BUILDINGIN FORMATION MODEL INGINSTRUCTURAL ENGINEERING

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Research Article

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ABSTRACT

The broad use of building information modeling (BIM) is transforming the architecture, engineering, and construction (AEC) industry and offers many opportunities to improve performance. As a result, BIM is a topic that is extremely relevant to the AEC industry in general and to the field of structural engineering in particular. This paper will provide readers with a thorough summary of the published works that connect structural engineering and BIM. Understanding the present level of scholarly activity on this issue will be enhanced by this review, which is based on bibliometric analysis of 369 works. The findings provide a current view of the chronological distribution across journals, authors, countries, and institutions of the currently available works that connect BIM advancements and applications in structural engineering. There are significant research gaps that need to be addressed, including the modeling of structural components, automation of the assembly process, off-site construction planning and optimization, and dynamic structural health monitoring. The field of structural engineering has seen a radical transformation because to construction Information Modelling (BIM), which introduced a digital approach to design, analysis, and construction processes. BIM encourages cooperation and coordination among project stakeholders by using advanced 3D modeling software that integrates data from several disciplines. In the realm of structural engineering, BIM offers several advantages. Engineers can accurately observe and simulate complicated buildings because to their capacity to create very accurate and detailed 3D models. By enabling a full analysis and evaluation of several design options, BIM technologies enhance structural performance and reduce mistakes. Clash detection technologies in BIM help minimize costly rework during construction by detecting and resolving conflicts between different building components. BIM also makes exact quantity take-offs possible, which results in precise cost estimates and efficient project scheduling. In the realm of structural engineering, BIM provides many advantages. Engineers can see and replicate complex buildings with precision because to their capacity to create very detailed and accurate 3D models. The ability to thoroughly analyze and assess many design options is made feasible by BIM technology, which enhances structural performance and reduces mistakes. By detecting and resolving conflicts between different building components, BIM's clash detection technologies help minimize costly rework during construction. Additionally, BIM facilitates exact quantity take-offs, which leads to precise cost predictions and efficient project scheduling.

Introduction

The architectural, engineering, and construction (AEC) sector is seeing a surge in the use of building information modeling (BIM), and studies indicate that BIM might completely transform the way the AEC sector functions. continues. The process of looking at the benefits of adopting BIM on projects is still going on. However, there is evidence in the literature that BIM combines information processing techniques and software for designing, documenting, visualizing, and reporting on buildings and other facilities in compliance with rules, laws, and other guidelines [1]. This is done to recognize the advantages of BIM for many professions and sectors across the AEC supply chain. It helps AEC professionals plan the next construction procedures, see a future building in a virtual environment, and identify any possible issues with design, construction, or operation. Such benefits might benefit the practices of all the relevant disciplines, including structural engineering in particular and civil engineering in general [2]. The wide range of structural engineering competencies and abilities might be advantageous for any kind of project. This includes both large-scale, towering building developments and projects that just need a little amount of slope fortification. For a structure and its systems to be safe, long-lasting, and sustainable, structural engineers need to figure out how to use structural materials and components effectively. They could create intricate structural designs. The outcomes of other disciplines, such architects and engineers of different building services, usually need to be linked with structural designs. Among other duties, structural engineers also supervise construction activities on-site and communicate with manufacturers and suppliers to resolve production concerns. In order to maintain the quality of the final product, structural engineers require tools that allow them to review the system's development parameters and verify the accuracy of the data sent. This requires a reliable data sharing platform because it requires a variety of different skills and a wide range of communication channels [3]. One choice that provides all of these options is BIM [4]. Structural engineering has undergone a revolution because to Building Information Modelling (BIM), which has changed how experts plan, evaluate, and build infrastructure and structures. Numerous benefits of this digital method have significantly improved project stakeholders' accuracy, efficiency, and cooperation. From early design ideas to construction and facility management, BIM has expedited the whole project lifecycle by using advanced 3D modeling tools and combining data from several disciplines. In the field of structural engineering, BIM gives engineers the ability to produce detailed and very accurate 3D models of structures, which facilitates accurate simulation and visualization of intricate designs. This degree of specificity allows for in-depth examination and assessment of various design possibilities and offers priceless insights. Engineers may save expensive rework during construction, decrease mistakes, and maximize structural performance by using BIM technologies. The clash detection capability of BIM, which finds conflicts between various building components, is one of its main benefits. This helps engineers to efficiently coordinate systems and settle conflicts, preventing any delays and problems during construction. Furthermore, precise quantity take-offs are supported by BIM, allowing for accurate cost estimates and effective project scheduling [5]. A sophisticated and all-inclusive integrated Building Information Modelling (BIM) platform designed especially for structural engineering is the suggested solution. It has very advanced 3D modeling features that enable engineers to produce precise and in-depth models of architectural structures. With the help of these models, engineers can precisely envision and evaluate intricate designs, leading to improved comprehension and well-informed decision-making. The system also provides design optimization tools that allow engineers to simulate structural performance, evaluate various design options, and optimize designs for safety, sustainability, and efficiency [6]. The system's powerful clash detection features help to prevent clashes between structural components during construction and reduce expensive rework. Reliable cost estimates and effective project scheduling are supported by accurate quantity takeoffs and cost estimating capabilities. With the help of the system's data analytics and visualization features, engineers may examine project data, monitor developments, spot patterns, and make informed choices to improve project results. A collaborative platform facilitates smooth information exchange and coordination among project stakeholders by streamlining collaboration and communication [7]. The goal of the suggested BIM system is to provide smooth interaction with industry standards and structural engineering software. The solution allows engineers to take use of the integrated BIM platform while using current tools and processes by guaranteeing compatibility and interoperability. Effective project management and remote collaboration are made possible by the system's cloud-based architecture, which provides scalability, remote access, and secure storage. This increases flexibility and efficiency by enabling project teams to collaborate from various places

[8]. Professionals with different degrees of experience may utilize the system because to its straightforward features and user-friendly design, which encourages broad adoption and usage. The suggested BIM platform's extensive feature set enables structural engineers to enhance project outcomes by streamlining processes, increasing accuracy and efficiency, decreasing mistakes and rework, and promoting teamwork. Professionals in structural engineering may fully use BIM by adopting this cutting-edge technology, which will increase project delivery, save money, and improve structural performance [9]. Structural engineering is a branch of civil engineering. Existing research has concentrated on a number of BIM implementation features in civil engineering projects, such as communication frameworks, frameworks for information management, the use of BIM in sustainable structures, existing buildings, and a variety of civil infrastructure assets. The challenges facing the facilities management industry; the use of semantic web technologies, concerns and recommendations for BIM and life cycle assessment tools, BIM and GIS, green BIM, BIM network cooperation, transportation infrastructure, road infrastructure, and highway maintenance; the classification of data, knowledge mapping in BIM, and research categories in BIM; the creation of a BIM-based facilities management framework; and the generation of large data using BIM. Because BIM is data-rich, it encourages data-driven decision-making, enabling engineers to make well-informed decisions based on up-to-date project data. Engineers may watch project progress, analyze the effects of design modifications, and detect and minimize possible hazards by using this abundance of data, which improves project outcomes and lowers uncertainty. Additionally, BIM helps project teams communicate and work together more effectively [10]. Project information is readily accessible and shared by stakeholders, improving collaboration and reducing misunderstandings. Project delivery and customer satisfaction are enhanced by this cooperative approach, which promotes cooperation and facilitates effective decision-making.

II. REVIEW OF LITERATURE

Salman Azhar et al. [11] presented this study. One of the most exciting new trends in the architectural, engineering, and construction (AEC) sector is building information modeling, or BIM. A precise digital model of a structure is created using BIM technology. This model, sometimes referred to as a building information model, may be used for facility planning, design, construction, and operation. In order to see any possible design, construction, or operating problems, it assists engineers, architects, and builders in visualizing the project in a simulated setting. Within AEC, BIM is a new paradigm that promotes the integration of the responsibilities of all project stakeholders. This paper discusses BIM's present trends, advantages, potential concerns, and upcoming difficulties for the AEC sector. For practitioners in the AEC sector thinking about integrating BIM technology into their projects, the study's conclusions provide helpful information. According to this study, which was first presented by Tatjana Vilutiene et al. [12], research efforts in this field have mostly focused on examining generic BIM issues, such as information management; structural engineering technical issues, which can be addressed with BIM capabilities, have been neglected. Furthermore, it is discovered that the majority of the study in this field is carried out independently, consisting of fragmented and unconnected investigations. Modeling structural components, automating the assembly process, off-site construction planning and optimization, and dynamic structural health monitoring are among the gaps and crucial topics for further study. Gwang-Hee et al. [13] presented this study. The publication of Building Construction and Planning Research (JBCPR), a new open access publication, will cover all of the aforementioned building construction and planning domains, with the exception of original structural and MEP engineering. Since they are related to buildings but distinct from HVAC (heating, ventilation, and air conditioning), one of the elements influencing the building environment, these topics are not included. Except in the two areas listed above, JBCPR welcomes submissions of any kind of paper in any area of building construction and planning. Geetopriyo et al. [14] introduced this research, which uses the existing RSM to determine the fragility of a group of buildings by taking into account structural parameter variability that can represent the overall structural geometric and material properties within a region. A case study is carried out for the collection of reinforced concrete (RC) buildings in the city of Silchar, which is

located in northeastern India, one of the most seismically active regions of the nation. The correctness of the fragility evaluation using RSM is confirmed by comparing the results of the traditional technique using Incremental Dynamic Analysis (IDA) with the fragility curve created using major building parameters from RSM. Ví´ctor et al. [15] presented this study, which is a multi-zone energy model of the building. Additionally, the as-is T-BIM model components' surface temperature data series allow for the computation of their thermal transmittances, expanding the possibilities for calibrating the resulting as-is BEM model. A case study contrasts the as-is BEM model produced using as-is T-BIM techniques with the one produced by normal methods for the same building in order to evaluate the as-is TBIM approach. The findings show variations in transmittance, shape, and infiltration results, as well as negligible variations in the comfort parameters examined or the yearly energy usage of air conditioning. This suggests that the as-is T-BIM model is more accurate and takes less time to model.
Considering the novelty of Immersive Technologies (ImTs) associated with Digital Twin (DT), Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR) in the context of the metaverse and its rapid and ongoing development in Building Information Modeling (BIM), knowledge of specific possibilities and methods for integrating ImTs into building process workflows remains fragmented and scarce [16]. This research was introduced by Iu, Z.; Gong et al. Thus, in order to provide a useful reference for comprehending the existing knowledge system and promoting future research, this study attempts to examine the research progress and trends of immersive technology-driven BIM applications. To the best of the authors' knowledge, this is the first effort to investigate the study issue of ImTs-driven BIM using both macro-quantitative bibliometric analysis and micro-qualitative analytic methodologies. In order to fight climate change and enhance energy conservation and emission reduction in the construction industry, prefabricated structures are progressively being promoted from pilot demonstration to scale, according to research presented by Wang et al. [17]. There is still much space for improvement even if the carbon emissions of assembled structures are much lower than those of cast-in-place buildings because of the large decrease in energy consumption during the materialization process. This research examines the strategies used by prefabricated building component manufacturers to reduce carbon emissions from the perspective of prefabricated building component production. We examine the evolutionary process of the strategy selected by the government and manufacturers of prefabricated building components by constructing a dynamic evolutionary game model between two parties. We then analyze the evolutionary stability of each side's strategy choice and, finally, we simulate the efficacy of the evolutionary stability using Matlab tools. Nikc et al. [18] first presented this study. 3D models, textures, pictures, and effects are created using procedural approaches. Computer-generated architecture (CGA) is a collection of rules that software employs to automatically build models. Procedural modeling is extensively used in fields like architecture, archeology, and video games and is based on a number of rules and algorithms. The technique of developing three models using procedural modeling and CGA rules is explained in this work. The geometry nodes system, which enables the user to procedurally alter geometry based on nodes, and the free Blender program were used to generate the models. A detailed description is given of the materials used, the steps involved in modeling the building's components, and the process of developing the procedural rules that are used to create the building models. High-rise structures use more energy and have bigger environmental consequences, according to this study, which was provided by Omrany et al. [19]. It highlights the need of implementing best practices for the use of BIM throughout the design stage. Nevertheless, little is known about the early design stage uses of BIM in high-rise structures, despite the literature's strong endorsement. Therefore, by examining 60 studies, this paper seeks to offer a comprehensive understanding of the current applications of BIM in high-rise buildings. A common data repository that can efficiently assist decision-making throughout the project lifecycle is provided by the multi-layered notion of BIM. The purpose of this research is to investigate how BIM is now used in the early phases of building design, paying particular attention to how this method is currently being used to produce high-rise structures.

The study, which was first presented by Panagiotidou et al. [20], reinterpreted the relationship between building information modeling contracts, execution plans, and model data while highlighting the current status of building information modeling management platforms. The study highlights the research gaps and offers practical implications for creating project-specific execution strategies. It also offers suggestions for the future creation of execution plans, which may be used as a tool to promote the usage of building information modeling and as a control mechanism for collaborative and digitalized processes.

III. TECHNIQUES

Because of the close connection between this BIM use and BIM use, the authors refer to the BIM process map in the BIMProjectExecutionPlanningGuide with reference to Figure 1. The reference process for the usage of BIM is shown in Figure 1. The procedure really starts with a concept design of the load-bearing structure, which provides an architectural information model and inputs the foundation soil and loads. Situations

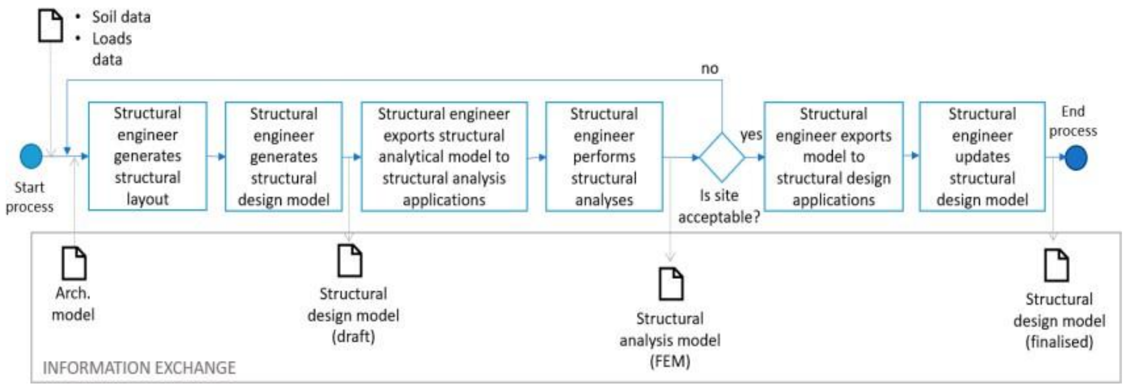


Figure1:-ReferenceBIMusageprocessstructuralanalyses

As the next step, structural engineers create a draft structural information model to create a structural analytical model that can be exported for any further structural analysis program. These may employ the structural analytical model, which is converted into a FEM, to carry out FEM calculations (see Figure 2). Thus, the structural engineers must choose a decision: If they see issues with the site conditions (as well as with the architectural model's compliance), they have the authority to demand major changes, which may involve the design principles of both the structural and architectural models [22, 23]. Consequently, under these circumstances, the whole process would be repeated, as seen in Figure 1. If there are no issues, the structural design may be completed. Post-processing plug-ins or similar software are used to finish the final structural design (as per the reference standard) with regard to the structural member evaluations, reinforcements, and connections. The last phase in the process is updating the structural information model [24].

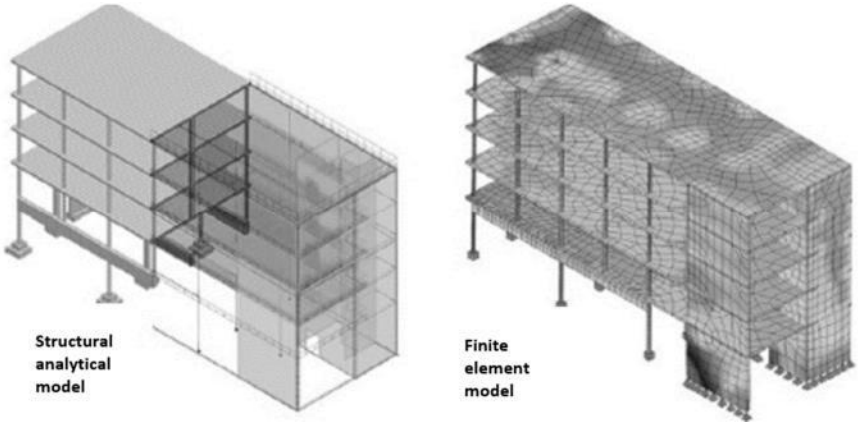


Figure2:-Analyticalstructuralmodelofanofficeblockandtheresultingfiniteelementmesh

However, since interoperability issues may arise and need the use of extra inputs (i.e., the reference standard), it could be necessary to do a great deal of rewriting in order to correctly set up the FEM for the structural investigations. These issues might significantly slow down the process [25, 26].

In order to reduce the residual rate and the kinds of cutting patterns for the final cutting scheme, the following mathematical model is proposed. MinZ1 is equal to (∑fifl)/(∑fiL). i=l minZ2=n n i=l When s.t.∑xijfi=djj=1,2,….,m i=l m∑xij≤Li=1,2,…,n j=l xij∊N,fI∈N+ Equations (1) and (2) provide the goal function to minimize the differential rate of rebar and the various cutting patterns. According to Eq. (3), which depicts the demand constraint for rebar components, the quantity of all rebar components in the cutting scheme is enough to meet demand [27, 28]. Eq. (4) constrains the cutting pattern by stating that the total length of the components of each cutting pattern cannot exceed the standard length of the bar [29]. The frequency of each cutting pattern must be a positive integer, and the number of the jth component in the ith cutting pattern must be a non-negative integer, according to the range limitation in Equation (5) [30]. I. OUTCOME The Primary BIMUses for the Structural Engineering BIM Approach

Through a qualitative analysis of the structural engineering data presented in, i.e., BIM usage, the authors identified six major areas in the field where BIM tools and methodology may be applied:

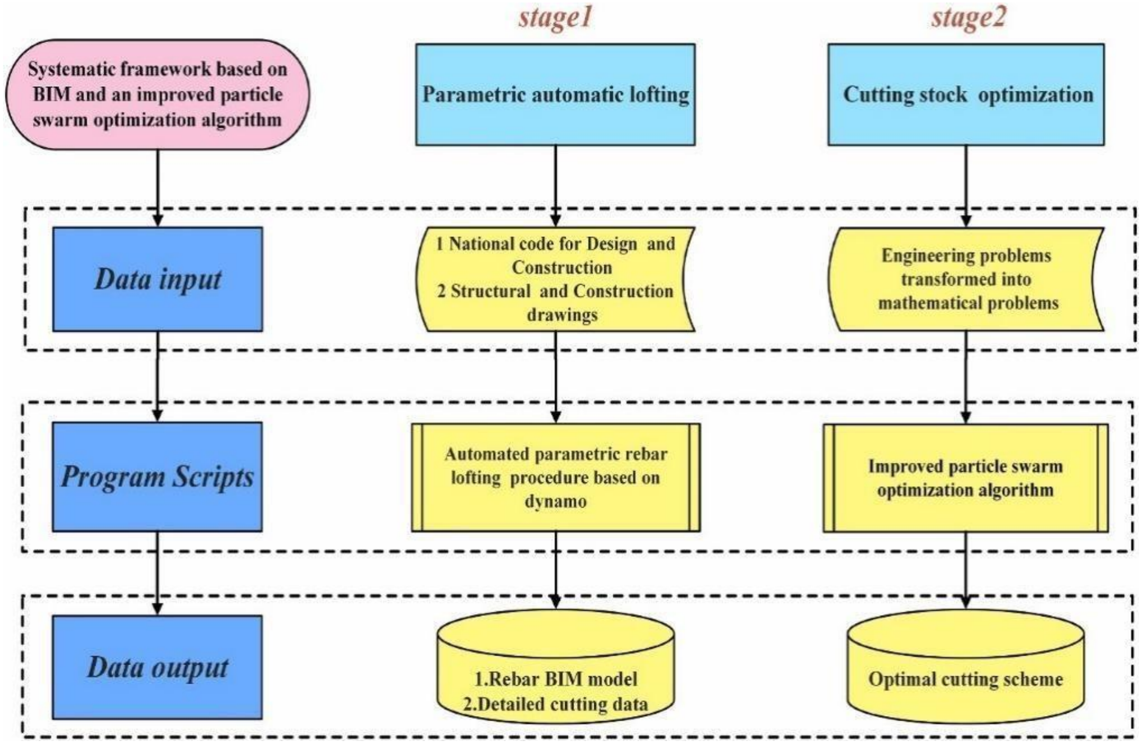
(1) structural assessments. (2) Drawings of industrial shops. (3) Early constructability problem identification and analysis of different structural choices are key components of optimized structural design.

(

4) assessments of seismic risk. (5) structural retrofitting and modeling of current situations.

(6) monitoring of structural health.

$$s.t.\sum x_{ij}f_i=d_j j=1,2,\ldots,m \quad {}_{i=l\ m}$$



$$\sum_{j=1} x_{ij} \leq L i=1,2,\ldots,n$$

Figure 3: An enhanced particle swarm optimization technique with a BIM-based systematic framework. Current research has greatly decreased rebarlosses, but researchers have seldom been able to correlate the different mechanisms that generate losses. In order to minimize the loss of rebars, this study proposes a two-stage systematic architecture that integrates the cutting and lofting operations utilizing BIM technology and an intelligent algorithm. For the rebar lofting process, a parametric automated lofting method customized for BIM technology is first developed. This technique enables the production of precise rebar-cutting data and the rapid and autonomous creation of a rebar model. A modified particle swarm optimization technique based on an adaptive strategy and a greedy strategy is then used to optimize the rebar-cutting method. The rest of the data is organized as follows. There is discussion of the mathematical problem of rebar cutting. A two-stage design based on BIM and the enhanced particle swarm optimization approach is recommended to lower the rebar-cutting loss. In Section 5, examples are given to illustrate the effectiveness and superiority of the proposed approach. In Section 6, the proposed method is used to solve practical project problems. finish. BIM software selection The suggested lofting approach is implemented by Dynamo, a visual programming platform built into the well-known modern software Revit, using Design Script and the Python computer language. Being a popular and effective design tool for pipelines, buildings, machinery, and other structures Revit is more computationally efficient and provides superior performance when compared to rival BIM software presently available on the market. or the capacity for parametric modeling. But making a rebar model is often challenging, and Revit alone is unable to provide the necessary outcomes. Dynamo solved this issue with skill. First and foremost, Dynamo provides users with a visual programming environment that enables them to write scripts in a range of text programming languages, define distinct logic components, and graphically design behavioral scripts. Users may work directly with the Revit model in the Dynamo environment. Second, Dynamo helps users automate tasks related to parametric conceptual design. Dynamo's built-in node library programming allows users to swiftly and effectively solve complex technological problems. The combination of Revit with Dynamo offers a practical and effective method for lofting rebar. Theoretically, the lofting method proposed in this research may achieve the same outcome as other BIM platforms and the corresponding secondary development plugins. For example, the 3D modeling program Rhino and its related parametric plugin Grasshopper may provide the same result in accordance with the lofting theory in this research. Furthermore, the vast majority of BIM software has an API capability that lets programmers build plugins to do certain tasks. Enhanced efficacy of design: BIM allows structural engineers to create accurate 3D models that fully represent a building's structural elements. With this level of detail, engineers can analyze and optimize designs for safety, sustainability, and efficacy. Engineers may save time and money by using BIM to identify potential issues early in the design process. It also offers simulation capabilities and real-time feedback. Better Cooperation: Architects, engineers, contractors, and other stakeholders must work together on structural engineering projects. Using BIM as a central platform, all project

participants may access and change the shared model. As a consequence, over the course of the project, coordination is enhanced, communication is simplified, and disagreements are decreased. By breaking down silos, BIM promotes multidisciplinary cooperation and facilitates efficient decision-making. Conflict detection and resolution: One of the key advantages of BIM is its ability to detect collisions and conflicts between various building systems, such as structural, architectural, and MEP (mechanical, electrical, and plumbing). By employing the clash detection analysis feature of BIM software to identify possible conflicts early on, engineers may prevent problems before construction even begins. By lowering on-site rework, cost overruns, and delays, this proactive approach guarantees a more effective construction process. Improved construction documentation accuracy: BIM facilitates the creation of comprehensive and precise construction documentation. By automatically generating comprehensive drawings, quantity take-offs, and material schedules from the 3D model, BIM speeds up the documentation process. In addition to reducing human error, this enables faster and more precise material and cost estimation. Because BIM documentation is digital, it is easier to monitor and update throughout the project. Analysis of Structure and Performance Prediction: By combining BIM with structural analysis tools, engineers are able to do complex simulations and studies. This facilitates evaluating the structural performance of a structure under different load scenarios, seismic events, or environmental factors. Building information modeling has ushered in a new era for structural engineering, allowing experts to work more efficiently, collaborate without interruption, and produce projects of greater quality. Engineers can optimize building designs for structural integrity, energy efficiency, and occupant comfort, resulting in safer and more environmentally friendly structures. By leveraging BIM's capabilities in design optimization, clash detection, documentation, analysis, and facility management, structural engineers can enhance structural integrity, reduce project risks, and help create a more sustainable built environment. As BIM advances, it will continue to have a significant impact on structural engineering, fostering innovation and transforming the field.

I.CONCLUSION

In conclusion, by bringing a digital approach to design, analysis, and construction processes, Building Information Modeling (BIM) has completely transformed the profession of structural engineering. Detailed analysis and assessment of design possibilities, collision detection for conflict resolution, precise quantity takeoffs for cost prediction, data-driven decision-making for improved project results, and very accurate and thorough 3D modeling are just a few of the many benefits that BIM provides. BIM's potential applications in structural engineering seem bright. Increased integration, sophisticated visualization and simulation, IoT integration, AI and ML applications, cloud-based collaboration, robotics and automation, and sustainable design and analysis are all included. Throughout the course of the project, these developments will promote efficiency, accuracy, and teamwork, which will save costs, lower risk, increase sustainability, and improve project delivery. Structural engineers and project stakeholders can anticipate streamlined workflows, improved collaboration, better decision-making, and optimized structural performance as the industry embraces these future possibilities. BIM will continue to develop, incorporating emerging technologies and industry best practices, further enhancing the sustainability, efficiency, and accuracy of structural engineering projects.

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