Intelligent Automation and Optimization of Structural Design in BIM-Based Workflows: Case Studies

Tafraout Salim[1] and Bourahla Nouredine[2]

[1] Ecole Nationale Supérieure des Travaux Publics ENSTP, LTPiTE Laboratory, Algiers, Algeria
[2] Ecole Nationale Polytechnique, Civil Engineering Department, LGSDS Laboratory, Algiers, Algeria
s.tafraout@enstp.edu.dz, nouredine.bourahla@g.enp.edu.dz

Abstract

This paper presents an AI-driven framework designed for automating and optimizing structural systems within a Building Information Modeling (BIM) workflow. The process begins by examining architectural layouts from IFC files to automatically define a valid search space for structural elements, ensuring that the solutions adhere to a set of structural design constraints. Central to this approach is a multi-objective optimization engine driven by a genetic algorithm (GA). It commences with an initial population of structural configurations, which are then validated against criteria for architectural, structural, and seismic design. Versatility and robustness of the framework are demonstrated through three challenging case studies. For reinforced concrete (RC) wall-slab systems and cold-formed steel (CFS) structures, a GA optimally determines the primary load-bearing elements to satisfy structural and seismic requirements. For RC dual systems (RCDS), a novel hybrid optimization strategy was implemented, beginning with a hill-climbing algorithm that performs a targeted search to determine optimal column placements. Following this, a genetic algorithm is employed to refine the positioning and configuration of shear walls within the established column grid, ultimately enhancing the performance of the dual system. The results indicate that the framework consistently produces high-performance, compliant structural designs rapidly. By automating intricate initial design tasks, this approach not only accelerates the design process but also enhances collaboration between architects and engineers, demonstrating significant potential for widespread adoption in the Architecture, Engineering, and Construction (AEC) industry.

Keywords –
Automation Design; Hybrid Optimization; Genetic Algorithm; BIM; Seismic Design; AEC Industry.

1 Introduction

The integration of artificial intelligence (AI) is catalyzing a profound metamorphosis within the Architecture, Engineering, and Construction (AEC) industry. Due to the iterative and multidisciplinary nature of design and construction processes, this sector is particularly well-suited for the application of AI-driven generative and optimization techniques. A comprehensive review of generative AI in structural engineering identifies several pivotal research domains, including data representation, intelligent generation algorithms, design evaluation metrics, and the synthesis of generation and optimization workflows [1, 2].

Architects are increasingly using AI to augment the design process [3, 4, 5]. Machine learning algorithms enable rapid iterations for complex geometries, facilitating the creation of more sophisticated architectural forms [6, 7]. Moreover, AI is optimizing mechanical, electrical, and plumbing (MEP) systems, thereby enhancing energy performance during the early stages of design [8, 9]. Within Building Information Modeling (BIM) environments, these advanced tools contribute to improved project oversight through automated monitoring and analysis [10].

Recent advancements in structural engineering have introduced innovative methods for automation in design and optimization that transcend traditional methodologies. A significant approach is represented by AIBIM, which incorporates Generative AI in conjunction with Building Information Modeling. This methodology employs a Physics-based Conditional Diffusion Model (PCDM) to generate high-quality structural designs, taking into account real-world constraints such as building height and seismic intensity [11]. Furthermore, the utilization of Generative Adversarial Networks (GANs) has been demonstrated in the automation of layout design for steel frame-braced structures, leveraging existing drawings from experienced engineers to enhance design efficiency [12].

Of particular interest, newly developed frameworks, rule-based approaches employing AI algorithms show high potential for BIM integration [13-15]; however, some more case studies for comparison and performance evaluation are required. In continuation of this previous work, the authors present a synthesis of these newly formulated frameworks in a single system-tool outlining the design processes for the three distinct types of structures made from various materials. The first type discussed is wall-slab reinforced concrete (RC) structures [13]. The second type focuses on cold-formed steel (CFS) structures [14]. Lastly, the RC dual systems, as detailed in [15].

The efficiency and robustness of these frameworks have been validated through testing BIM models of 17 architectural buildings, incorporating various configurations and levels of complexity. The unified GA/HCA pipeline automates the process of converting IFC to structural layouts across common systems.

As novelty, our proposed framework advances beyond our prior individual system studies [13-15] through three key innovations: (1) a unified IFC-to-layout pipeline integrating all three structural systems within a single framework; (2) standardized multi-objective fitness functions enabling direct performance comparison across RC, CFS, and dual systems; and (3) comprehensive validation across diverse BIM models demonstrating framework generality and robustness. These advancements transform fragmented single-system tools into a production-ready, multi-material seismic design platform.

2 AI-based structural design framework

The proposed framework addresses three common seismic-resistant structural systems for low to medium-rise buildings: Reinforced Concrete (RC) wall-slab systems, Cold-formed steel (CFS) shear wall panels, and RC dual systems, which combine moment frames and shear walls. These systems represent the load-resisting configurations that are commonly found worldwide.

The approaches reviewed for optimizing structural design start with the implementation of an architectural 3D-BIM model. This model aids in identifying suitable locations for structural elements while taking into account architectural considerations such as openings, slab limits, and partition walls. This ensures a continuous load path from the roof to the foundations. The optimization problem is inherently multi-objective, aiming to select the most effective structural configuration from a range of alternatives. Once common architectural constraints are established, the methodologies diverge based on the type of structure, utilizing specialized algorithms and design focuses. For reinforced concrete (RC) wall-slab systems, a single genetic algorithm is employed to generate an optimized structure from a given set of elements. In contrast, cold-formed steel (CFS) structures use a tailored genetic algorithm to optimize the layout of shear walls, while also evaluating various weights for the objective functions. For dual systems, a hybrid protocol begins with a hill-climbing algorithm to determine an optimal frame, followed by a genetic algorithm to effectively distribute the shear walls. All of these approaches ensure that the optimal solution complies with established structural rules and meets stability criteria in accordance with relevant codes of practice.

3 Structural constraints and design rules

In contemporary architectural practice, it is imperative that structural systems afford architects enhanced flexibility in spatial planning while simultaneously optimizing surface utilization. Engineers are tasked with the challenge of devising efficient structural solutions that align with the architectural design, ensuring that strength and stability are not compromised. Typically, buildings employ self-supporting vertical elements, such as columns and walls, complemented by horizontal components like beams and slabs, to manage lateral forces resulting from seismic and wind loads, effectively transferring these forces to the foundation. This section outlines the structural criteria for the developed Generative Algorithm (GA) and Hill-Climbing Algorithm (HCA) within an automated design framework. Focusing on prevalent structural systems for common multi-storey buildings, the GA optimizes the placement of discrete elements, such as shear walls or CFS panels, while the HCA is utilized to optimize the column positions along the axes in dual systems.

3.1 Reinforced concrete wall-slab system

The design of Reinforced Concrete (RC) Wall-Slab systems adeptly confronts various construction challenges by ensuring a rigid connection between the slabs and RC walls. This integration results in a monolithic structure that significantly enhances stability through inherent redundancy. The walls function as load-bearing elements, effectively resisting both vertical loads and lateral forces. The essential criteria for the genetic algorithm employed in the multi-objective optimization process are summarized as follows [13]:

3.2 Individual shear wall lengths

Seismic design codes, such as the Algerian RPA2024 and Eurocode EC8, delineate the parameters for reinforced concrete (RC) shear walls, specifically in terms of their thickness and length. These parameters critically influence the walls' stiffness, strength, and modes of failure. The minimum thickness of these walls is determined by the free height of the floor, thus ensuring adequate structural integrity. Within the context of the developed framework, the permissible lengths for these shear walls range from 0.8 to 5.5 meters, which aligns with the requirements for low- to medium-height buildings. This framework aims to optimize the performance and reliability of shear walls under seismic loading conditions.

3.3 Total length of RC shear walls

The total length of reinforced concrete (RC) shear walls can be defined as the ratio of their total cross-sectional area to the surface area of the corresponding floor. To ascertain the requisite shear wall length for ensuring structural stability and strength, an iterative parametric analysis, in conjunction with established earthquake engineering recommendations, was employed. The minimum length is calculated based on the floor area (Sf) and the overall height of the building (H) using the following methodology:

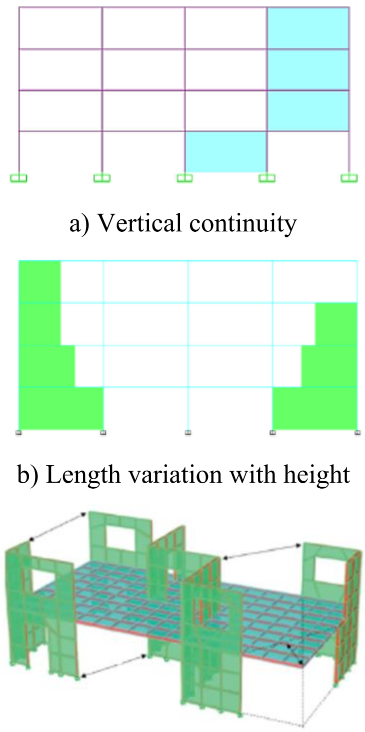
$$L_{w,m} = 0.007H.\ S_f \text{ for } H < 30\text{ m} \quad (1)$$
$$L_{w,m} = 0.013H.\ S_f \text{ for } 30\text{ m} < H < 100\text{ m} \quad (2)$$

3.4 RC shear wall layouts

The configuration of reinforced concrete (RC) walls is essential for optimizing a structure's torsional response in the face of seismic activity. Two primary criteria are delineated in this context: Firstly, shear walls should be strategically positioned in proximity to the center of stiffness and aligned with the center of mass across both horizontal axes. Secondly, these walls should be situated as distantly as possible from the center of the floor to increase torsional stiffness. This specific arrangement plays a crucial role in preserving plan uniformity and facilitating non-torsional flexibility, thereby enhancing the overall seismic performance of the structure.

3.4.1 Other criteria

- Load path continuity: It is imperative to maintain load path continuity to ensure the effective vertical transfer of lateral forces to the foundation system, as illustrated in Figure 1-a.
- Variation in shear-wall length with height: An optimal structural design necessitates a progressive reduction in the stiffness of shear walls, which is achieved by decreasing their length from the base to the top of the structure, as depicted in Figure 1-b.
- Geometric slab conditions: Established guidelines regarding geometric slab conditions highlight critical parameters, such as the span distance between two reinforced concrete walls and the maximum allowable free length of a cantilever, which is typically restricted to a maximum of 2.5 meters, as shown in Figure 1-c.



a) Vertical continuity

b) Length variation with height

c) Geometric condition for slab

Figures 1. RC Wall-Slab design criteria

3.5 Cold-formed steel structures

A cold-formed steel (CFS) structure represents a sophisticated form of light-frame construction characterized by the assembly of vertical and horizontal components comprised of repetitive framing members (Figure 2). The integration of rigid connections between the slabs and walls significantly contributes to the overall stability and redundancy of the system. Vertical loads are efficiently transferred from the floor joists to lipped channel "stud" members, which are anchored to the foundation utilizing unlipped channel "track" sections. Furthermore, lateral forces resultant from seismic or wind loads are effectively transmitted to the foundation through the incorporation of shear wall panels or bracing systems, presuming the presence of rigid diaphragms and strict adherence to capacity design criteria. This structural configuration underscores the importance of careful design considerations in ensuring the resilience and performance of cold-formed steel construction in various loading scenarios.

Figure 2. Examples of CFS structure

The shear wall system (SWP) serves as the principal lateral load-resisting framework, employing cold-formed steel (CFS) C-shaped framing affixed to either steel or wood sheathing through mechanical fastening. This system is engineered to exhibit inelastic behavior at the connection points until failure occurs.

The nominal strength of the system will guide the preliminary design process concerning the requisite lengths for each floor, subsequently followed by comprehensive cross-section evaluations.

Fundamental criteria necessary for the effective implementation of this system in the framework of GA multi-objective optimization are delineated below [14]:

3.5.1 Joist directions

The orientation of joists within a structural slab is predominantly influenced by the spans involved as well as the configuration of wall openings. It is recommended that joists be aligned with the longer span; in instances where the dimensions are comparable, they should be oriented parallel to the walls that exhibit fewer openings.

3.5.2 Length of individual wall

The minimum length of a single wall panel is dictated by the spacing between two consecutive studs, with a specified minimum distance of L_{wmin} = 60 cm. Furthermore, the height-to-width (h/w) ratio of an SWP is constrained by a maximum allowable ratio of 4:1. It is posited that the optimal length of an SWP is represented by L_{wopt} = h, where "h" denotes the height of the storey.

3.5.3 Total Length of SWPs

Shear wall panels (SWPs) must exhibit the capacity to withstand lateral loads induced by wind or seismic events from both directions. The minimum total length of shear walls required "L_{wtmin}" at each level and for each directional influence is determined by calculating the level shear lateral load (Vi) and dividing it by the nominal strength of the shear wall per unit length ($R_{nom.}$). This calculation is essential for ensuring structural integrity and stability in the face of lateral forces.

3.5.4 Other criteria

In alignment with the principles established for the RC-SW system, it is imperative to incorporate two critical structural criteria into the objective function on this structural configuration: the continuity of the vertical load path and the spatial distribution of the shear wall panels (SWP) in plan view. The integration of these criteria facilitates a reduction in overall stiffness while mitigating the risk of vertical discontinuities, thereby minimizing the torsional response of the building. This approach not only enhances structural performance but also contributes to the overall stability and resilience of the system.

3.6 Reinforced concrete dual systems

The automated design process for the structural system initiates with the identification of optimal layouts for moment-resisting frames (MRFs), a task that presents significant challenges due to the various configurations available for column placements. The subsequent phase encompasses the strategic arrangement of shear walls within the established MRF framework [15].

The process starts by overlaying architectural floor plans to facilitate the alignment of wall partitions and non-structural components, such as doors and windows, thereby aiding in the identification of potential column locations. To optimize this arrangement, a Hill-Climbing Algorithm (HCA) is selected to define the axis positions of the columns. This is particularly suitable for a given set of predefined potential axes. It iteratively moves from one solution to its neighbors by applying slight changes to the positions of the axes. At each iteration, neighbors of the current solution are generated and evaluated. The best one, based on the given criteria, is then selected to replace the current one for the next iteration. This allows for rapid convergence to optimal axis positions.

This automated methodology, founded upon the geometric data provided by the Industry Foundation Classes (IFC), yields feasible column positions, as presented in Figures 3 and 4.

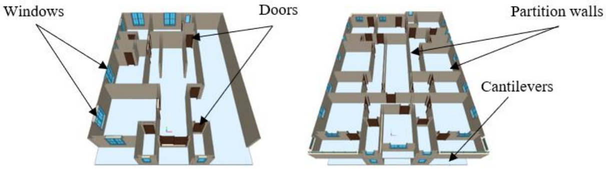


Figure 3. 3D-BIM model (IFC)

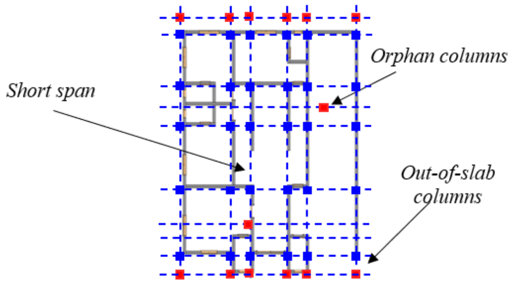


Figure 4. Potential column positions

Once optimal MRF grids have been established, the positioning of shear walls to facilitate the creation of reinforced concrete dual systems (RCDS) must be meticulously aligned with this predetermined grid framework.

It is imperative to enforce a minimum distance constraint to avert the formation of short links between load-bearing elements. Furthermore, in compliance with prevailing seismic codes, the moment-resisting frame (MRF) is required to endure a minimum of 25% of the base shear. The lateral loads acting on the structure are simultaneously resisted by the shear walls (SWs) and the MRF, with their capacity to resist loads being determined by their respective stiffness characteristics.

The seismic design classification of the RCDS as per Eurocode 8 (EC8) is contingent upon the proportion of shear resistance contributed by both the MRF and the shear walls. In scenarios where either the MRF or the shear walls account for more than 50% of the total shear resistance of the structure, stringent control measures must be implemented. This is achieved through the imposition of minimum and maximum length constraints for the shear walls in both principal directions. Optimization of the RCDS layout is facilitated through a scoring approach predicated on a defined fitness function.

In addition to shear wall dimensions, other critical parameters, such as the total slab area and the effective covered area, which accounts for the surface area directly supported by the shear walls while considering overlaps with adjacent structural elements and overhangs from the slab edges, are systematically calculated for each configuration. Scoring formulas are developed and systematically integrated into a multi-objective optimization function, thereby regulating the ratio of shear walls' contributions to the gravity load-bearing capacity within the RCDS framework.

4 GA-based process for generating structural design

In an architectural BIM platform, the IFC protocol facilitates the export of the model's geometry and elements. The algorithm defines slab boundaries and wall partition layouts for each floor, including openings. Structural elements are generated iteratively based on genetic actions. The Genetic Algorithm (GA) optimizes the structural layout after a set number of iterations, effectively meeting constraints and maximizing the objective function.

1. Random generation of the initial population: The algorithm commences by generating an initial population that comprises a diverse set of structural elements. These elements are randomly allocated within the architectural partitions to establish a foundational layout for subsequent iterations.
2. Selection: The selection phase operates on the principle of fitness ranking, wherein the layouts of the subsequent population are chosen based on the performance metrics of all individuals within the current population. This evaluation encompasses layouts produced through crossover and mutation processes, ensuring that the most promising designs are carried forward.
3. Crossover: This function facilitates the unification of structural characteristics from two or more existing configurations to produce a novel layout. This process ensures that the resultant solution retains desirable attributes from the parent layouts while adhering to established structural constraints, thereby enhancing the viability of the new configuration.

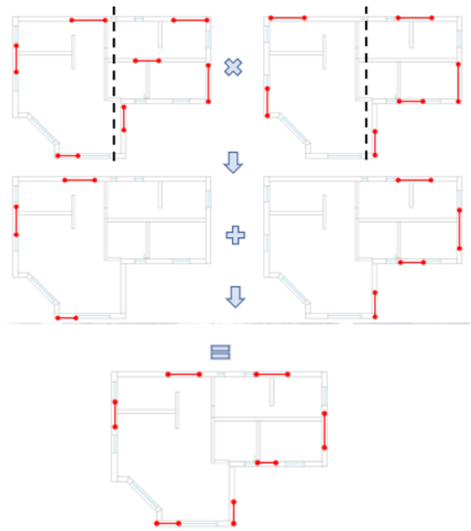


Figure 5. Crossover function

4. Mutation: The mutation function serves to enhance the variability within the population by implementing alterations to the structural layout. This may involve the insertion of the new elements, the removal of an existing one, or the modification of the dimensions of the current elements, such as shortening or extending the length of the SW. These changes expand the range of possible designs, enhancing innovative structural solutions.

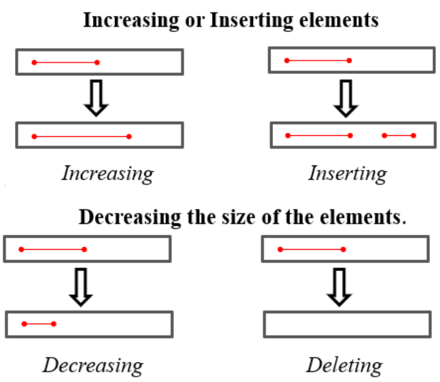


Figure 6. Mutation function

A multi-objective optimization function has been established to direct the population towards an optimal solution, grounded in the established criteria pertinent to each structural type. This optimization function encompasses a diverse set of criteria, each designated with a score ranging from 0 to 1.0, reflecting the validity of the criterion's condition.

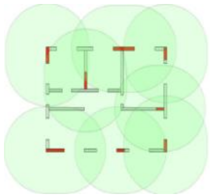
The fitness value of a given layout solution is computed through a weighted linear combination of scores across the various criteria. Initially, uniform weights of 1.0 were applied, yielding acceptable outcomes. Subsequently, a sensitivity analysis was conducted to fine-tune these weights in accordance with the significance of each criterion.

The termination process occurs following the completion of the primary evolutionary loop, typically when the objective function reaches a predetermined threshold. However, in the context of multi-objective functions, defining a specific value poses significant challenges. Consequently, a limited number of iterations, generally ranging from 50 to 100, has been implemented, resulting in satisfactory outcomes.

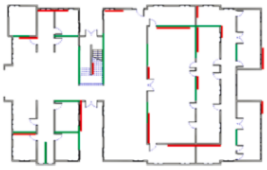
5 Performance criteria of the multi-objective function

The performance parameters associated with the multi-objective function were rigorously evaluated through the analysis of seventeen (17) architectural BIM models, specifically to assess the efficacy of GA in structural design. The selection of samples was methodical, reflecting a diversity in dimensions, forms, placement of openings, and configurations of partitions. The input extracted from the IFC models was instrumental for the GA, which subsequently generated optimized structural solutions through a series of iterative processes. Generated structural designs conformed to established architectural standards, catering to the specified requirements for interior partitions, positioning of openings, and the delineation of wall load paths.

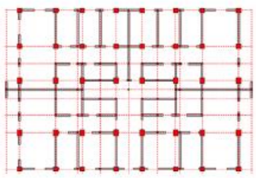
For RC-SW and Dual designs, three-dimensional numerical models were developed utilizing BIM-compatible finite element (FE) software to rigorously evaluate the structural performance of layouts generated through the GA. The assessment was conducted to ascertain compliance with established structural design constraints. The findings reveal that all design criteria were satisfactorily fulfilled, particularly regarding stability conditions and structural strength [13-15]. For the SWP design, the structural performance was evaluated by juxtaposing the GA-generated layout with a conventional structural layout [14]. Figures 7a, 7b, and 7c present examples of generated designs for each type of structure.



a) RC-SW design



b) SWP design



c) Dual system design

Figure 7. Various generated structural designs

Table 5.1 summarizes key metrics that quantify performance, robustness, and efficiency claims across these 17 BIM models:

Table 1: Performance metrics across 17 BIM models

Criterion	RC W-S	CFS SWP	RC Dual
Const. Satisfaction	100%	100%	100%
Avg. Conv. Iterations	50 - 100		
Tors. Irreg. Reduction	~35%	~35%	~30%
Overstrength Factor	> 2.0		

These results confirm the framework's robustness: 100% of seismic code compliance across all systems, consistent convergence within design limits, significant torsional improvements, and ductile overstrength meeting seismic performance objectives, where more than 90% of the structural members of tested models remain in the elastic branch [13-18].

The genetic algorithm demonstrated notable robustness and efficacy in the generation of layouts, particularly for the RC-SW system. This was substantiated by varying key design constraints and adjusting the weight scales within the objective function, which indicated a significant efficiency in managing the design criteria [16-17].

Additionally, a recent analysis reviewed the models based on the hill-climbing algorithm (HCA) for the development of moment-resisting frames (MRFs) structural designs. The structures were subjected to pushover analysis, which facilitated the identification of capacity curves and performance points tailored to specific seismic demands. Notably, despite the utilization of general objective functions, the evaluated layouts exhibited strong performance and adhered to seismic standards. The analysis demonstrated that over 90% of structural members did not exhibit the formation of plastic hinges, with the MRFs sustaining performance within the Immediate Occupancy (IO) to Life Safety (LS) range, indicative of substantial overstrength. These insights suggest promising avenues for future research aimed at enhancing the algorithm through the integration of a Performance-Based Design (PBD) approach, thereby improving the control of structural performance [18].

6 Conclusion

The integration of automation and optimization within the Architecture, Engineering, and Construction (AEC) industry signifies a pivotal transformation in the paradigms of building design and construction methodologies. The deployment of advanced computational tools, artificial intelligence, and data analytics serves to enhance the efficiency, precision, and innovative capacity inherent in structural design processes.

This paper presents a comprehensive review of a newly developed framework proposed by the authors, which employs Genetic Algorithms (GA) and Hill-Climbing Algorithm (HCA) to facilitate the automatic generation of optimal structural systems predicated on specified architectural configurations in a three-dimensional Building Information Modeling (3D-BIM) format. The core premise of this methodology is the establishment of a multi-objective optimization process. This process entails the stochastic generation of a vast array of potential structural configurations that adhere to architectural constraints, alongside a defined set of general structural and seismic design principles. Through successive iterations, the optimization process converges towards solutions that increasingly align with the predetermined criteria.

The proposed method has been systematically applied to three prevalent structural designs:

Reinforced Concrete Shear Wall and Slab (RC SW-Slb), cold-formed steel Panels (SWP), and dual systems. The outcomes relative to the performance, efficiency, and robustness of the generated structures indicate substantial advancements in the formulation of optimized structural configurations for the examined design samples, all of which conform to the specified design criteria for a given architectural layout.

References

[1] W. Liao, X. Lu, Y. Fei, Y. Gu, Y. Huang. Generative AI design for building structures. *Automation in Construction, 157, 105187*, 2024. https://doi.org/10.1016/j.autcon.2023.105187

[2] A. Nikitin, S. Sinenko. Features of the use AI in generative design of building and structures. *Journal of mechanics of continua and mathematical sciences, Vol – 19 No – 5,* 2024. https://doi.org/10.26782/jmcms.2024.05.00001

[3] Y. Li, H. Chen, P. Yu, L. Yang. A Review of Artificial Intelligence in Enhancing Architectural Design Efficiency. *Journal of Applied Science, 15, 1476*, 2025. https://doi.org/10.3390/app15031476

[4] S. W. Dharmatanna, E. S. Wijaya. The Study of AI integrated Simulation in Building Information Modelling (BIM) Use at Architectural Design Studio. *Journal of Artificial Intelligence in Architecture, vol. 4, no. 1, pp. 23–34*, 2025. https://doi.org/10.24002/jarina.v4i1.9415

[5] J. Anshul, K. Ananda Babu. Application of Artificial Intelligence (AI) in the sustainable design of green buildings. *Journal of Environmental Pollution and Environmental Modelling, Vol. 8(1): 59-65*, 2025.

[6] A. Ayman, Y. Mansour, H. Eldaly. Applying machine learning algorithms to architectural parameters for form generation. *Automation in Construction, Volume 166, 105624*, 2024. https://doi.org/10.1016/j.autcon.2024.105624

[7] D. D. Shuvo, I. Mobasshira, S. Md. Habibur Rahman, A. Shakil, K. Moumita. Artificial intelligence and machine learning applications in the project lifecycle of the construction industry: A comprehensive review. *Heliyon, Volume 10, Issue 5, e26888,* 2024. https://doi.org/10.1016/j.heliyon.2024.e26888

[8] R. Deng, X. Li, Y. Tian. A Review: The Application of Path Optimization Algorithms in Building Mechanical, Electrical, and Plumbing Pipe Design. *Buildings, 15(12),2093,* 2025, https://doi.org/10.3390/buildings15122093

[9] D.N. Tahat, A. Mansoori, K. Tahat, R. Alfaisal, H. Yousuf, S.A. Salloum. Integrating Generative AI into Predictive Modeling for Energy Efficiency Optimization in Building Design. Generative AI in Creative Industries. *Studies in Computational Intelligence, vol 1208. Springer,* 2025). https://doi.org/10.1007/978-3-031-89175-5_36

[10] G. Wei, D. Zhou, X. Yuan. Target Detection Technology of Mechanical, Electrical, and Plumbing Components Based on CV. *Applied Science, 15, 2803*, 2025, https://doi.org/10.3390/app15052803

[11] Z. He, Yu-H. Wang , J. Zhang. Generative AIBIM: An automatic and intelligent structural design pipeline integrating BIM and generative AI. *Information Fusion (114) 102654*, 2025, https://doi.org/10.1016/j.inffus.2024.102654

[12] B. Fu, Y. Gao, W. Wang. Dual generative adversarial networks for automated component layout design of steel frame-brace structures. *Automation in Construction, 146, 104661*, 2023, https://doi.org/10.1016/j.autcon.2022.104661

[13] S. Tafraout, N. Bourahla, Y. Bourahla, A. Mebarki. Automatic structural design of RC wall-slab buildings using a genetic algorithm with application in BIM environment. *Automation in Construction 106 102901*, 2019, https://doi.org/10.1016/j.autcon.2019.102901

[14] N. Bourahla, S. Tafraout, Y. Bourahla, A. Serier El-Hirtsi, A. Skoudarli. GA based design automation and optimization of earthquake resisting CFS structures in a BIM environment. *Structures 43, 1334–1341*, 2022, https://doi.org/10.1016/j.istruc.2022.07.041

[15] N. Bourahla, S. Larfi, K. Souaci, Y. Bourahla, S. Tafraout. Intelligent automation and optimization of reinforced concrete dual systems for earthquake resisting buildings in a BIM environment. *Journal of Building Engineering 76, 107111*, 2023, https://doi.org/10.1016/j.jobe.2023.107111

[16] N. Bourahla, S. Tafraout, Y Bourahla. Performance evaluation of an intelligent structural design process in a BIM environment: case of RC wall slab resistance systems. *In Proceeding of the conference RACEI,* pages 604-610, India, 2019.

[17] N. Bourahla, S. Tafraout, Y. Bourahla. Intelligent structural design in BIM platforms: Optimization of RC wall slab systems. *European Conference on Product and Process Modeling, ECPPM,* Russia, 2021, http://dx.doi.org/10.1201/9781003191476-36

[18] S. Tafraout, N. Bourahla. Seismic performance of automatically generated ductile moment resisting frames. *Conference of the Civil and Environmental Engineering for Resilient, Smart and Sustainable Solutions CEES*, Saudi Arabia, 2024, https://doi.org/10.21741/9781644903414-23.