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Simulating Complex Structures with Structural Engineering Software

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Abstract--- Computer programs aid in the modeling and evaluation of structures required in design projects and reinforced elements required to construct safe facilities such as buildings and bridges. This article discusses the new development in the structural engineering software and their applicability in representing complex geometries, determining the nonlinear material response, and defining load conditions. Through the use of tools such as FEA and BIM, engineers can easily estimate structural reactions to these forces such as seismic forces, wind forces and load forces. This article describes how such software solutions enable the evaluation of various design concepts, efficient utilization of materials, as well as evaluating possible weak points in structures. It also emphasises the need to incorporate the tools into the design process in order to bolster cooperation, minimize mistakes an improve the results of a project. Examples are provided which show how the simulation and optimisation of complex forms such as those involved in tall buildings and long-span bridges has been achieved using sophisticated software. The article highlighted issues like for instance the calls for expertise and the application of multi-disciplinary data. The application of structural engineering software has ensured that the field heads in the direction of innovative, efficient, and safer designs of structures to support the growing world population, in the complex structures that are being developed to support human activities.

Keywords--- Building Information Modeling, Finite Element Analysis, Load Conditions, Material Optimization, Structural Design, Structural Simulation.

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I. Introduction

Computer software for structural engineering has indeed made a big revolution concerning the manner in which engineers develop and analyze intricate structures. There exists impressive sets of applications that allows structural engineers to build realistic 3D models, analyze different types and levels of loading and fine tune models with remarkable speed and precision. With large and complex edifice such as tall buildings and intricate bridges to mention but few, structural engineering software finds practical use in the determination of the structural safety, structural stability as well as predicted performance of current structural construct (Al-Maghrabi & El-Abbasy, 2014).

This paper aims to investigate on the changes in structural engineering software that has been developed in the recent past. Today's software levies procedures like the finite element method and the Applied Element Method (AEM) to analyze structures with a great degree of accuracy. Some of these tools enable the engineers to predict the response of various material such as the reinforced concrete at various conditions. Also, cloud computing has increased the effectiveness of structural analysis to solve problems of various complexities and mutual cooperation in structural design (El-Tawil et al., 2014).

II. Evolution of Structural Engineering Software

Structural engineering has gone through rapid evolution especially due to the increased development in technology. We cannot continue working with the primitive way where calculations have to be made by hands, and the blueprints have to be drawn by hand. The use of modern computers and modeling software is present in the industry today, where the structural engineers have been capable of developing three dimensional models, running through real life situations, as well as calculating the structure's behavior with high levels of accuracy though high speed (Fu, 2015).

2.1. From 2D to 3D Modeling

Structural engineering software has seen a major advancement in transitioning from 2D modeling to the 3D modeling shown in Figure 1. Nonetheless, it is puzzling that about 75% of manufacturing industries continue to perform design operations on 2D CAD models even though the new features in 3D modeling present numerous advantages. There are numerous reasons why designers have not embraced 3D technology, such as: They are yet to grasp some of the benefits of using the 3D technology on their designs They have developed their skills in 2D and are not ready to let go.

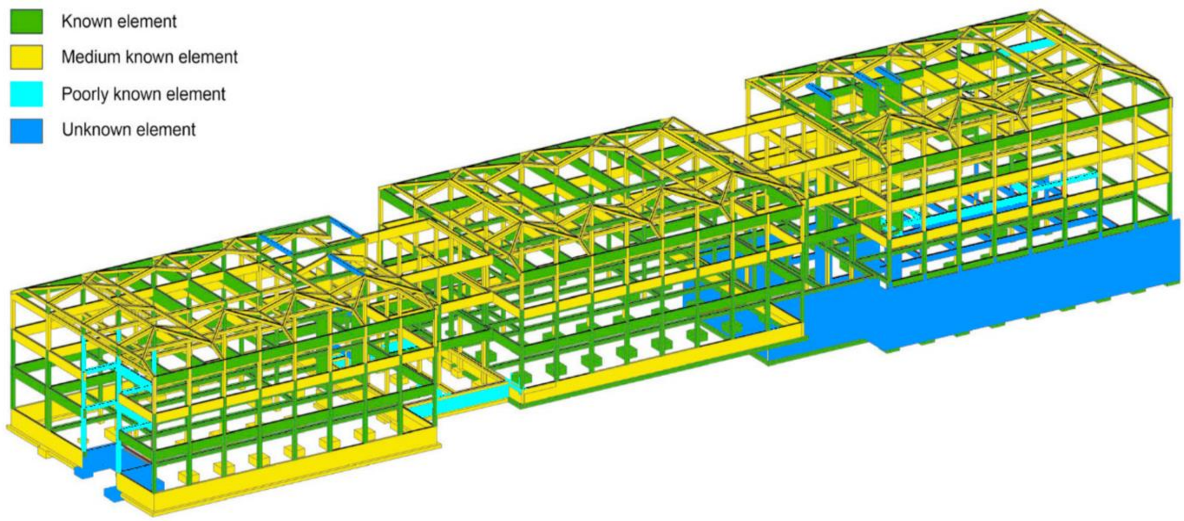

Figure 1: From 2D to 3D Modeling

Yet, the advantages of using the 3D modeling are beyond doubt. As we see modern products competing in the market, engineers and designers are in a dilemma in presenting designs that can be manufactured a lot more quickly. 3D modeling shortens the time taken in the design process, fosters creativity and highlights potential mistakes in the design process. In 3D CAD systems, the engineers are able to develop accurate solid geometric models that are useful through the different stages of production as seen in the Table 4 (Al-Rabghi & Hittle, 2001).

One of the primary benefits that comes with it is the fact that an architect can easily note any problems or weaknesses in a design before the construction process starts. This is more so since through the simulations, the engineers will be able to note the areas that are prone to failure, the best point at which failure will occur and even the design that can allow maximum safety and efficiency. This capability has given structural engineers a new outlook on design problems by expanding the realms of structural possibility.

2.2. Increasing Computational Power

Right from the nineties and up to the current century, a breakthrough in the power of computational systems made a significant contribution to the development of structural engineering software shown in Figure 2. Due to advancement in technology coupled with increased availability of computers there has been a tremendous improvement in the various engineering software. Due to this it has been possible to come up with better simulation methods as well as simulation analysis methods which can assist the engineers to overcome design difficulties that were deemed to be impossible to overcome.

There has been a huge change in Building Information Modeling (BIM), widely recognized as one of the most influential advancements in the industry. Through BIM it is possible to develop digital models of buildings; in addition to the shape of the buildings, the different parts, and systems of the building can also be developed. Through integrating design and analysis into one platform, this has brought a change in the approach to engineering design through structural engineering.

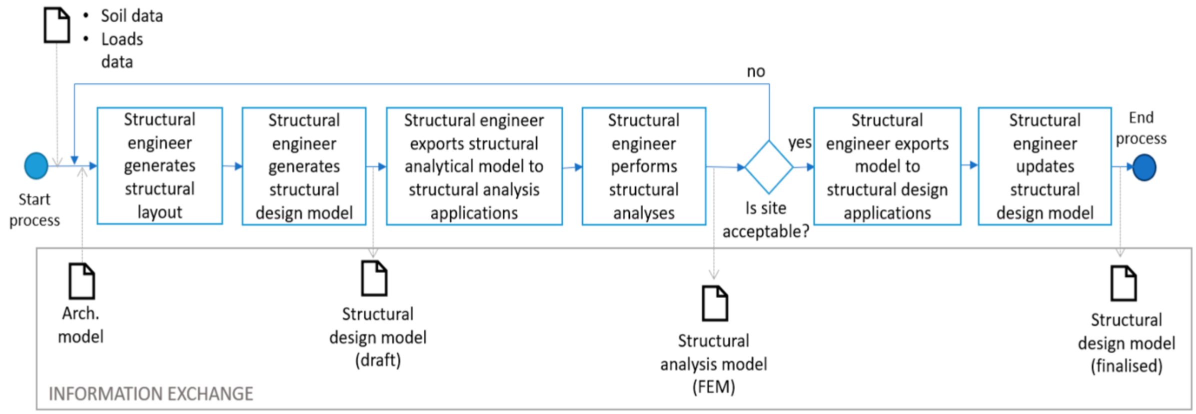

Figure 2: Increasing Computational Power

Also important is the incorporation of artificial intelligence and machine learning into the structural engineering software. These technologies thus have a potential to make design & analysis tools more powerful and precise, that may lead to more creative and effective structural systems. Future advancements in computational capabilities will only mean that system driven design elements within structural systems will become even more powerful in the future. Virtual reality (VR), augmented reality (AR) together with artificial intelligence are seen as the perfect combination that drives computer aided design (CAD) towards new heights and higher levels of creativity and effective application in structural engineering (Almusallam et al., 2010). Lastly, if today's structural Eng. Software can be defined then their advances have revolutionized the field where experts are now able to develop such high levels of accuracy, velocity, and creativity that was not possible before. Therefore concluding the importance and necessity of technology and software tools and simulation techniques, it is easy to predict a progressive incorporation of these sophisticated tools in modern structural engineering.

III. Core Components of Structural Simulation Tools

In recent years, there has been advancement in the structural engineering programs to allow engineers to design accurate digital models of structures. These tools are based on a number of fundamental components that collect information as a basis for the simulation of a system. They consist of geometry creation, materials definition and meshing technique among others.

3.1. Geometry Creation

Structural modeling in any simulation undertaking starts with the building of a model that is the replica of the physical structure. Today CAD programs contain extensive and various standard material databases and predefine components to make complex 3D models easily and effectively for engineers. Such programs allow for a generation of complex geometries, which can be adjusted and fine-tuned as the design process advances.

However it should be mentioned that CAD tools are excellent at producing drafted models for manufacturing while not all the details are required for simulation. In this context, engineers have to eliminate extra details or "defeature" product geometries to emphasize various forms that define structural behavior. It also makes the analysis to become simpler and reduces the computational needs that are involved.

For example, when engineers have the tools, such as Ansys SpaceClaim, to perform operations including the reduction of the model to remove all but the illustrative nameplates and minor structural details that would have little influence on the final design. This simplification process is an essential part of the simulations for it enables the engineers to focus on the pertinent aspects of the design (Li et al., 2021).

3.2. Material Definition

Realistic material properties are the foundation to effective simulations of structures. To obtain the desired stress and strain characteristics of the components structural engineering software contains extensive libraries of the predefined material. Several of these libraries make data readily available to engineers for the primary materials thus facilitating the simulation setup.

However, material selection becomes more of a concern especially when conducting nonlinear analysis or when a material is subjected to stress beyond the yield stress. For such cases, engineers may have to introduce new materials or adjust some of the existing ones in order to model the response of the structure at certain conditions.

As will be described in some details below, modern simulation tools allow flexible definition and management of material properties. For example, in Autodesk Simulation Mechanical, engineers can:

1. They also allow users to choose from a set of defined material that is already available in the software package.
2. Incidental: Recollections of content created and used: touching up existing materials to meet certain criteria.
3. Develop new ones that have characteristics the designer wants the material to have.

This is a very useful facet given the ability to define own material types is especially helpful when one works with materials which are not necessarily available in common libraries. Engineers can key in certain properties like elastic modulus, Poisson's ratio, yield strength and thermal expansion coefficient to make sure that the simulation being made corresponds with the of the actual structure (Kassem et al., 2017).

3.3. Meshing Algorithms

Of all the steps involved in performing FEA, meshing is one of the most important for it determines the preciseness of the simulation and the time required to complete the simulation shown in Figure 3. It splits the geometric relationship of the car into smaller units which are manageable by the FEA solver.

There are two primary types of 3D meshing methods:

1. Tetrahedral element meshing (tet).
2. Hexahedral element meshing (hex).

Hexahedral elements are in general preferred more than tetrahedral ones because the former gives better accuracy with fewer element than the latter one. Nevertheless, it is stated that for geometries with more complicated shapes, tetrahedral elements might offer advantages as these distend with irregular outlines.

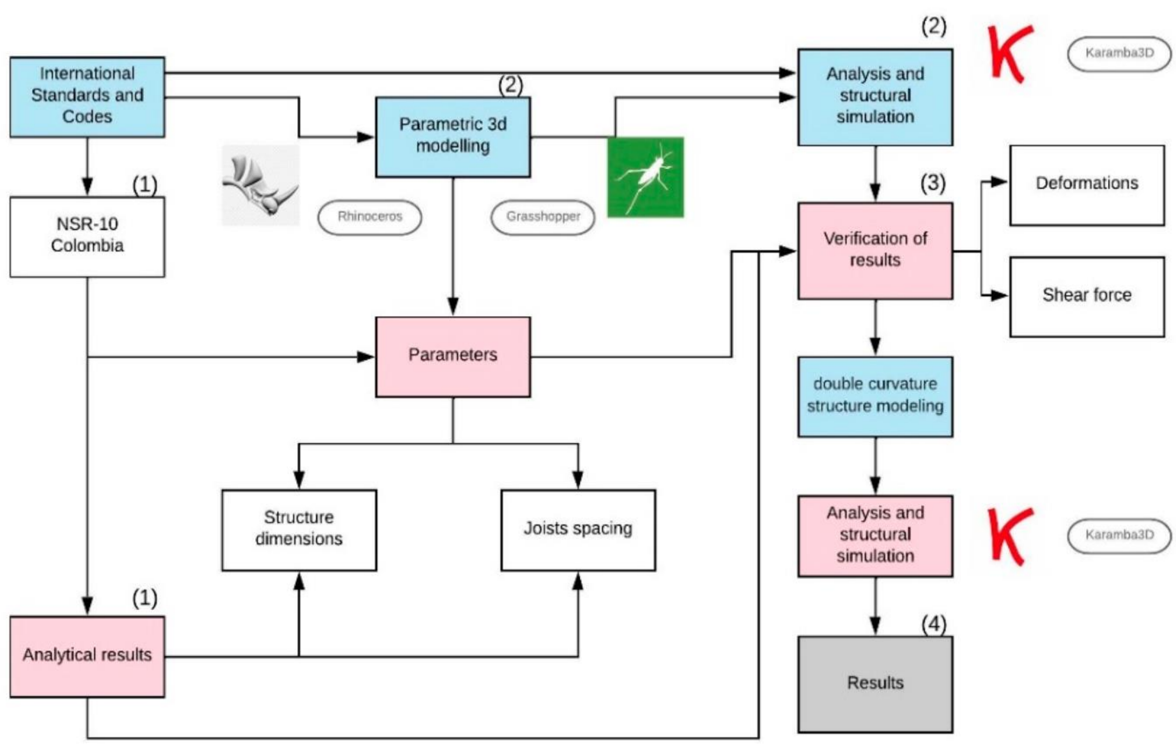

Figure 3: Meshing Algorithms

Advanced structural simulation tools offer various meshing controls to optimize the mesh quality:

- **Multizone Method:** A hybrid approach combining hexahedral and tetrahedral elements, allowing for efficient meshing of different parts of the geometry.
- **Sweep Meshing:** This technique "sweeps" the mesh through volumes and faces, creating an efficient mesh with regular sizing.
- **Local Mesh Controls:** These allow engineers to refine specific areas of interest without increasing the overall element count unnecessarily (Taleb & Sharples, 2011).

The selection of the meshing method and controls vary with concerns such as the type of analysis employed whether it is explicit or implicit, accuracy, and computational power. An ideal mesh takes a trade-off of being accurate while at the same time being computationally fast without having to spend much time solving.

IV. Advanced Analysis Techniques

Advanced analysis techniques have been integrated into structural engineering software to allow engineers to analyze various situations and engineer the structural behavior with high level of precision. These are superior to basic techniques that employ simple mathematical models of a line, though the methods let account for response of structures under various conditions.

4.1. Non-linear Analysis

There are many structural engineering conditions that cannot undergo linear analysis since the structure shows non-linear behaviour. In structures where high stress, large deformation or complex material characteristics are present then nonlinear analysis becomes important. This approach takes into consideration the variation of the force applied as well as displacement and therefore is much more accurate when modeling the behavior of structures.

Non-linear effects can originate from three primary sources:

1. **Geometric Non-linearity:** This situation can occur in a structure where one or several geometrical characteristics change its form considerably. For instance, a fishing rod is a very good example since it receives a significant degree of bending when there is a catch on it.
2. **Material Non-linearity:** If the yield strength has been reached and surpassed then the stress and strains graph takes another slope and becomes nonlinear as the material is permanently deformed. The linear stress strain relationship characterized by $\sigma = E\,\varepsilon$ is thus succeeded by a non linear relationship characterized by $\sigma=f(\varepsilon)$.
3. **Contact Non-linearity:** This is as a consequence of two parts and surface interfacing thereby leading to a change of stiffness and formation of zones of material deformation adjacent to the contact area.

The use of non-linear analysis has several benefits, for instance, it can predict behavior in a more accurate manner by adopting into account large displacements material non-linearity. It enables the engineering professionals to predict the ability of a system to react to various loading conditions more realistically. But it should be also remembered that while using non-linear analysis, far more computational work is done, and data analysis must be much more delicate as compared to linear analysis (Al-Ahmari et al., 2016).

4.2. Buckling Analysis

Buckling analysis is a considerable part of structural engineering that deals with determination of the stability failure load of a certain structure under compression. This type of analysis is used when engineering structures such as columns, beams or frames in order to determine whether these structures can be subjected to compressive force without buckling or yielding.

The process of buckling analysis typically involves the following steps:

1. **Modeling the Structure:** The process of building the 3D representation of the structural design, above and beyond assigning the geometric form and relevant material properties, and the implementation of the constraints as well as the loads.
2. **Meshing:** Partitioning the structure into finite elements with the mesh quality as one of the critical factors that have a bearing on the outcome.
3. **Defining Analysis Settings:** Determining if linear or non-linear solution has to be carried out, choosing the right solver for the problem and defining the buckling mode shapes for the solution.

4. **Solution and Post-processing:** Information on the critical buckling load factor and bucksling modes obtained from solving of the eigenvalue problem, presentation of the results and further analysis of the results obtained.

Buckling analysis is particularly important in industries such as aerospace, automotive, and civil engineering shown in Figure 4. It helps in designing aircraft components, automobile chassis, tall structures, bridges, and towers, ensuring their stability under various loading conditions while optimizing material usage.

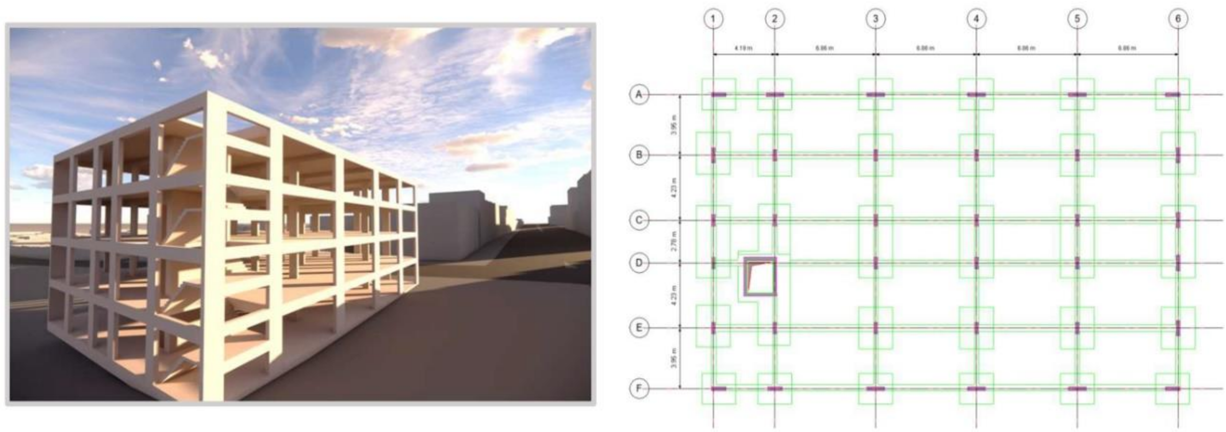

Figure 4: Buckling Analysis

4.3. Fatigue Analysis

Fatigue analysis is crucial for designing and optimizing products that require high durability and reliability. It helps identify potential points of failure and prevent product malfunctions or catastrophic events. Fatigue failure occurs when a material is subjected to cyclic loading, even at stress levels below the material's yield strength (Al-Ahmari et al., 2016).

There are several methods involved in fatigue analysis:

1. **Stress-life Method:** Used for high cycle fatigue when expected stresses do not exceed the material's elastic limit. It entails making a graph where the vertical axis is the level of stress used in the application while the horizontal axis is the cycle number to failure.
2. **Strain-life Method:** Used in the application of low cycle fatigue when some of the stresses applied exceed the material's elasticity limit. This method provides a graph of strain amplitude on the y – axis and number of cycles on the x – axis.
3. **Linear Elastic Fracture Mechanics (LEFM):** First employed for evaluating the length of fatigue crack propagation, especially when stress field at the crack notch is Elastic.

Fatigue analysis usually involves the need to perform simulation and often uses special tools such as Finite Element Analysis (FEA) in order to determine the resulting stresses or strains on a particular component. They require that the engineers design and redesign some of the parts so that they can be as durable, reliable and as good performers as possible.

Through the inclusion of these superior analysis methods into structural engineering software, engineers can be able to better understand complex static and dynamic structural behaviors that result to more efficient designs, safety and innovation across various sectors.

V. Simulating Complex Loading Scenarios

Most structural engineering software have evolved over the years and it is now possible for engineers to perform actual loading on the structure with a high level of realism. These simulations are important in assuming structures which may be able to cope with several environmental forces and other events. With the help of advanced software applications engineers can analyze and study what are the best feasible designs that are safe, durable and can take different loads.

5.1. Wind Load Simulation

Wind loads are a major problem in structural design particularly for tall buildings as well as bridges. Current structural engineering software contains enhanced means of modeling wind loads with more sophisticated simulation features to assist engineers in identifying these potential risks. For example, the features of the SkyCiv Load Generator include the possibilities to generate wind loads according to the different codes and design loads.

It can design or calculate the wind speed easily on this software when the engineer inputs the project's location or coordinates. These comprehend importance levels and risk categories and other terrain data factors such as topography. The tool creates clear elevation profile graphics for the representation of site terrain factors and helps engineers understand how local conditions affect the wind loads. Once again when the wind speed is ascertained then the engineers are able to give details of the building to come up with pressures exerted by the wind onto the building.

The program calculate design pressures for walls and roofs as well as for windward, leeward and side walls. It also determines loads for the roof and wall components and cladding together with the factors that include topographical, directional, gust and exposure coefficients (Abu-Hamdeh & Alnefaie, 2016). Another benefit for the typical modern wind load simulation tools is the compatibility with the 3D structural analysis applications. With this integration, engineers are made to be in a position to apply design pressures on the structural model that he or she is working on. It can also change the wind loads depending on modifications required in the structure, load combination and factors and calculate internal member widths.

5.2. Seismic Load Modeling

Earthquakes can be greatly damaging to infrastructures, which is why there is need for good seismical loads modeling especially in areas that are most prone to seismicity. The latest structural engineering software come with complex seismic load calculation tools that meet different global codes including ASCE 7-16, NZS 1170. 5, NBCC 2020, NSCP 2015.

These tools allow engineers to calculate seismic base shear and diaphragm forces using site specific seismic parameters available with organizations such as the US Geological Survey. They are capable of producing design response spectra which can then be directly implemented in fully 3D structural models to give an accurate picture of how a given structure might behave when subjected to an earthquake.

The software generates comprehensive seismic reports, giving engineers assurance in their results hence reducing guess work when deciding on any design for the structure. This capability is most useful in evaluating the seismic performance of existing historic masonry structures, where lack of information on structural properties, construction practices, and prior damage conditions present critical difficulties.

5.3. Impact and Blast Analysis

As security issues become an important factor in the modern world, structural engineering application has adopted complex impact and blast analysis tools. These tools are essential in the design of structures that will be subjected to more severe loads for instance through explosion or have high velocity impacts. Services offered by advanced software in blast analysis involve the determination of blast loading on particular structures from threat profiles given by clients.

For structural and non-structural engineers, it means that they can simulate and predict behavior of the structure under BLAST loads preach vulnerability of structure and delineate the risk zones and stand-off or threat distances. Some of the developments in this area include Extreme Loading® Technology (ELT) that originates from the Applied Element Method (AEM). From this technology, engineers are able to monitor and model structural behavior from an elastic state right up to cracking, separation of elements and impact.

It gives a much needed picture of the actual damage that is actually occurring to the structure, as well as secondary effects of debris that regular conventional tools cannot depict as effectively. The blast loads can be generated automatically using standards such as UFC3-340-02 or pressure-time histories which can be generated based on customers' input. It also facilitates a determination of debris and glass fragment velocity and distribution which are considered in determining he overall effect of a blast on a structure and its environment.

VI. Structural Optimization Using Simulation

Robustness design for optimization continues to be powerful most important weapon within the hands of contemporary engineer where it is possible to be able to design lightweight, strong and inexpensive structure at initial design phase. This approach is very important especially for businesses that are in aerospace, automobile, and construction businesses where issues of reliability and safety are vital. To be specific, through innovations within simulation techniques, engineers can solve more intricate analyses faster than ever before and apply a method of efficient and repeatable simulation-driven design (Al-Saadi & Al-Jabri, 2020).

Structural optimization is in essence means to provide designs which will effectively perform their intended function and also be optimally light and strong and yet cost effective. This usually uses complex math computations such as algorithms and simulation geared toward identifying possible solutions to the problem so as to establish the most suitable design out of all possible designs.

6.1. Topology Optimization

Topology optimization also known as TO is a strong tool that works via algorithmic inputs to determine a pattern of where the material must be provided based on the loads, conditions as well as constraints set by the user shown in Figure 5. This technique is used to increase performance and also to make efficient designs by eliminating unnecessary material in areas of low or nominal loading so as to reduce the weight or solve problems such as resonance or thermal stress.

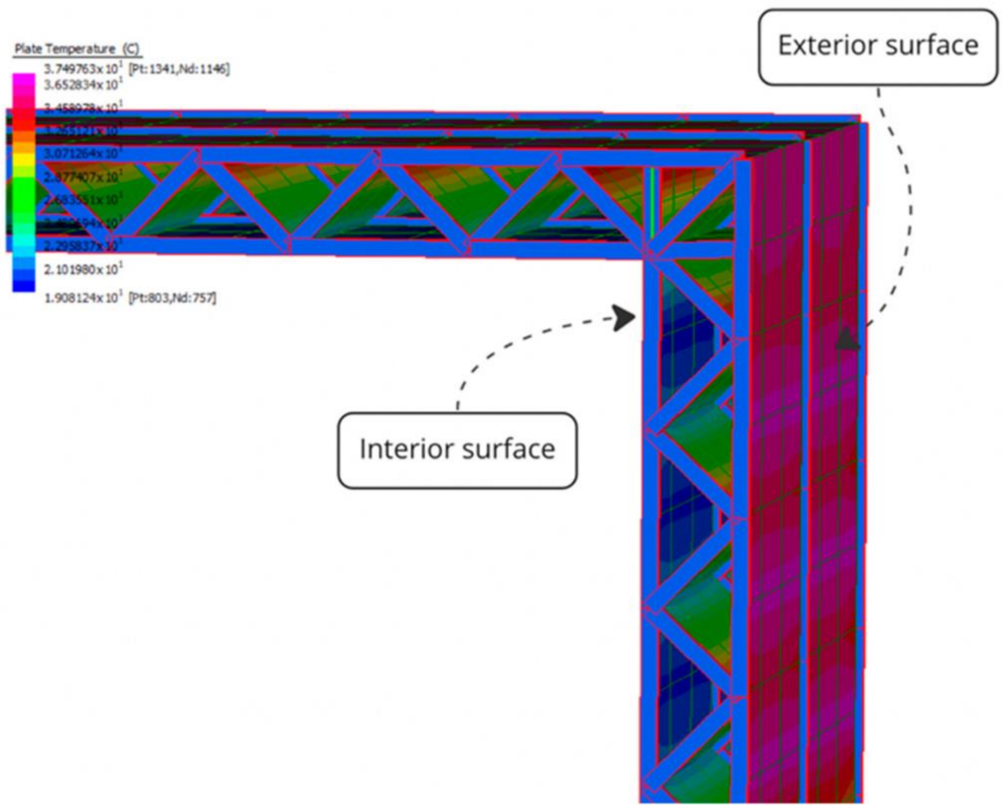

Figure 5: Topology Optimization

The process starts with identification of the smallest regions of feasible design space that should be used in shape optimization. Of all the approaches, practical and the most popular one is Finite Element Method (FEM). It divides the design and takes each small part apart for the rigidity, compliance and redundant material check; After this each part is assembled to make the final complete design. Finally, validation of the design involves defining a value in between 0 and 1 for threshold of element density field. If a value is set to 0 it makes a certain area in the space as void and if the value put is 1 then it makes the same area as solid material. It also enables the designers to remove excess material until they achieve the desired thin shell structure of the model and conclude the topology optimization part of design.

6.2. Shape Optimization

Shape optimisation is target ed towards optimising the outer surface of the structure. This process often consists of changing the current shape, to decrease the areas of high stress, improve air flow or just to have a nicer look. It is possible for engineers to present new ideas whenever they are challenged with a scenario that has the potential to include a number of design factors, which may range between tens, fifty, and even hundreds. These tools predict the impact of varying numerous design parameters, including not only geometry scaling but also, more generally, geometry shape change. Shape optimization uses linear and/or nonlinear finite element analysis essential in various complex design problems solved suitably.

6.3. Size Optimization

Size optimization is all about the change of specific parameters depth of beams, cross-sectional area of columns, etc., to accomplish certain performance objectives. This approach is most valuable during multiple design stages and it covers cross section and thickness characteristics of the finite element. In civil engineering, size optimization is usually used for designing steel sections or prefabricated concrete sections for buildings whereby the engineer will select catalog sections which are suitable. It is possible to optimize size of the components such as the columns to make sure that the structure is optimal while at the same time being economical on material. Due to the simplicity of calculating the sensitivities in the sizing optimization, it is suitable for application even when dealing with the more challenging issues. In this approach, there is effective utilization of materials and resources that lead to cheap ways of designing and engineering various scenarios in an effective way.

VII. Cloud Computing and Structural Analysis

Cloud computing has become the effective tool to use in the field of structural analysis since it provides the engineers with the opened access to the powerful computation. This sort of technology refers to the provision of computing services through 'the cloud' where it involves services such as storage space, servers, software, and even databases. In regard to the construction Industry, Cloud computing has been very useful especially for sharing construction drawings.

7.1. Advantages of Cloud Solution

This means that one can avoid massive capital outlay that is usually incurred in procuring hardware for cloud-based simulation. Earlier, simulation involved considerable initial investments for organizations to undertake and would not always be possible for large comprehensive style analyzes. Cloud computing have shifted this paradigm to a situation where organizations can obtain HPC as a service. This shift has addressed a critical challenge in physics-based simulation: There for, the government has the responsibility of ensuring that the internet is made available. Using the cloud computing one is able to simulate without being limited by the available equipment's locally. This flexibility reduces the number of scenarios in which users may avoid specific simulations or adjust their model to fit available resources, which could affect the quality of physics-based simulation and thus erode users' confidence in the output data. The platforms which are available in clouds can scale up the CPU core numbers to any degree to suit the users' problems. This scalability allows engineers to: This scalability allows engineers to:

Cloud computing has revolutionized the field of structural analysis, offering unprecedented accessibility and computational power to engineers. This technology allows for the delivery of computing services over the internet, including storage, servers, software, and databases. For the construction industry, cloud computing has brought significant benefits, particularly in sharing and collaborating on construction drawings.

1. Run higher fidelity simulation models at a lower resolution, therefore, having a larger mesh size.
2. Performance is improved and the results are obtained faster with more amount of CPU Cores.
3. Run multiple design variants simultaneously in order to have better exploration of the design space.

7.2. Collaborative Engineering

Among all the aspects that cloud computing can support in collaborative engineering, the 3DEXPERIENCE platform demonstrates how this is beneficial. Focused at the idea of collaboration from the start, this platform helps to improve collaboration throughout the product development process. It enables a user to on real-time status of a project and data rich dashboards populated with results from simulation to enhance decision making.

Key collaborative features include:

1. Real-time project progress tracking.
2. Dashboards for data-driven decision-making.
3. Improvement of partnership between the company and third parties.
4. However, there should be an overall integrity of data traceability and decisions made about the data.

This reduce duplication of work and enhances simplicity and efficiency in work since every member works on the same product has one timeline in the project, and data and decision making traceability is also consistent across the team. Information sharing and access on the platform are easy since the platform is located on the cloud regardless of the location of the members of the team.

With the help of cloud computing in structural analysis, there is an ability to solve more complex problems, increase the amount of fidelity simulations and enhance collaboration. This advancement in technology has not only enhanced the validity of the structural analysis, and enhanced its speed but has also created opportunities for developments within the structural engineering field.

VIII. Emerging Technologies in Structural Simulation

Currently, the area of structural engineering is rapidly developing with the help of new technologies' inclusion. These advancements are cropping up and are changing the way of working of engineers in the aspects of designing, analyzing and optimizing structures and systems. Machine learning and virtual/augmented reality are two of the technologies that are applying greatest implications.

8.1. Machine Learning Integration

Machine learning (ML) has been embraced as a standard tool in constructing high-dimensional interatomic potentials and is therefore considered smarter and more efficient means of structural engineering shown in Figure 6. Specifically, ML can mimic human cognitive skills to provide exclusive possibilities in decision making, problem solving and managing of projects. ML is endowed with numerous implications; intelligent algorithms improve the operational efficiency while the potential of safer and more innovative structures exists. ML is the principles applied to make analytical decisions, using data to predict outcomes. With it, engineers can analyze large datasets and predict the structural behavior of elements, fine-tune design variables, and overall improve the results of projects.

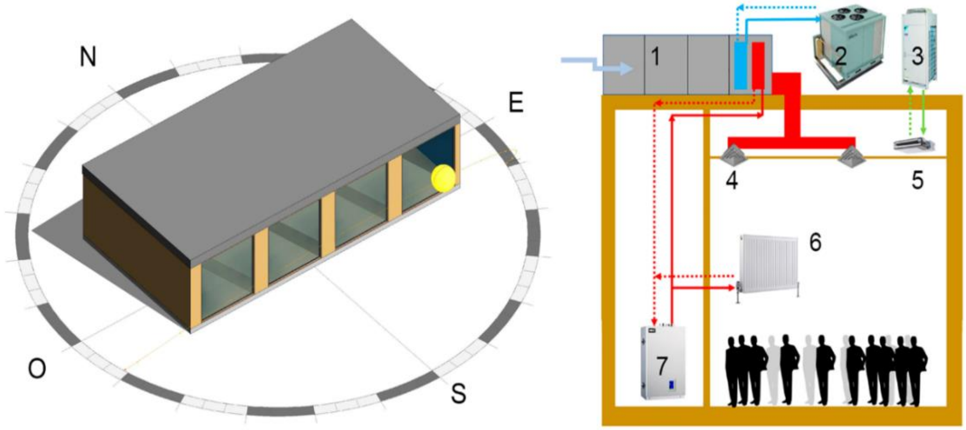

Figure 6: Machine Learning Integration

In this way, engineers can employ ML to make a quick estimate of project-preliminary designs that leverage cost, safety issues, and system performance. Pattern recognition, which forms the core of ML, is very useful to real-time monitoring and analysis of structures. Since it involves analysis of patterns, the ML has the capacity to forecast when such failures are likely to happen hence aiding preventive measures. Neural networks in deep learning are hence used in machine learning to improve the software functional ability and precision from the large data sets as it learns progressively. Appropriate to structural engineering, deep learning can go through project experiences and even when it has no prior experiences, it applies them from previously designed projects.

8.2. Virtual and Augmented Reality

Augmented reality, as applied nowadays, is gradually forging a Web of entangled social connections of people, products, machines, and systems. It is this technology that has shifted and revolutionized the way engineers perceive and model structures respectively.

AR blends the digital world to the real world in order to enhance efficiency in the use of tangible items. Optimally, it facilitates engineers and developers to communicate better with the business side as well as other engineers and developers and can flag quality issues, potential process problems, or consumer issues before the problems interfere with the development process or customer satisfaction.

Still, one of the most promising and attractive advantages of AR applications is to facilitate spatial learning. Due to the influences of AR technology, engineers, managers and business professionals can all be on the same team of an agile product and have similar spatial intelligence. If it is in an AR glass format, a real 3d model can be placed on a table then rotated to view the different aspects of 3D geometry, improving collaboration. Thus, augmented reality enhances several aspects of engineering education and training in the following ways: C" It is enabling the training process to embrace somewhat of a visual, audial and kinesthetic orientation and modality so as to meet the needs of the Trainees. Among these potentials, AR has the capacity to destalize engineering engineers' explorations in prototype prototype development through the visual and navigational representations of conceptual models, AND instructions, tools and part connections in reality. These emerging technologies are promising with the potential of extending paradigms of design, analysis, and optimization in structural engineering. It is not only improving the efficiency of the process and expanding the horizons of the machine learning possibilities as a tool for data analysis, but also it is also enriching the opportunities for the development of structure simulation with the help of augmented reality.

IX. Conclusion

The emergence of structural engineering software is also one of the most impactful events in the field; it has led to the revolution in engineering practice regarding the thinking process about complex design tasks. From creating premiere models all the way down to intricate coolest such as non-linear and fatigue, these tools have helped the possibilities of being able to develop more secure and efficient structures. Cloud computing has been incorporated seamlessly into application and collaboration which have in turn enabled the engineers to solve more complex problems and fine-tune design solutions with a degree of precision previously impossible. In the future, combining the utilization of AI based machine learning and virtual or augmented reality with engineering tools based on structural simulation will open entirely new areas of application. It has been established that these technologies will revolutionalise ways in which engineers work by enabling them to visualise, model and optimise structures. In the future, therefore, the software to structural engineering will hold a lofty important position in construction of new and challenging structures to cater for increasing exponentially challenges that face humanity in the future.

References

[1] Al-Maghrabi, M. N. N., & El-Abbasy, A. A. A. (2014). Educational computer program for simulating behavior of structures under dynamic loads. *In IEEE Proceedings of the 2014 Zone 1 Conference of the American Society for Engineering Education*, 1-7.

[2] El-Tawil, S., Li, H., & Kunnath, S. (2014). Computational simulation of gravity-induced progressive collapse of steel-frame buildings: Current trends and future research needs. *Journal of Structural Engineering*, *140*(8), A2513001. https://doi.org/10.1061/(ASCE)ST.1943-541X.0000897

[3] Fu, F. (2015). *Advanced Modelling Techniques in Structural Design*. John Wiley & Sons.

[4] Al-Rabghi, O. M., & Hittle, D. C. (2001). Energy simulation in buildings: overview and BLAST example. *Energy conversion and Management*, *42*(13), 1623-1635.

[5] Almusallam, T. H., Elsanadedy, H. M., Abbas, H., Ngo, T., & Mendis, P. (2010). Numerical analysis for progressive collapse potential of a typical framed concrete building. *International Journal of Civil and Environmental Engineering*, *10*(2), 36-42.

[6] Li, S. H., Sifton, V., Lundgren, J., McClellan, C., & Gibbons, M. (2021). Extreme wind climate of the Arabian Peninsula characterized by using WRF simulation. *Weather and Climate Extremes*, *33*, 100330. https://doi.org/10.1016/j.wace.2021.100330

[7] Taleb, H. M., & Sharples, S. (2011). Developing sustainable residential buildings in Saudi Arabia: A case study. *Applied Energy*, *88*(1), 383-391.

[8] Kassem, A., Al-Haddad, K., & Komljenovic, D. (2017). Concentrated solar thermal power in Saudi Arabia: Definition and simulation of alternative scenarios. *Renewable and Sustainable Energy Reviews*, *80*, 75-91.

[9] Al-Ahmari, A. M., Abidi, M. H., Ahmad, A., & Darmoul, S. (2016). Development of a virtual manufacturing assembly simulation system. *Advances in Mechanical Engineering*, *8*(3), 1687814016639824. https://doi.org/10.1177/1687814016639824

[10] Abu-Hamdeh, N. H., & Alnefaie, K. A. (2016). Design considerations and construction of an experimental prototype of concentrating solar power tower system in Saudi Arabia. *Energy Conversion and Management*, *117*, 63-73.

[11] Al-Saadi, S. N., & Al-Jabri, K. S. (2020). Optimization of envelope design for housing in hot climates using a genetic algorithm (GA) computational approach. *Journal of Building Engineering*, *32*, 101712. https://doi.org/10.1016/j.jobe.2020.101712