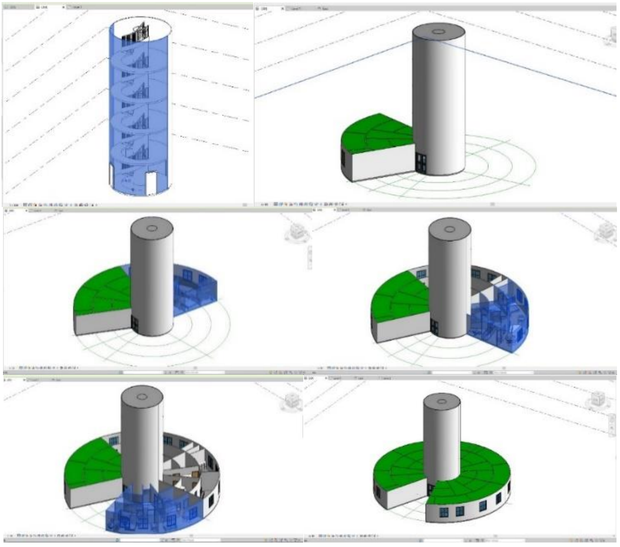

Fig. 10. Pizza structure view module by module

The staircase and elevator system have been modularly designed as shown in the Fig. 10. , with each floor having a combination of 2 separate modules. The modules and apartments have been placed around pre-installed staircase-elevator modules. Our structure has been modeled in SAP2000 (Fig. 11.-12.) and IDEA StatiCa programs, and their analyses have been conducted.

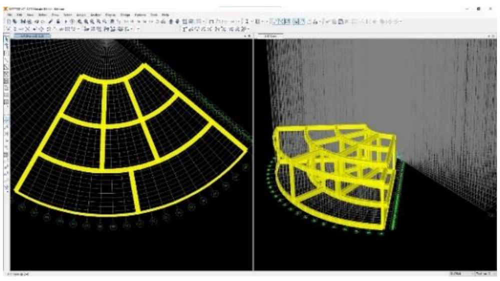

Fig. 11. Sap2000 apartment static model

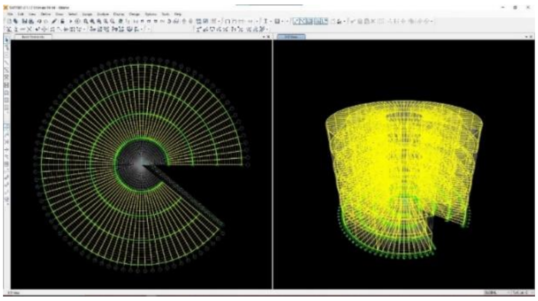

Fig. 12. Sap2000 Pizza statik model

V. MODULAR OPENING AND CLOSABLE STEEL TREE HOUSE (TRAYNA)

Taking a different perspective on modular structures, Trayna emerges as a design that is foldable and mountable onto a tree. Through the use of two long flat pieces mounted on either side of the tree, Trayna is designed to be easily transported to the site and effortlessly assembled onto the tree. Figure 13 illustrates presentation of the project.

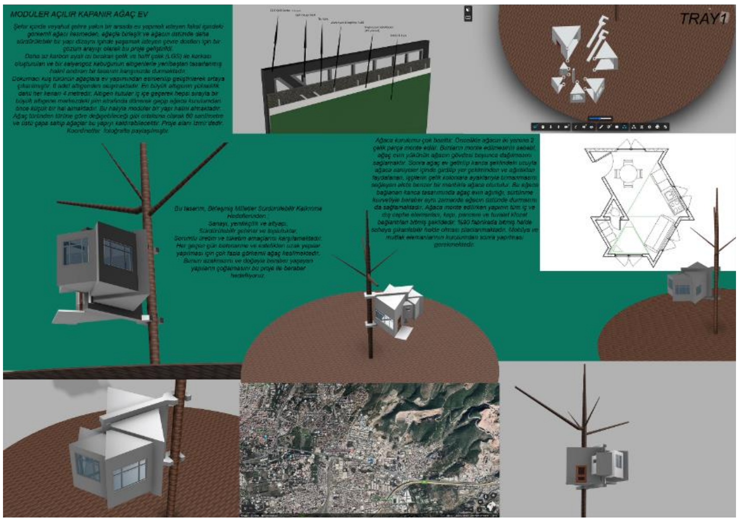

Fig. 13. Modular opening and closable steel tree house poster

Developed as a solution for environmentally conscious individuals who want to build a house within or near a city without cutting down the magnificent tree on their property, and instead live in a sustainably integrated modular structure atop the tree, this project has been devised. Trayna stands before you as a design reminiscent of a snail shell reimagined with hexagons, constructed with

S235-grade steel and light gauge steel (LGS) to form its framework.

Inspired and evolved from the nesting habits of weaverbirds, Trayna consists of six hexagonal units. The largest hexagon, including its height, measures 4 meters per side. The hexagonal boxes nest within each other, revolving around a central pin in the larger hexagon sequentially, contracting in size before mounting onto the tree. In this state, it takes on a modular structure.

The installation onto a tree is remarkably simple. Firstly, two steel pieces measuring 800 * 2.5 * 10 cm are mounted on either side of the tree. These are installed to ensure that the weight of the treehouse is evenly distributed along the tree's trunk. Following this, the treehouse is brought to the tree and effortlessly positioned using a hook-shaped mechanism. This mechanism, resembling a device that utilizes gravity and weight to aid workers in ascending steel columns, allows the treehouse to be placed on the tree within seconds, harnessing the forces of gravity and weight to assist the workers in their climb. The hook attached to the tree not only supports the weight of the treehouse but also employs friction to hold it firmly atop the tree. During installation, all interior and exterior elements of the structure, including doors, windows, and toilet connections, are completed. The aim is for it to be 90% finished when transported from the factory to the site. Furniture and kitchen elements are to be installed after mounting. Depending on the tree species, but generally, trees with a diameter of 60 centimeters or more can accommodate this structure. As each day sees more magnificent trees being felled for the construction of concrete and aesthetically detached buildings, this project strives to decrease this unfortunate trend and promote the growth of structures that coexist harmoniously with nature.

VI. MODUL RAY

The "Modul Ray" is a connection design for modular and volumetric steel structures. There is no similar connection design available. The aim of the Modul Ray design is to minimize errors arising from labor and thus human and environmental conditions. It enables construction sites to complete buildings with all details in a matter of days. The skeletal framework, fine craftsmanship, installations, and furniture are all included in the fully finished volumetric steel modules, which can be easily connected to each other using cranes. Large structures can be completed in a matter of days with only a few workers and equipment, significantly reducing on-site costs. This drastically reduces noise and other negative aspects and has minimal impact on city traffic compared to traditional construction sites. The upper part connects to the lower part and complementary rods also enter the interlocked parts to complete the assembly of the modular rail and volumetric module. The connection between the foundation and the modules will also be made using the Modul Ray. The connection of the foundation to the Modul Ray will be done with chemical anchors. Figure 14 visually shows the structure of Modul Ray.

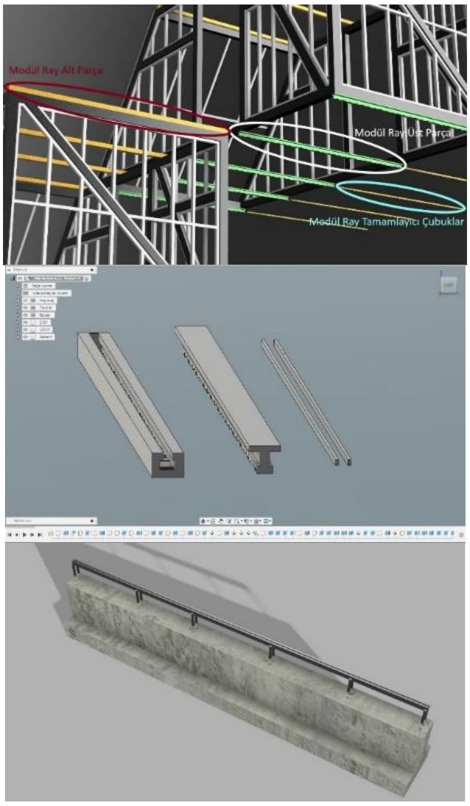

Fig. 14. Modul Ray connectors, Modul Ray parts, Modul Ray and foundation connection

"Modul Ray" is a connection design for modular and volumetric steel structures. There is no similar connection design available. It has been designed as a means to facilitate the assembly of innovative, environmentally friendly, portable, volumetric steel modules that are becoming increasingly popular in Europe and America. These modules, which make extensive use of the advantages of steel and are manufactured in factories up to 95%, can be assembled in a manner reminiscent of interlocking bricks, allowing for quick installation. Modul Ray aims to eliminate the use of welding and bolts in the field, reducing manufacturing errors and minimizing construction time. The design element of Modul Ray was modeled in Fusion software and solved in SolidWorks software.

The upper part shown in Figure 14 , as well as the lower part and complementary rods, enter the interlocked parts to complete the Modul Ray assembly. Initially, the design was sketched and analyzed with estimated thicknesses, followed by optimization. After optimization of the sections, a smart design was achieved that could safely carry the same loads as the original design with half the section sizes that illustrated in Fig. 15. These mentioned loads include dead and live loads in a room module. This means that Modul Ray serves both as a connecting element and a load-bearing element. In the calculations, the S235 steel grade was used.

Bringing the invention to consumers in our country could have lower costs due to local expenses. However, exporting it abroad has the potential to yield substantial financial returns. This is because steel structures are expensive in our country, and reinforced concrete can be more cost-effective. With labor costs in our country being notably lower than in Europe and America, products can be sold to those regions at a more competitive price, leveraging the lower labor costs here, which would still result in lower costs compared to their domestic prices. This would create a source of income for workers and employers producing and exporting volumetric steel modules with Modul Ray connections in our country.

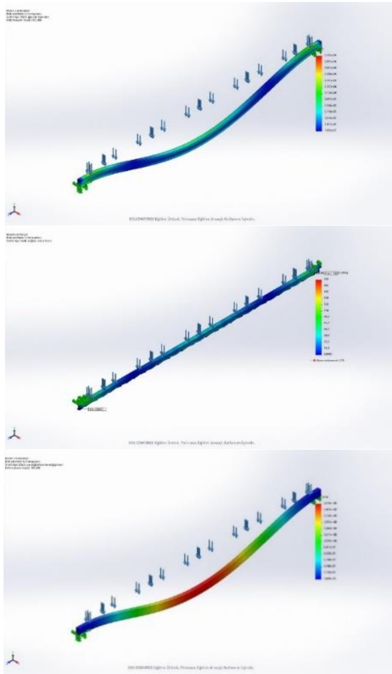

Fig. 15. Modul Ray strain analysis, stress analysis, displacement analysis (SolidWorks)

As evident from static solutions, the design is sufficiently robust and practical.industrial settings, once manufacturing is completed using these dimensions, the assembly can be achieved by attaching the modules horizontally using cranes to either the lower module or the foundation in a single direction, in conjunction with completing the volumetric steel modules in the factory.

VII. MODUL PIN AND MODUL CONNECTOR

"Modul Pin" and "Modul Connector" are connection elements designed for modular and volumetric steel structures. There is no similar connection design available. These connection elements are designed to eliminate the use of welding and bolts in the field, aiming to minimize manufacturing errors and reduce construction time. They were modeled and solved in Fusion software that illustrated in Fig. 16. The steel grade is S235.

"Modul Pin" is an element that passes through the box profile columns and facilitates the connection between the modules. It was created and implemented with the concept of utilizing the most effective tensile strength of steel in the modules. When there are multiple intersections of modular elements, they are connected to each other using the "Modul Connector" connection element. "Modul Pin" was modeled in Fusion software and under necessary stresses, factors such as safety, stress, tension, and contact forces were measured and analyzed (Fig. 17.)

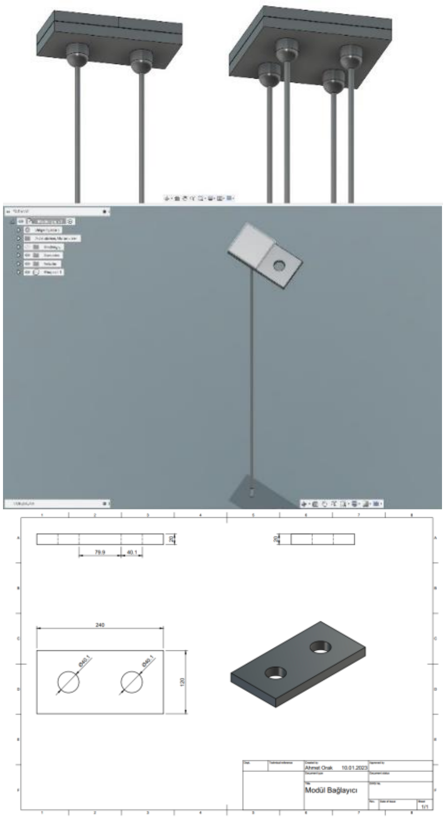

Fig. 16. Modul Pin and Modul Connector connections parts

For the analysis, the loads applied to the connection element have been taken from the vertical seismic equivalent load. According to TBDY 4.4.3; Ed (z) = (2/3)* Sds*G = (2/3)1.151.75 = 1.34 tons, each Modul Pin connection element is affected by this load.

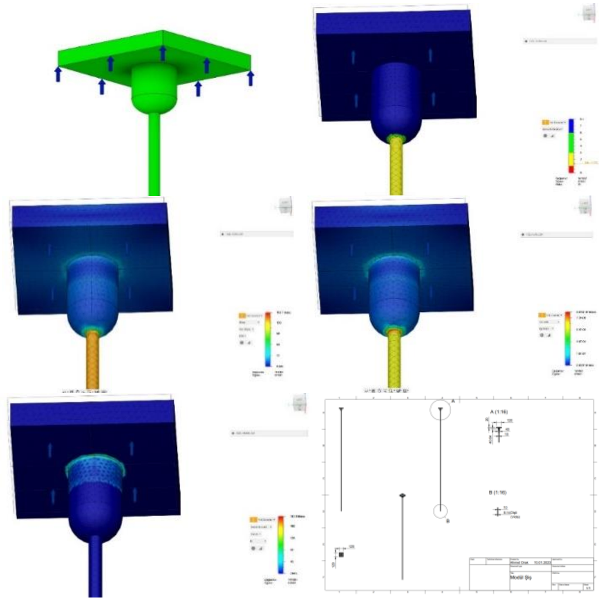

Fig. 17. Modul Pin applied forces, safety factor, stress, tension, contact force analysis and values (Fusion)

VIII. RESULTS, DISCUSSION AND CONCLUSION

Volumetric modular steel structures are largely manufactured in a factory environment and then transferred to the construction site. While some modules contain only structural elements, others include both internal and external facades, and some even come with finished furniture, all of which are assembled on-site. This approach aims to minimize errors caused by human factors and enhance production efficiency, while avoiding the negative impacts of adverse weather conditions on the construction site. However, fully finished modules are not yet prevalent in today's volumetric modular steel construction market, and on-site assembly of connecting elements is still required.

In this project, four volumetric modular steel structures have been designed to be constructed without the need for welding or bolting, ensuring a seamless assembly process. To achieve this, more user-friendly and functional connecting elements have been designed. Two different types of connections have been developed (Modul Ray – Modul Pin and Connector), which will expedite and simplify the module assembly process. These two connection types can be used together or separately. If only Modul Ray is used as the connecting element for module assembly, modules need to be assembled similar to interlocking bricks. This requires proper optimization to ensure column alignment and overall structural integrity. If only Modul Pin and Modul Connector connections are used for module assembly and proper calculations are performed, there should be no issues, as these connection elements join the corners of the modules both in the x and y axes and in the z (vertical) axis.

One of the designed structures in this project is a three-story building featuring fixed rectangular room modules. This design stands out due to its ability to be fully assembled without welding or bolting, making it more efficient compared to similar volumetric modular buildings. It offers stability and can be produced in a factory setting using a series production approach. The structural components are cost-effective, and the design is economically sound.

The "Prizm of Life" building design aims to demonstrate a fully sustainable structure achieved through modular construction, which is a pioneering approach in sustainable building design. Inspired by the Great Pyramids of Giza, this design features a slope of 54 degrees, similar to the largest pyramid. While resembling other modular structures, it differs in terms of its sloped external structure, varied module sizes, and the exclusive use of Modul Ray and Modul Pin-Modul Connector connections. This design can be used for residential or hotel purposes, as well as offering social spaces, rooftop greenery, and rainwater collection capabilities. The sloped exterior, however, increases labor and production costs.

The "Modular Pizza" design showcases that not only rectangular or square modules are viable in volumetric modular steel construction but also slanted modules. It highlights a design that can be efficient and functional. The structure uses the same structural elements as other designs, with Modul Pin-Modul Connector connections. If both the rectangular and the Pizza designs occupy the same area and are built, the rectangular design would be more cost-effective due to the added cost of the sloped elements in the Pizza design.

In the context of sustainability and harmonious living with nature, the "Trayna" modular structure is designed for those who seek a peaceful lifestyle among trees. This design features retractable modules that can be easily placed on trees without any additional processing. It facilitates easy transportation and fits together when moved. It offers a unique perspective and is economical in terms of both assembly and moving. Additionally, its long-lasting nature is ensured with proper maintenance.

Through research, the four architectural designs and two steel connection element designs presented in this report demonstrate the applicability of volumetric modular steel structures for a wide range of conventional and unconventional building projects. The differences, advantages, and disadvantages of each design have been highlighted. While these structures may not be attractive in today's economic conditions in our country, considering the lower labor costs here and the potential profitability of exporting to foreign countries through proper planning, the benefits to the construction sector should be consider.

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