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INTEGRATING ETABS WITH BUILDING INFORMATION MODELLING (BIM) FOR INTELLIGENT STRUCTURAL ENGINEERING

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Abstract - Because it allows for integrated workflows between architectural modeling platforms and finite element analysis (FEA) software, Building Information Modeling (BIM) has greatly altered structural engineering practice. The disparities in data representation, analytical model generation, and information communication standards make it very difficult for BIM authoring tools and structural analysis environments to reliably share structural information. This research examines the reliability of BIM-to-FEM transfer procedures using Autodesk Revit and CSI ETABS by systematically evaluating native API-mediated and IFC-based approaches. Through the use of element-based accuracy measures that took into account columns, beams, slabs, analytical alignments, and nodes, we assessed the structural information exchange in a five-story reinforced concrete residential structure that served as a case study. Although the analytical axes, node connectivity, and slab section characteristics had to be corrected by hand, the native Revit-ETABS process managed to achieve full transfer reliability for main structural members, with 100% accurate interpretation of beams and columns. While the IFC-based process was more dependable when it came to transferring geometric information, it was less accurate when it came to assigning member properties and interpreting slabs. Instead of a totally automated conversion technique, the findings show that BIM-to-FEM interoperability is still a somewhat automated process that needs rigorous verification. To lessen the burden of human correction and increase dependability, we offer an integration process based on checkpoints that uses controlled modeling methods, validates models after transfer, and coordinates federated models. The results add to our knowledge of the constraints on BIM and FEM platform compatibility and provide useful recommendations for structural engineering firms using Revit-ETABS-based BIM processes.

Important Terms - Structure analysis, OpenBIM, Revit, ETABS, IFC, BIM-to-FEM interoperability, and Finite Element Model are all part of Building Information Modeling (BIM).

I. INTRODUCTION

Because it facilitates the generation, administration, and interchange of digital information all through a building's lifespan, Building Information Modeling (BIM) has grown into a crucial approach in the AEC sector. Through the ability to communicate geometric and semantic information across many software platforms, BIM enables structural engineers, architects, and other project stakeholders to work together more effectively. Nevertheless, a major obstacle that has persisted despite the considerable progress in BIM adoption is the lack of dependable compatibility between structural analysis tools and BIM publishing systems. Moving from building information modeling (BIM) to finite element modeling (FEM) entails more than just exchanging geometric data. Models for structural analysis need supplementary data such as analytical axes, connection relationships, material characteristics, section definitions, boundary conditions, and load-related factors. Data structure differences between building information modeling (BIM) platforms and finite element analysis (FEM) software sometimes lead to inaccurate analytical model development, inadequate information transfer, or the need of manual modification prior to structural analysis. The structural analysis and design of reinforced concrete and steel structures are greatly assisted by CSI ETABS, while Autodesk Revit is among the most popular building information modeling (BIM) authoring systems for architects and engineers. The dependability of these workflows is dependent on software implementation, modeling practices, and the capacity of different platforms to accurately interpret exchanged data. Direct interoperability tools and open exchange formats like Industry Foundation Classes (IFC) offer mechanisms for information transfer.

There isn't just one software combination that may have issues with BIM-to-FEM compatibility, as shown in earlier research. Problems with transmitting boundary conditions, inaccurate analytical connectivity, missing material characteristics, and insufficient slab information

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transfer are some of the recurrent challenges found in studies that have examined exchanges between Revit and other structural analysis platforms. Colajanni et al. (2025) examined the extent to which Revit-based exchanges with Robot Structural Analysis, PRO SAP, and JASP contributed to architectural and structural interoperability within BIM workflows. While they did find success in transferring fundamental structural aspects, they also found that there were substantial constraints in generating analytical models and preserving information. Despite ETABS's prominence as a structural analysis platform, there has been no quantitative investigation into the dependability of Revit-ETABS interoperability using systematic element-level evaluation techniques. Instead of assessing the unique efficiency of native and IFC-based Revit-ETABS processes, previous research has concentrated on broad restrictions on BIM data interchange. That is why it is critical to evaluate this software suite in depth in order to find its realistic limits and create appropriate verification processes. Through a controlled case-study analysis, this research intends to assess the interoperability performance of Autodesk Revit and CSI ETABS.

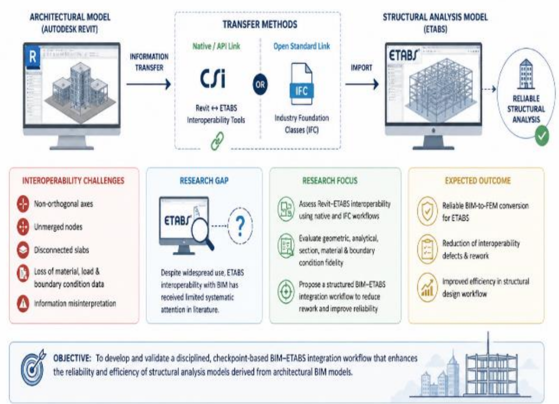

Figure 1. Introduction

This research aims to accomplish the following:

1. Examine the precision of structural element data transfer between Revit and ETABS using the native API.
2. In order to assess how well Revit-ETABS exchange operations that rely on IFC execute.
3. To determine which kinds of structural elements are most prone to data loss or misunderstandings.
4. 4 to evaluate the current state of interoperability in relation to earlier research on BIM-to-FEM.
5. To provide a step-by-step process that uses checkpoints to make BIM-enabled structural analysis more reliable.

Using both native and IFC procedures, a five-story reinforced concrete building model is created and transferred. We compare the transferred models at the element level using metrics including geometric correctness, connectedness, and data completeness. The findings provide credence to the idea that more trustworthy BIM-based structural design processes may be created by shedding light on the present strengths and weaknesses of Revit-ETABS interoperability.

II. OVERVIEW OF THE LITERATURE AND CONTEXT

The growing need for data-rich, collaborative design processes has prompted much research on structural analysis software integration with building information modeling (BIM). Structural analysis software necessitates an analytical representation appropriate for numerical simulation, while building information modeling (BIM) permits the generation of digital models of structures including geometric, material, and semantic data. Due to their distinct data formats and intended uses, BIM and FEM models present unique interoperability issues when transitioning between the two environments. The dependability of BIM-based data interchange with IFC and software-specific interoperability tools has been investigated by several researchers. Although building information modeling (BIM) environments promote cooperation, information loss happens often during model translation (Sibenik and Kovacic, 2020), who examined model-based data interchange across architectural design and structural analysis platforms. When compared to the analytical and semantic data needed for structure analysis, the results showed that geometric data is often more reliably conveyed.

While research by Muller et al. (2017) on IFC-based interoperability in structural design processes has shown that open standards enhance data sharing across diverse software platforms, there are still limits as a result of software providers' varying degrees of IFC implementation. Based on their further analysis of IFC-based data sharing, Lai and Deng (2018) found that object categorization, property mapping, and interpretation procedures varied greatly, which has a substantial impact on interoperability performance. Building information modeling (BIM) to finite element modeling (FEM) is a process that, in structural engineering, involves creating an analytical model from a physical BIM model. During this procedure, the structural components are identified, analytical connectivity is

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established, the characteristics of materials and sections are defined, and suitable boundary conditions are assigned. Transferring structural elements like columns and beams is often more reliable, according to previous research, but dealing with slabs, analytical connections, and constraint information is more difficult. Complete automation of structural model production is still challenging, according to Birkemo et al. (2019), who studied BIM-FEM workflow improvements; this is due to the fact that engineering judgment is still needed after data transfer. Similarly, Gomes et al. (2022) found that one of the primary obstacles to fully integrated digital processes is the lack of interoperability when analyzing BIM deployment in structural projects.

The employment of parametric modeling, scripting, and AI techniques to enhance BIM-based structural automation has been the subject of recent study. Although there is promising evidence that automated structural model generation from architectural data may significantly cut down on modeling time, most of these methods rely on regulated modeling environments and predetermined criteria. The work of Singh et al. (2024) showed that BIM interoperability can be improved by automated structural model generation, while the work of Singh et al. (2025) delves deeper into the use of BIM-enabled automation in reinforced concrete design. Even still, validation is still necessary for these methods since automated procedures might make mistakes when dealing with complicated architectural geometry. There has also been a lot of focus on IFC's function as a standard for open BIM interchange. To facilitate communication between various BIM programs, IFC offers a neutral data format. The quality of the exporting and importing software has a significant impact on the efficacy of processes that are based on IFC. Maintaining a consistent representation of structural analysis data across platforms is especially difficult for analytical relationships, loads, constraints, and design parameters.

Colajanni et al. (2025) compared Revit exchanges with Robot Structural Analysis, PRO SAP, and JASP to investigate architectural and structural compatibility within BIM processes. Their research indicated that main structural parts were more reliably linked using native software, while IFC procedures improved geometric transfer but made it harder to preserve engineering features. Slabs, analytical axes, and connection data were also highlighted as crucial areas that needed human verification. These developments aside, there is still a lack of adequate quantification of Revit and ETABS interoperability performance using similar element-based assessment approaches. To put ETABS into practice, one must be familiar with how it interacts with BIM authoring environments, since it is still one of the most used FEM platforms for building analysis. Thus, this research builds on earlier interoperability studies by evaluating Revit-ETABS processes that are based on IFC as well as those that are local to the platform using a structured evaluation technique.

III. RESEARCH APPROACH

3.1 Research Methodology

Autodesk Revit and CSI ETABS BIM-to-FEM compatibility is examined in this paper using an empirical case-study technique. This study's methodology is based on an adaptation of Colajanni et al.'s (2025) interoperability evaluation framework, which allows for comparison with other studies that have used Revit-Robot Structural Analysis, Revit-PRO SAP, and JASP-based processes. There are five primary steps to the methodology:

- The creation of a realistic model of a reinforced concrete structure.
- Using Autodesk Revit, I create building information models for both structures and architecture.
- Data exchange processes between Revit and ETABS, both native and based on IFC, are being tested.
- Assessment of transmitted structural components quantitatively.
- Building on the identified gaps in compatibility, create a verification-focused methodology for integrating BIM and FEM.

The reliability of structural element transfer, analytical model creation, and structural information preservation necessary for finite element analysis are the main areas of attention in the assessment.

3.2 Establishing a Case Study

The case study model was a five-story residential structure made of reinforced concrete. We chose this building layout to be consistent with earlier BIM interoperability studies and to portray a typical medium-scale reinforced concrete construction. Reinforced concrete stair treads, beams, slabs, and columns make up the structural structure. The normal storey height of the structure is 3 meters, and its rectangular design is about 28 meters by 11 meters. Traditional building information modeling (BIM) techniques were used to build the structural model, with a focus on preserving analytical

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appropriateness and avoiding too precise geometric details.

Table 1. Features of case-study construction

Parameter	Description
Structural system	Cast-in-place reinforced concrete frame
Number of stories	5 above-ground floors
Plan dimensions	Approximately 28 m × 11 m
Typical floor height	3.0 m
Structural elements	Columns, beams, slabs, stairs
BIM modelling approach	Structural analytical-oriented modelling

3.3 Program Setting

Data from the compatibility test was collected and reported in Table 2. The chosen software versions stand as examples of widely used platforms for structural analysis and building information modeling.

Table 2. The research software

Software	Purpose	Version
Autodesk Revit	Architectural and structural BIM modelling	2021 / 2024
CSI ETABS	Structural analysis and FEM modelling	ETABS Ultimate 21/22
CSI Revit–ETABS interoperability tools	Native BIM-to-FEM exchange	ETABS bundled tools
Autodesk Navisworks Manage	Federated model coordination	2021 / 2024
Solibri Anywhere / BIM Vision	IFC model inspection	Latest available version

The Revit structural BIM model was built using a regulated LOD/LOI technique. Details such as material type, structural classification, and estimated section dimensions were included when defining structural elements to facilitate analytical transfer.

3.4 Transferring BIM Data to FEM Processes

There were two main transfer techniques that were examined:

- Process for native Revit-ETABS compatibility.
- Revit and ETABS interoperability method based on IFC files.

In the native process, CSI interoperability tools were used to immediately convert the structural Revit model into ETABS. Analytical models are created using this approach by transforming Revit structural objects into analytical elements in ETABS. By configuring IFC4 Reference View and IFC2x3 Coordination View 2.0, the Revit structural model may be produced for the IFC workflow. We used ETABS's built-in IFC import feature to bring the generated IFC files into the program.

Additionally, the interpretation of FEM-generated information inside BIM settings was examined using a reverse ETABS-to-Revit transfer. Here are the tested procedures for interoperability (Table 3):

Workflow	Objective	Exchange Method
Revit → ETABS (Native)	Evaluate direct interoperability performance	API-mediated CSI link
Revit → ETABS (IFC)	Evaluate openBIM exchange reliability	IFC2x3 / IFC4
ETABS → Revit	Assess reverse FEM-to-BIM interpretation	IFC2x3
ETABS → Navisworks	Federated coordination assessment	IFC2x3

3.5 Criteria for Assessment

An element-based accuracy measure was used to evaluate the interoperability performance. The proportion of items that were transported properly was determined by:

$$\text{Import Accuracy } (\%) = \frac{\text{Correctly Imported Elements}}{\text{Total Source Elements}} \times 100$$

The transfer of an element was deemed successful when:

- The target model already has the matching item.
- This model's geometry was identical to the original.
- All connections to neighboring pieces were intact.
- The structural qualities that were necessary were accurately determined.

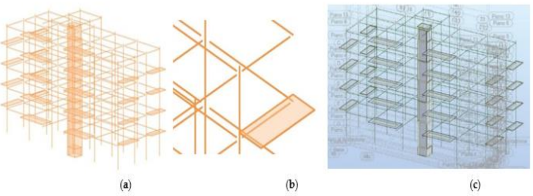

Figure 2. (a) A model for analysis in Revit v.2024, strictly using axes, nodes, and geometric planes; (b) A breakdown of the disconnections in that model; (c) A model for analysis in Robot v.2024, strictly using the same elements.

The evaluation was carried out independently for:

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- Scale
- Peims
- Blocks
- Alignments for analysis
- Nodes that do analyses

3.6 Methodology for Verifying Models

After every transfer procedure, the Revit structural model and the ETABS model that was generated from it were compared. An element comparison record, model inspection tools, and ETABS object attributes were used for verification. Among the steps used for comparison were:

- Making sure the element is present.
- Confirmation of geometric coincidence.
- Verifying that all members are connected.
- Assessing assigned materials and sectional property.
- Making a note of problems that need human intervention.

In order to ensure that fix actions would not impact future assessments, each workflow was evaluated separately using maintained copies of the original BIM model.

3.7 Possible Integration Process

A methodology for integrating BIM and FEM was suggested, based on the observed behavior of interoperability. What makes up the workflow are:

1. Step regulated building information modeling
    - Standards for structural modeling defined.
    - Determining appropriate LEOD/LOI specifications.
2. Stage of the transfer
    - Checking just after the BIM-to-FEM conversion!
    - Find the element types that need fixing.
3. Validation of the Analytical Model
    - Verifying structural characteristics, axis alignment, and connectedness
4. The stage of affiliated cooperation
    - Navisworks structural, architectural, and mechanical, electrical, and plumbing (MEP) model integration.

This method acknowledges that engineering verification is necessary in present BIM-to-FEM procedures instead of relying only on automated conversion.

IV. FINAL THOUGHTS AND FINDINGS

4.1 Performance of Native Revit-ETABS Transfer

When it came to moving main structural members, the native Revit-ETABS interoperability process proved to be quite reliable. The translation of columns and beams was executed flawlessly, with no geometric errors whatsoever. Results show that CSI interoperability tools successfully translate Revit structural objects to ETABS analytical elements for standard reinforced concrete frame members. The creation of analytical connectedness and secondary structural information, however, has several limits. At many points where members with varying cross-sectional depths met, the analytical axes needed to be adjusted. Some analytical continuity was lost because of these discrepancies, which impacted the correctness of the alignment. Particularly for section-property transfer from complicated multilayer floor assemblies, slab information shown lower dependability. Transfer accuracy between Revit and ETABS natively (Table 4).

Structural Category	Correctly Imported
Columns	100%
Beams	100%
Analytical alignments	75%
Analytical nodes	85%
Slabs (section properties)	60%

Despite the native workflow's apparent effectiveness for principal load-carrying structural parts, engineering verification is still necessary before using the analytical model for final design calculations, according to the observed behavior. There was a consistent pattern, similar to what was previously shown for Revit-Robot interoperability, with columns and beams showing excellent transfer reliability and analytical connections being the primary source of correction. The current study's improved node-connectivity performance, on the other hand, suggests that various structural analysis platforms use distinct logic for analytical model building.

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4.2 Performance of the Revit-ETABS Transfer Based on IFC

When compared to the native exchange mechanism, the interoperability behavior of the IFC-based workflow was different. There was a larger loss of information when it came to structural attributes linked to individual members, in contrast to the reasonably reliable transmission of geometric information such analytical alignments and nodes. Table. 5: Accuracy of Revit-ETABS transfer based on IFC

Structural Category	Correctly Imported
Columns	70%
Beams	78%
Analytical alignments	95%
Analytical nodes	90%
Slabs	40%

Failure to properly map properties, such as section definitions and material allocations, was the primary cause of subpar performance in slabs, columns, and beams. On the other hand, the model's geometric structure was mostly undamaged. In general, geometric representation is more robust than semantic and analytical information, which is a frequent disadvantage of IFC-based BIM sharing. This finding illustrates that. Even though IFC offers a neutral communication method, the quality of structural information transmission is nonetheless affected by variances in software interpretation of IFC entities and property sets. The biggest problem with the IFC process was slabs. Prior research on BIM interoperability has also shown that structural analysis tools does not always reliably understand layered architectural floor representations, which is a problem.

4.3 Evaluation of Native vs. IFC Processes

Both workflows fail to provide a fully automated solution for converting BIM to FEM, as can be seen from the comparison. Rather, many methods have their own set of benefits and drawbacks. With the native approach, structural member geometry transfers were more reliable and needed less human intervention. Although more work was necessary to restore structural features, the IFC method improved platform independence and conserved the model's geometric structure. Table 6: Revit-ETABS Workflow Comparison

Parameter	Native Workflow	IFC Workflow
Column transfer	100%	70%
Beam transfer	100%	78%
Alignment transfer	75%	95%
Node transfer	85%	90%
Slab information	60%	40%
Manual correction effort	Lower	Higher

According to the results, when using Revit and ETABS together in a project setting, native interoperability is better. Additional verification methods are needed, although IFC interchange is still useful for cooperation across diverse software ecosystems.

4.4 Turnaround Time for ETABS to Revit Transfer

The capacity of BIM platforms to understand data produced by FEM was tested by transferring it backwards from ETABS to Revit. While the IFC-based reverse exchange proved that much geometric information was retained, Revit's structural-domain interpretation was less reliable for several types of elements. Reverse transfer performance from ETABS to Revit, as shown in Table 7.

Destination Environment	Columns	Beams	Alignments	Nodes	Slabs
Revit Architectural Domain	95%	100%	100%	100%	85%
Revit Structural Domain	45%	95%	80%	100%	40%
IFC Viewers	100%	100%	100%	100%	100%
Navisworks	95%	100%	100%	100%	85%

The fact that the produced IFC files maintained accurate geometric information is supported by the full interpretation shown in IFC viewers. It seems that information loss happened more often during software-specific interpretation than during IFC production, based on the lower performance inside Revit structural settings.

4.5 Coordinating Federated Models

In order to assess the capacity for federated coordination, the structural model that was obtained from ETABS was combined with the architectural and MEP models in Navisworks. There were a number of geometric crossings found throughout the coordination phase, although the majority of them were just predicted structural links and not real design conflicts. Intersections of beams and

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columns, for instance, were identified as collisions automatically, although they did not indicate any issues with the construction. There were six actual issues with coordination that were found, most of which were MEP services that went via structural members. Minor changes to the MEP routing were enough to overcome these problems; structural redesign was not necessary. The findings highlight the continued usefulness of federated BIM coordination after BIM-to-FEM communication, especially in revealing interdisciplinary conflicts that may not be obvious in standalone software.

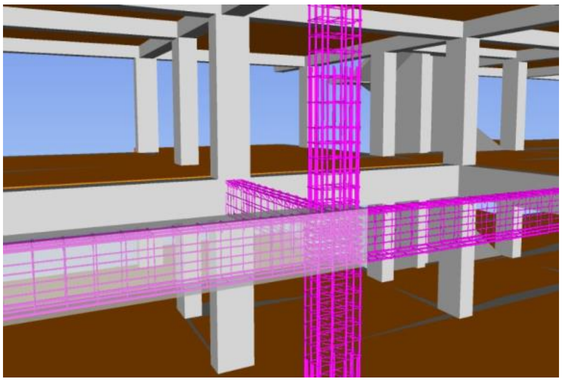

Figure 3. A federated structural model in Navisworks, depicting the integration of reinforcing detail into the concrete frame, is shown in this representative image.

4.6 Efficiency in Workflow and Time Required for Manual Corrections

Despite the fact that both transfer methodologies needed human verification, BIM-based processes saved a lot of time as compared to manually generating an analytical model in ETABS. Table 8. Necessity of manual correction

Workflow	Correction Time	Estimated Manual Modelling Time	Time Saving
Native Revit–ETABS	95 min	6.5 hours	≈76%
IFC Revit–ETABS	165 min	6.5 hours	≈58%

Since most main structural pieces were translated accurately, the native process acquired greater efficiency. Due to property-mapping constraints, the IFC process needed extra modification; nonetheless, it still saved a lot of time compared to recreating the analytical model manually. Instead of seeing BIM-to-FEM interoperability as a substitute for engineering judgment, these findings suggest it is best seen as an automation strategy for cutting down on repetitious modeling work without sacrificing verification needs.

V. CONCLUSIONS

This research systematically evaluated native API-mediated and IFC-based BIM-to-FEM processes to assess the interoperability performance between Autodesk Revit and CSI ETABS. Using a case study of a five-story reinforced concrete structure model, the correctness of structural elements, analytical connectedness, and preservation of structural attributes were utilized to evaluate the dependability of information transmission. The following are the key takeaways from this study: Primary structural components are very reliably produced using the basic Revit-ETABS process. Converting traditional reinforced concrete BIM models into ETABS analytical models was made easy using the direct interoperability technique, which achieved 100% transfer accuracy for columns and beams. This proves that the workflow enabled by CSI is successful. Transferring slab properties, connecting nodes, and ensuring analytical axis alignment were all tasks that still needed human intervention.

Reliable geometric interchange is provided by the IFC-based process, although property preservation is degraded. With great precision for analytical alignments and nodes, the structural model's general geometric framework was preserved throughout IFC transfer. Disagreements in how BIM and FEM interpret the IFC led to less reliable member characteristics, material allocations, and slab information. There are still major obstacles to interoperability with slabs and analytical connections. Slabs showed the greatest vulnerability to data loss in both directions of the transmission. Full automation of BIM-to-FEM conversion is still a ways off, according to the findings, due to factors including layered BIM representations and methodology discrepancies between analytical and physical modeling. The best approach to achieving BIM-to-FEM interoperability is not to automate the process entirely, but rather to establish a regulated and validated workflow. For a realistic plan to lessen mistakes while keeping the advantages of BIM-based automation, use the suggested checkpoint-based integration method. It comprises regulated BIM modeling practices, post-transfer verification, and federated coordination.

We still need to evaluate the compatibility of each platform separately. Differences in particular performance categories, especially analytical connectivity, show that interoperability behavior cannot be assumed to be identical across software systems, even though the overall failure patterns seen in this study are in line with prior investigations involving other structural analysis platforms. While engineering judgment is still required for analytical model verification, the research shows that Revit-ETABS compatibility may greatly minimize

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structural modeling labor. Results show that structural processes provided by building information modeling (BIM) that use partial automation in conjunction with rigorous quality-control methods are the way to go. The assessment has to be expanded to include bigger and more complicated structures, other structural typologies, and more software platforms in future study. In order to achieve more dependable BIM-to-FEM integration in future structural engineering practice, it may be helpful to further investigate automatic correction procedures employing ETABS API tools, enhance IFC implementations, and develop model validation methods based on artificial intelligence.

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