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Structural Design of a Building: A Comprehensive Overview

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Abstract: When determining a building's structural design, designers must comprehend the subsequent processes. Building a residential, commercial, or industrial structure that can withstand all applied loads without failing over the course of its lifetime is the primary goal of structural analysis and design. A simplified, step-by-step procedure is used by structural engineers to design a structure that is structurally sound. The structural analysis and design process is facilitated by BIM tools such as Tekla and Autodesk Revit. An architectural piece needs to be both occupant-safe and structurally sound. Typhoon and earthquake resistance should be built in. The maximum shear and moment forces that occur in floor beams, columns, or stresses in steel trusses should be known by architects with sufficient expertise. As a result, the building's components, lifetime, Quality, strength, and other factors are affected by the structural design evaluation's missing sequence. You can follow the instructions in this document to design a building step-by-step: conceptual design, load analysis, structural analysis, system design, and other ideas in this document.
Keywords: Building Plans, Shear Force, Torsion Stress Diagram, Bending Moment Diagram, BIM Software, Load Analysis.

I. INTRODUCTION

A. Indian Architecture History

Our past dramatically influences how our present will be. The antique technology that our ancestors used is incredibly iconic. In ecological balance in the early ages. To preserve the environment's natural beauty, they firmly felt that to create a gorgeous scene. India currently possesses 3650 or more outstanding historic heritage buildings and places significant to the country.

India is renowned throughout the world for its diverse culture and its contributions to it. When considering every heritage building, the construction method and structural stability that guarantees its survival even today despite being subjected to calamities, artificial disasters, and carelessness stand out as common factors that appear to be distinctive. Supports and contributes to our nation's unique cultural legacy. Each building has a striking originality and specialty when divided into numerous architectural types and styles. I am not sure if the English or our Aryan ancestors contributed to the field of building. However, these locations come up with many unusual, even though some structures.

Moyna Garh, located in the Purba Medinipur area of India's West Bengal, is one of the most significant discoveries of humankind in Fig. 1. Two concentric wide moats with enormous mounds extending up to 13 acres ultimately ring the fort. The fort is only accessible by water. The first moat is 200 meters away from the second. The defense makes a magnificent setting because it is dense, concentric foliage. With the passage of time and development, just one moat remains. The West Bengal Heritage Commission currently owns Moyna Garh.

Fig 1. Satellite Image Of Moyena Garh Palace In 2014 And 2015, West Bengal

B. Architectural Implications

1) Location

Historical precincts have paved the way for other well-known constructions by serving as examples of using avant-garde methods in earlier eras. To protect the buildings, it is evident that a natural security scape has grown up around the enormous moat of Moyena Garh.it is that they planted bamboo plantations liberally around the canal and introduced crocodile infestations into the deep jungle. It amplifies the strong sense of security organically grown in the area. Around the boundary, a robust ecological field had grown. The place offered sustainable resources and was self-sufficient.

2) Aspects of The Architecture

In earlier centuries, the architectural style of Europe was present in all the forts. A sequence of arches supported the massive load-bearing structures in Fig. 2a and Fig. 2b, helping to distribute the load uniformly and uphold rhythm and harmony—buildings using a courtyard planning strategy, which enhances natural ventilation. The construction method was straightforward but excellent. One of the most cutting-edge techniques used by individuals was the final calculation of a load-bearing wall constructed of brick building. It served as a brick lintel on which as well.

Fig 2a. The Series Of Arches And The Courtyard Inside Tamluk Palace, West Bengal

Fig. 2b Details Of Brick Arches Acting As A Lintel For Bearing The Load

Burnt clay bricks and lime mortar were the most widely used building materials. The makeshift kiln built on the site produced smaller bricks with a height of 2 inches. Brick to construct the pillars, giving them their own, typically round, shape. Even though it appears flat outside, the temple's interior has a dome-shaped roof. This technique makes the construction heat-resistant. Round arches and multi-foiled arches transport enormous loads without harming the structure beneath them, which helps to reduce costs.

Rani Rasmoni established the Dakshineshwar Kali Temple in Kolkata in 1855. The building's 'Nava-Ratna' style, or nine spires evenly spaced on each corner and in the upper-story center, represents typical Bengali architectural form in Fig. 3. Materials like lime mortar and brick were used to build the spires. The temple's interior has a vaulted roof. The three-story temple is perched atop a lofty platform that leads up to it by stairs. The attractive multi-foiled arched entrance improves the building's architectural appeal while also providing stability for the tall, heavily weighted spires at the top. Arches are thought to be capable of supporting large loads while also lowering construction costs.

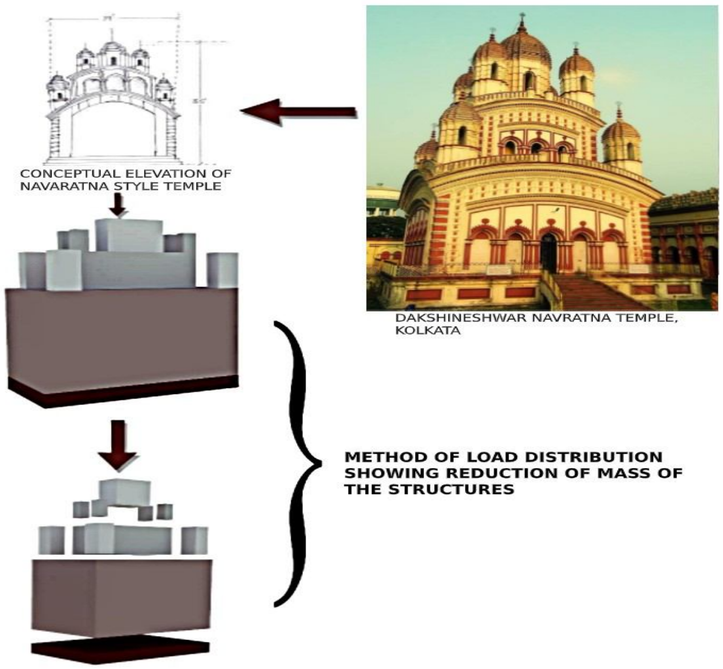

Fig. 3. Dakshineshwar Kali Temple At Kolkata, West Bengal, And the Multifoiled Arch Highlighted

The structure's burden was distributed unusually from the top to the bottom. It can be observed in the above image that the mass of the system maintained a lowering from the base to the top. This unique load reduction method can prevent a max and the Multifoiled Arch Highlighted.

Any religious edifice with a flat roof would always have dome roofing within in Fig 4. It was thought that by using this construction technique, heat inside the structure would be reduced. To prevent heat transfer inside, the space between the flat roof and the dome was typically filled with dirt and rice husk. Even the columns were constructed of brick in Fig 5. This decreased the need for cement concrete and increased the structure's strength.

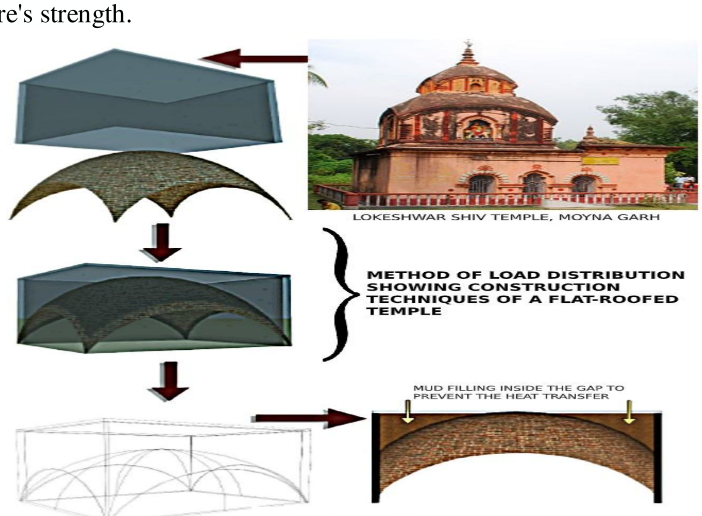

Fig. 4. A Conceptual of Distribution of Load From Top to The Plinth of The Structure

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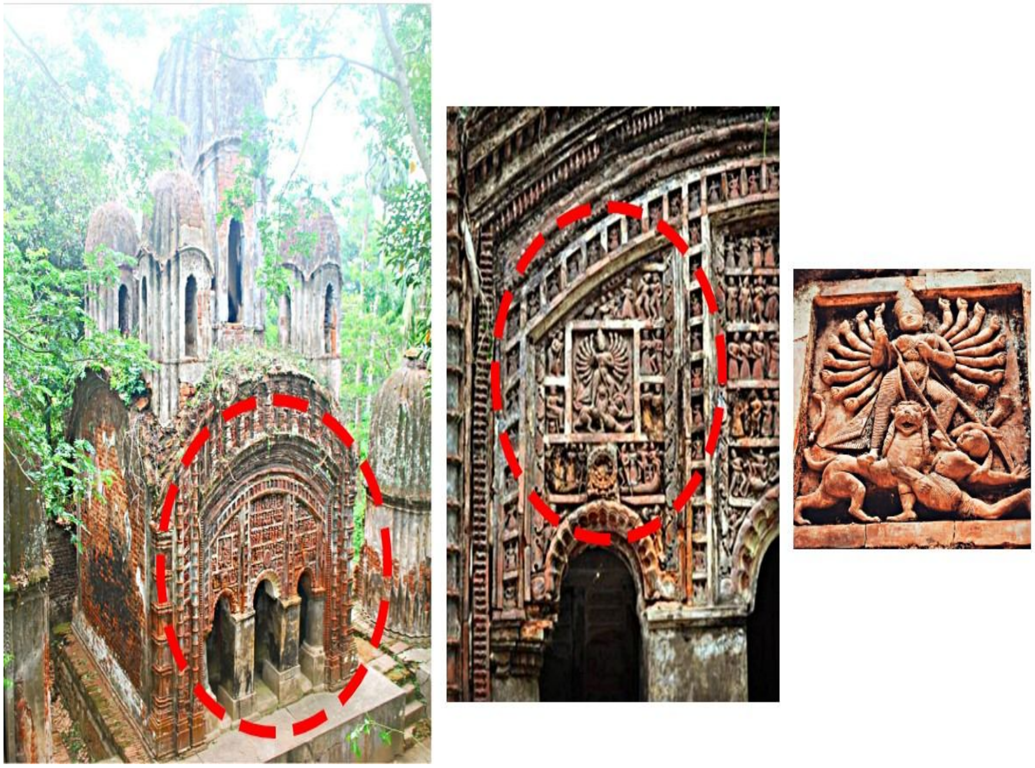

Fig 5. Terra-cotta Tile Art at the temple in Purba Medinipur, West Bengal

3) Building Specifications

Terra-cotta tiles that were curving in different shapes and figures provided the building's outer face with the finishing touch. When decorating a home in the past, this was the cheapest and most popular option. These tiles, which were curved into a variety of human or geometric patterns, highlighted its many legendary figures or settings. Beautiful flower motifs on pilasters served as a distinctive form of embellishment in residential structures. The exterior façade seemed more appealing due to the creation of large and intricate ornamentation. It is important to learn from history how an opulent and enhanced appearance can be achieved by utilizing inexpensive decorating approaches. also, buildings used light construction methods, but they also managed to stand out.

The conclusions reached from these illustrations and buildings show the different wonderful building construction methods used by the populace in the early eighteenth century. Numerous other techniques were used, including the use of Gothic architectural elements like domes. The low-cost traditional homes kept their resource utilization to an absolute minimum. The major ingredients acted as mud and rice husk. These homes were constructed from clay blocks that were afterwards coated with mud or lime mortar or from raw clay that had been combined with rice husk. These homes typically had a sloping roof supported by a timber truss and may be up to three stories tall.

4) Terminology

Ath-Chala: Bengali architecture is typical. A single, square, or rectangular room with four sloped roofs and a smaller, identical roof structure (curvy or straight) on top.

Chandni: temple with a flat roof, a smaller square or rectangle, and no more than three entrances.

Nava-Ratna: Traditional Bengali architectural design. There are an additional nine spires evenly spaced over the roof's center and four corners of a religious building.

II. BUILDING STRUCTURAL DESIGN PROCESS

A structural design method entails creating a structurally sound building that can withstand the harshest loads possible. To create Structural Drawings, a civil structural engineer must analyze, design, and detail the construction of a building. In addition to conceptual and creative thinking, structural planning and design require a thorough understanding of pertinent practical information, such as current design codes and bylaws, as well as a good deal of expertise, competence, and sound judgment.

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A. The Procedure

1) Conceptual

To establish a civil and structural design of the building plan, a structural design engineer will first evaluate the drawings made by the architects. To construct a civil engineering design, the engineer will examine the various spaces in the residential, commercial, or industrial building. For the design of steel structures and concrete structures, the site's conditions are assessed, including the soil report, the exposure category, the wind load, and the seismic load.

Engineers carry out preliminary designs of architectural elements, such as roof, wall, and floor plans in accordance with architectural drawings for structural steel building design, after environmental factors have been established. After identifying and resolving conflicts in the mechanical, electrical, and plumbing systems, footings, slabs, load-bearing walls, beams, and columns are planned in Fig 6.

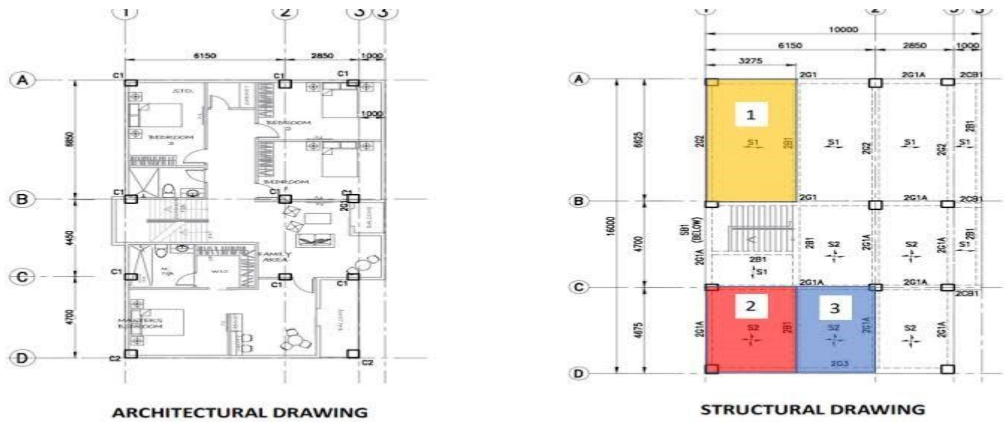

Fig 6. Architectural Drawing Converted to Structural Drawing

2) Load Analysis

An analysis by a civil engineer is required for all conceivable live and dead loads that a building may encounter over its lifetime. As a result, you must consider the different loads depending on where your construction is. The values of these loads can be discovered by examining the pertinent structural design references and codes. In the actual world, the building is being affected by several loads simultaneously in Fig 7.

The entire load must be considered while designing and drafting steel constructions. Determining which load combinations are the worst for your structure is a step in the loads analysis process. Two examples of BIM structural engineering software that can be configured to automatically generate all potential loads are Autodesk Revit and Tekla in Fig 8a and 8b.

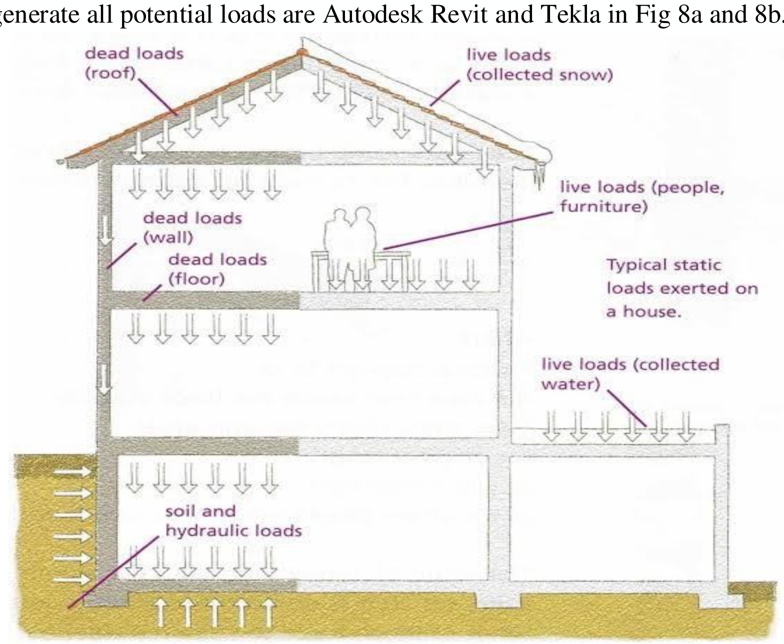

Fig 7. Load on Building or Modelling

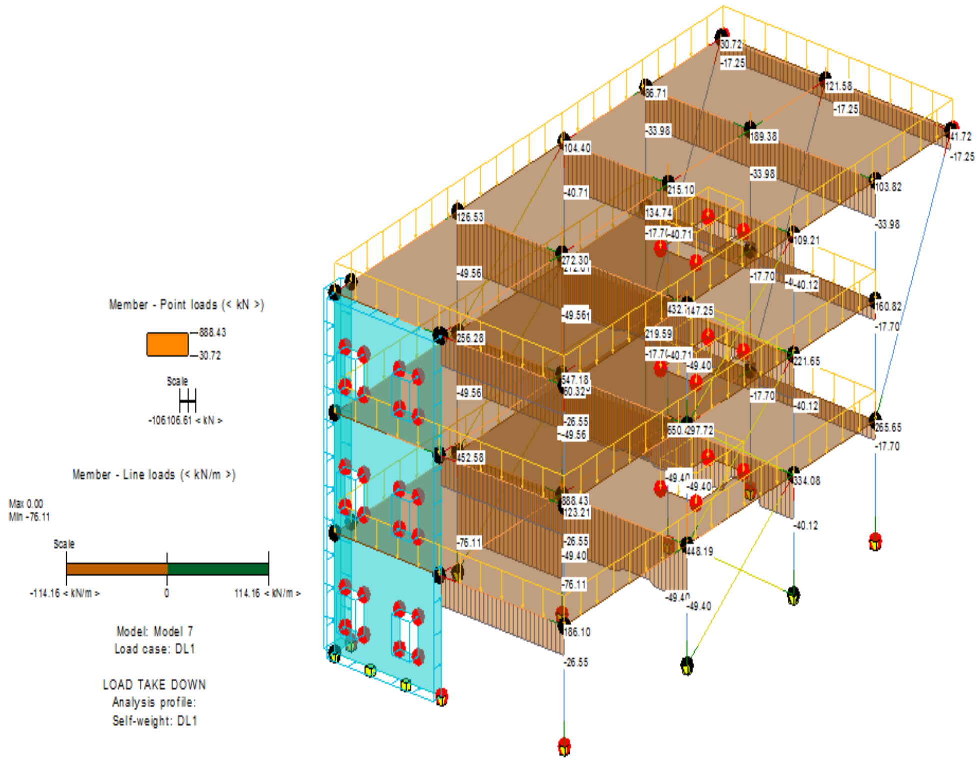

Fig 8a. Example of Load analysis by Revit

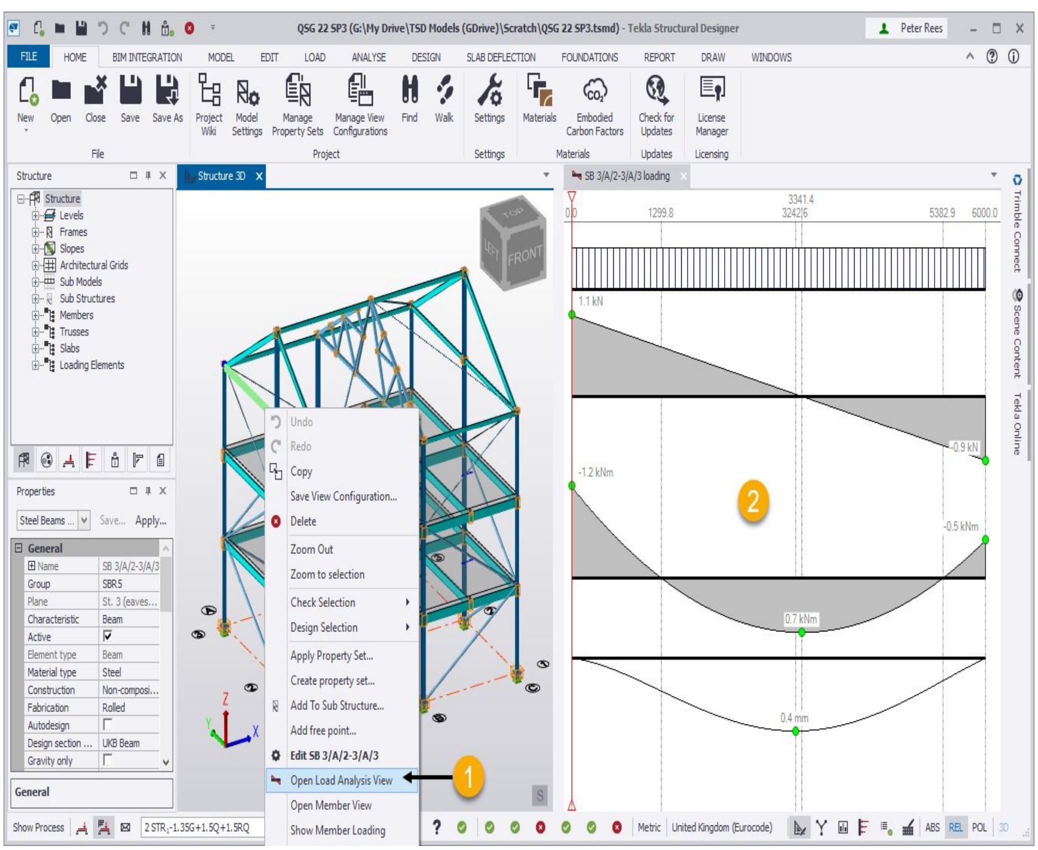

Fig. 8b Example of Load analysis By Tekla

3) Structural Analysis

The task of conducting a structural study on the structural members falls to civil engineers. The structural analysis includes responses and deformations or deflections brought on by the various load combinations, as well as shear, bending moment, normal, and torsion stress diagrams. Both fundamental and sophisticated structural analyses are performed using Building Information Modeling (BIM) structural analysis software, such as Autodesk Revit and Tekla in Fig 9a and 9b.

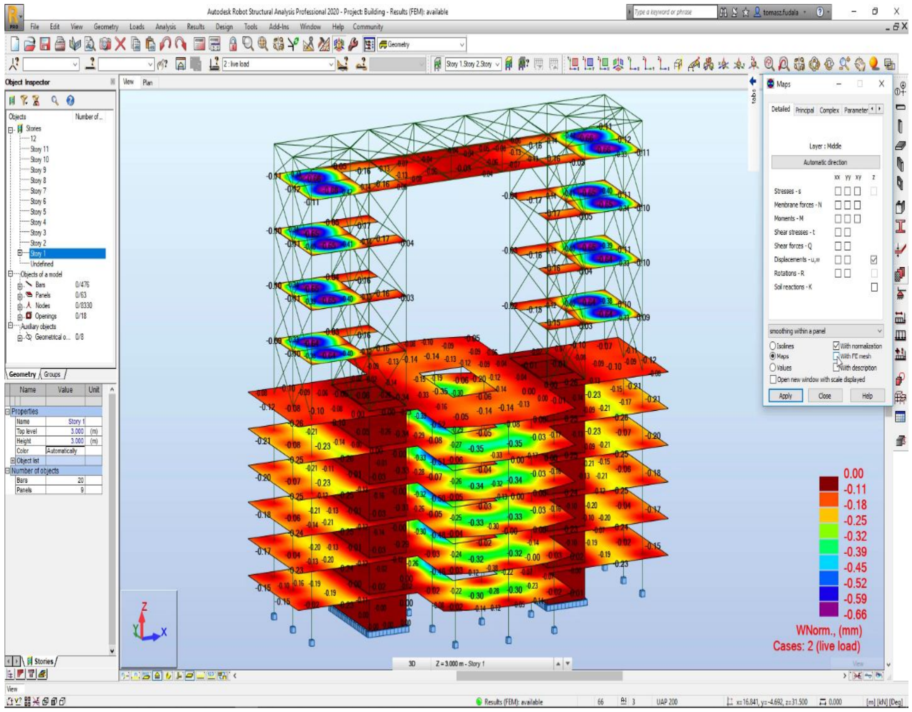

Fig 9a. Example of structural Analysis in Revit

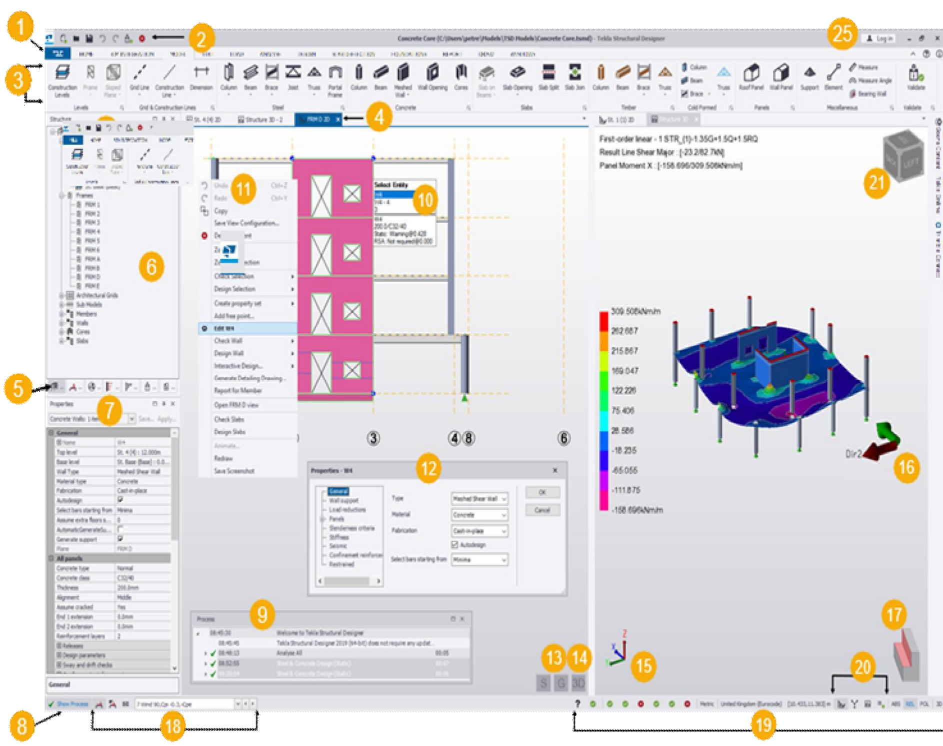

Fig 9b. Example of structural Analysis in Tekla

4) System Design

An engineer will focus on system design in a top-down way after completing an initial conceptual design. It is essential to comprehend the load path of the structure, considering the effects of gravity loads, lateral loads, and uplift on the different structural elements. The first designs of various structural systems will be started by the engineer once they have a general understanding of the load path of the structure. Engineers will create preliminary roof system designs first, working their way down from the top. The floor systems will then be designed, followed by the walls, which will include any necessary beams and columns as well as gravity and lateral force resisting systems. The number of floors and various unit types in the structure will determine how many times these steps are repeated. Using data from the soil report obtained during conceptual design, the foundation and footings will be designed after the roof, walls, and floor system have been completed. The preliminary structural construction designs are created using the data from this general study.

5) Element Design

The engineer uses geometry coordination, as specified in 2D or 3D CAD software, to ensure precise dimensions for the various building project components before starting the element engineering phase. The engineer will start specific member analysis for the given spans, assuming the dimensions are correct in Fig 10. This will involve figuring out how much of the roof's weight is transferred to the inner and external bearing walls. When combined with window and door perforations that call for headers and beams, the lateral force resisting systems typically take the longest to engineer. This approach integrates the trajectories of lateral loads, wind uplift, and gravity. To give the engineer a basic understanding of the variety of loads within the structural parts and where more attention will be necessary in following design phases, this load path analysis will also be performed to the floor system and foundations. Engineers will employ structural design-specific software programs like SAP 2000, STAAD, and/or RAM to help with this study.

The engineer will be able to apply a range of loads, including dead, live, wind, and seismic, thanks to this analysis program. The engineer will be able to calculate the combined forces, axial forces, bending moments, shear force, and drag force because of this analysis. The first member sizing can start as soon as the forces are established, enabling the engineer to create a "rough draft" that can be further refined in later design stages.

Fig 10. Example of Building Elements

6) Iterative Design and Drafting

To refine the different components into final structural element designs, engineers employ an iterative process. Consider this as repetitive labor toward the ultimate objective of an effective design that satisfies the range of needs the configuration of the structure places on the route the applied load must follow to reach the ground. The engineer begins with a general grasp of the loads on each component before focusing more intently until each component, and eventually the complete structure, is built to safely transmit all loads, comply with code requirements, and offer a workable solution that can be sealed and signed. The load routes are precise, focused, and dependable because of this procedure. Drafting can be finished and fully comprehensive structural designs ready for construction can be obtained with the exact load routes.

7) Construction Administrations

The design and construction of the building structure should follow the construction shop drawings, according to structural contractors responsibility. Consequently, effective construction management is necessary for a building's structural integrity. The engineer is frequently requested to carry out duties such as reviewing requests for information (RFI) and deferred submittals, obtaining code approvals, or creating construction schedules in the later phases of the building process.

Engineers will oversee the construction process on the client's behalf and ensure that the building is constructed in compliance with the structural design. Additionally, they will frequently visit the site to make sure that the construction is proceeding as planned and that no mistakes were made during the product installation.

III. CONCLUSION

The procedure does not begin since plan reading is not done with awareness, and if it is, there is no concept where to place the beams, columns, and walls or in what size. The system design cannot be completed if the load path's purpose and mechanism are unknown. Cost, strength, and quality are all impacted by incorrectly dimensioned beams, columns, and slabs in the design software. Organizational structures are code-driven, and their workflow is jeopardized if they are not checked in a timely manner. These are all included in the process of designing a building's structure. This essay discusses structural design processes and what must be done to ensure that such issues never arise.

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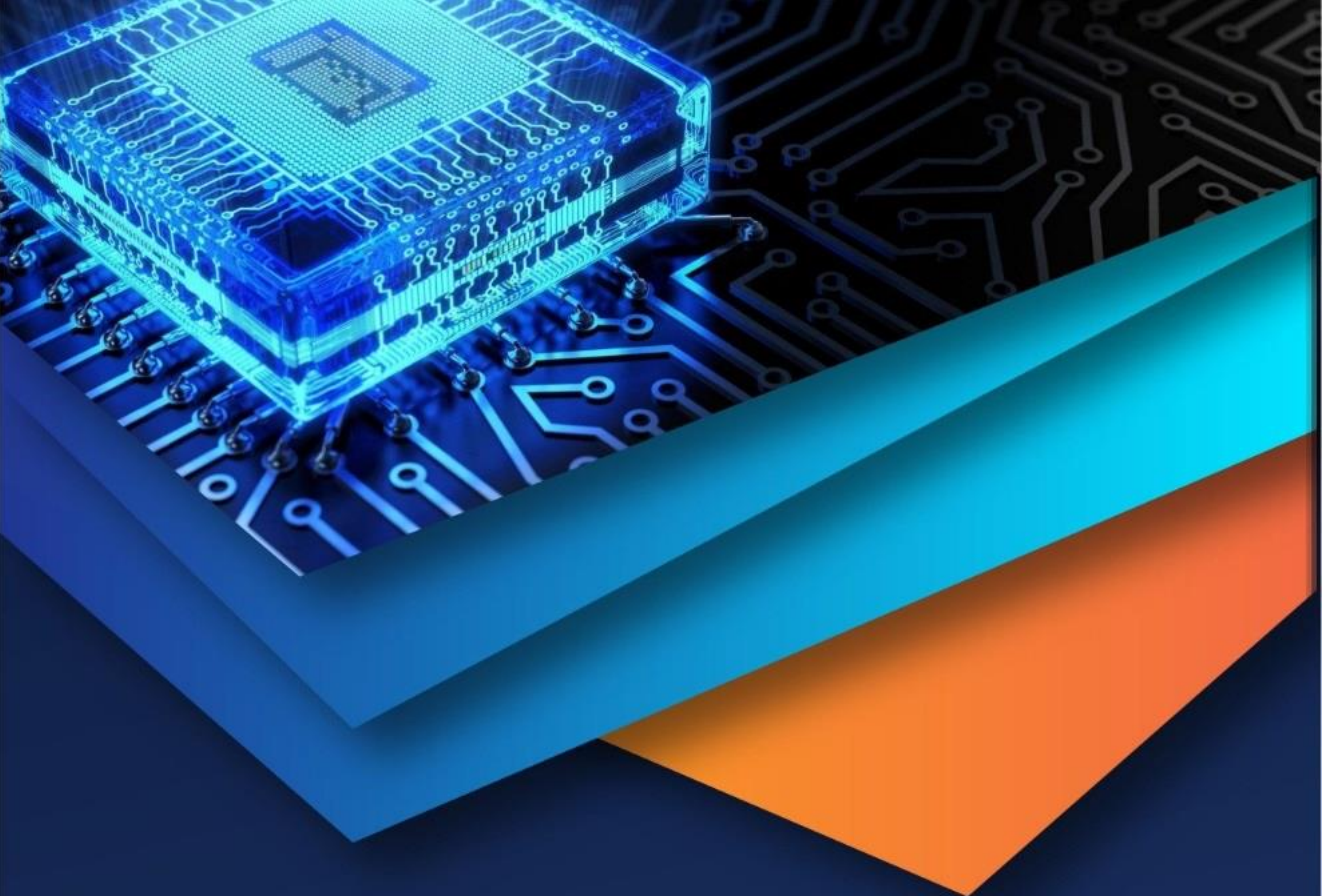

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