NIST Technical Note
NIST TN 2345

User’s Manual of DAD_PBD:
3D Viewer Graphical User Interface

DAD_PBD version 2.1

Daniel M. Rhee
DongHun Yeo
Tyler Gorton
Charys Clay

This publication is available free of charge from:
https://doi.org/10.6028/NIST.TN.2345

NIST Technical Note
NIST TN 2345

User’s Manual of DAD_PBD: 3D Viewer Graphical User Interface

DAD_PBD version 2.1

Daniel M. Rhee
DongHun Yeo
Materials and Structural Systems Division
Engineering Laboratory

Tyler Gorton
Charys Clay
Arup

This publication is available free of charge from:
https://doi.org/10.6028/NIST.TN.2345

August 2025

U.S. Department of Commerce
Howard Lutnick, Secretary

National Institute of Standards and Technology
Craig Burkhardt, Acting Under Secretary of Commerce for Standards and Technology and Acting NIST Director

NIST TN 2345
August 2025

NIST Technical Series Policies

Publication History

Approved by the NIST Editorial Review Board on 2025-08-04.

How to Cite this NIST Technical Series Publication

Rhee, D. M., Yeo, D., Gorton, T., Clay, C. (2025), User's Manual of DAD_PBD 3D Viewer Graphical User Interface. (National Institute of Standards and Technology, Gaithersburg, MD), Technical Note (NIST TN) 2345. https://doi.org/10.6028/NIST.TN.2345

Author ORCID iDs

Daniel M. Rhee: 0000-0002-4213-6075
DongHun Yeo: 0000-0002-8019-9624

Contact Information

daniel.rhee@nist.gov
donghun.yeo@nist.gov

Submit Comments

donghun.yeo@nist.gov

Abstract

The DAD_PBD is a user-friendly structural design tool for mid- and high-rise buildings, developed at the National Institute of Standards and Technology (NIST). It incorporates the commercial software ETABS for structural and dynamic analysis and applies the Database-Assisted Design (DAD) approach, utilizing time-domain analysis, directional aerodynamic pressure data, and site-specific wind climatological data to advance structural design under wind loads. In recent years, the DAD_PBD has been continuously improved by expanding both its applications and capabilities. However, the visual capability remained limited, as the DAD_PBD calculates the design parameters independently of ETABS, which does not permit the design results to be imported back into the interface for visualization. This lack of visualization capability made interpreting the DAD results particularly challenging for high-rise structures with numerous structural elements.

To address this limitation, DAD_PBD version 2.1 included a three-dimensional (3D) viewer designed to improve user comprehension of the DAD results. The 3D viewer and structural member modeling were developed using Helix-Toolkit, an open-source library for 3D components within the .NET framework. The 3D viewer features 3D building modeling, structural member filtering, and color-coding based on design results. Additionally, a view cube facilitates navigation and viewing from various angles.

This NIST Technical Note provides a User's Manual for the DAD_PBD software (version 2.1) and outlines its most recent enhancements. To demonstrate the software's versatility, three design examples of buildings with individual structural systems and shapes are included. The scope of this report is limited to the 3D viewer. Users are advised to consult other NIST Technical Notes for information regarding DAD analysis.

Keywords

Database-Assisted Design (DAD); Demand-to-Capacity Index; ETABS; High-rise buildings; Irregular-shaped buildings; Python; Reinforced-concrete structures; Steel structures; Structural design; Three-dimensional visualization; Windows Presentation Foundation.

Table of Contents

List of Tables

List of Figures

Acknowledgments

This project was supported by the National Institute of Standards and Technology under contract (1333ND22PNB730647) awarded to Walter P Moore. The authors thank Brian Carmen from Arup for his feedback on the DAD_PBD version 2.1. The authors are also grateful to Mohammed Ali Morovat from NIST and Mehedy Mashnad from Thornton Tomasetti for their thorough reviews of the manuscript. Professor Yong Chul Kim from Tokyo Polytechnic University is also appreciated for providing the geometry and pressure data of the tapered building.

Author Contributions

Daniel Rhee: Methodology, Visualization, Validation, Software, Writing- Original draft preparation. **DongHun Yeo**: Conceptualization, Methodology, Project administration, Supervision, Writing- Reviewing and Editing. **Tyler Gordon**: Visualization, Validation, Software, Writing- Reviewing and Editing. **Charys Clay**: Project administration.

1. Introduction

Database-Assisted Design (DAD) for high-rise buildings, developed at the National Institute of Standards and Technology (NIST), is a framework aimed at improving the design and performance evaluation of tall buildings subjected to wind loads [1]. The DAD framework employs a rigorous and data-driven informed approach utilizing (1) wind tunnel time history data to analyze aerodynamic responses sensitive to building shape and (2) climatological data (i.e., site-specific directional extreme wind speed data) to determine the structural responses at different Mean Recurrence Intervals (MRIs).

Over the past decades, the number of skyscrapers and high-rise buildings has been steadily growing in urban habitats, obliging structural engineers to move away from a prescriptive code-based approach to performance-based design (PBD), which is based on specific performance objectives or expectations. In 2023, the American Society of Civil Engineers (ASCE)/Structural Engineering Institute (SEI) published a Pre-standard for Performance-Based Wind Design (PBWD) to advance building design for winds and offer comprehensive guidance on PBWD [2]. The pre-standard requires a rigorous and data-driven approach to estimate the structural responses of high-rise buildings – a requirement well-supported by the DAD methodology. A recent study showed that the conventional code-based method showed significant discrepancies compared to the DAD approach, demonstrating the capability of DAD for the advanced design of high-rise buildings [3].

NIST has been developing a series of DAD software applications to facilitate the DAD approach for structural engineering practitioners. The DAD_ESWL is a MATLAB-based software that allows users to perform the DAD and the Equivalent Static Wind Load (ESWL) methods on rectangular-shaped steel and Reinforced Concrete (RC) high-rise buildings, using its integrated structural analysis solver [4]. DAD_ETABS is another MATLAB-based software for high-rise steel structures, incorporating Computers and Structures, Inc. (CSI) ETABS [5], a widely used structural analysis software among practicing structural engineers [6]. Despite this integration, both the cost and limited availability of MATLAB licenses within structural engineering firms' offices have been a significant drawback, limiting its use and adaptability within the structural engineering profession [7]. Thus, the Python-based DAD_PBD (version 1.0) was developed. This version not only superseded its predecessor but also incorporated the Deformation Damage Index (DDI) as an additional parameter for serviceability design [8]. Most recently, the DAD_PBD (version 2.0) capability was significantly improved by extending its application to (1) RC structures using commercial design software of RC members (e.g., via spColumn [9]) and (2) irregular-shaped buildings, and (3) substantially reducing computational time through parallel processing of the ETABS analysis [10]. Although the DAD_PBD capability has immensely improved with the incorporation of commercial software, the DAD_PBD software still lacked visualization capabilities of the design results. Because the DAD_PBD only relies on structural and dynamic analysis of the ETABS building model and independently calculates the design parameters (e.g., Demand-to-Capacity Index, Inter-story Drift, Acceleration, DDI), the final design results could not be viewed in the ETABS 3D model. Instead, the design results were presented in a text-based table format in the previous versions of DAD_PBD (version 1.0 and 2.0). This limitation can impede users' ability to interpret design results, particularly for high-rise buildings, which often contain thousands to tens of thousands of structural members.

Through a collaborative effort with Arup Group Limited, the DAD_PBD software was further enhanced with Graphical User Interface (GUI) refinements and the addition of a Three-Dimensional (3D) viewer, displaying the structural model and the DAD results in 3D. The 3D visualization can assist the users in holistically evaluating the design results and easily identifying the under-/over-designed members by color-coded design results. The 3D viewer also includes a view cube, allowing easy navigation and rotation of the 3D model.

This report summarizes the most recent updates on DAD_PBD version 2.1 (v2.1), a user's manual for the 3D viewer, and three design examples. Note that DAD_PBD v2.1 only includes modifications to the GUI, and no changes or new additions were made to the DAD analysis method.

2. User's Manual

2.1. Overview

DAD_PBD v2.1 supersedes v2.0 by enhancing user-friendliness through improved GUI features and integrating a 3D building model viewer. This report solely focuses on the development and manual for the GUI and the 3D viewer. For the procedures related to the DAD approach, including calculation of wind loads and Demand-to-Capacity Index (DCI), users are advised to refer to NIST TN 2308 [10]. Note that DAD_PBD v2.1 is only compatible with Windows operating system and can only display the design results of the DCI on the 3D viewer.

The overall procedure and flowchart of DAD_PBD v2.1, including the DAD analysis, are illustrated in Fig. 1. The tasks performed in DAD_PBD v2.1 are highlighted in the red box, while the processes carried out in ETABS are enclosed in the blue solid box, along with the required input data from the wind engineer shown in blue dashed line. The tasks related to the 3D viewer are represented in bold yellow lines. The steps to perform the DAD analysis and visualize the results using DAD_PBD v2.1 are as follows:

1. Determine Performance Objectives and Acceptance Criteria: The user defines the performance objectives for a design building and establishes the corresponding acceptance criteria for design parameters of interest for the structural design. For detailed information on acceptance criteria, refer to the PBWD Pre-standard [2].
2. Establish Preliminary Design: The user establishes a preliminary ETABS model with initial member sizes based on the ASCE 7 gravity and wind loads [11]. Refer to Section 2.3 of NIST TN 2308 [10].
3. Read ETABS Model: The software extracts the Cartesian coordinates of the joints and structural members from the ETABS model based on the preliminary design. See Section 2.4 in this report.
4. Calculate Wind Loads: The software calculates the wind load time history assigned to each floor using the pressure data from Wind Tunnel (WT) tests or CFD simulations. Refer to Section 2.4 of NIST TN 2308 [10].
5. Perform Dynamic Analysis: The time history wind loads are applied to each floor, and the dynamic analyses are performed for various wind speeds and directions in ETABS. The time histories of the structural response (e.g., internal forces on members, joint displacements, and joint accelerations) are extracted from ETABS. Refer to Section 2.5.3 of NIST TN 2308 [10].
6. Construct Response Surfaces: The software generates response surfaces derived from the peak structural responses across a range of wind speeds and directions of interest. Refer to Section 2.6 of NIST TN 2308 [10].
7. Generate Design Response Curve: With the input of the climatological data, the design response curves based on storm-produced peak structural responses and their corresponding MRI values are generated. Refer to Section 2.7 of NIST TN 2308 [10].

8. Visualize and Check Design Results: Using the coordinates of the joints and structural members (Step 3), the software replicates a 3D model of the building and visualizes the design results based on the design criteria (Step 1). See Section 2.6 in this report. If the design results exceed the acceptance criteria requirements, the member sizes (or reinforcement details in the case of RC building) should be redesigned, and Steps 5 to 7 should be repeated until all the acceptance criteria are met. Refer to NIST TN 2308 [10] for more details.

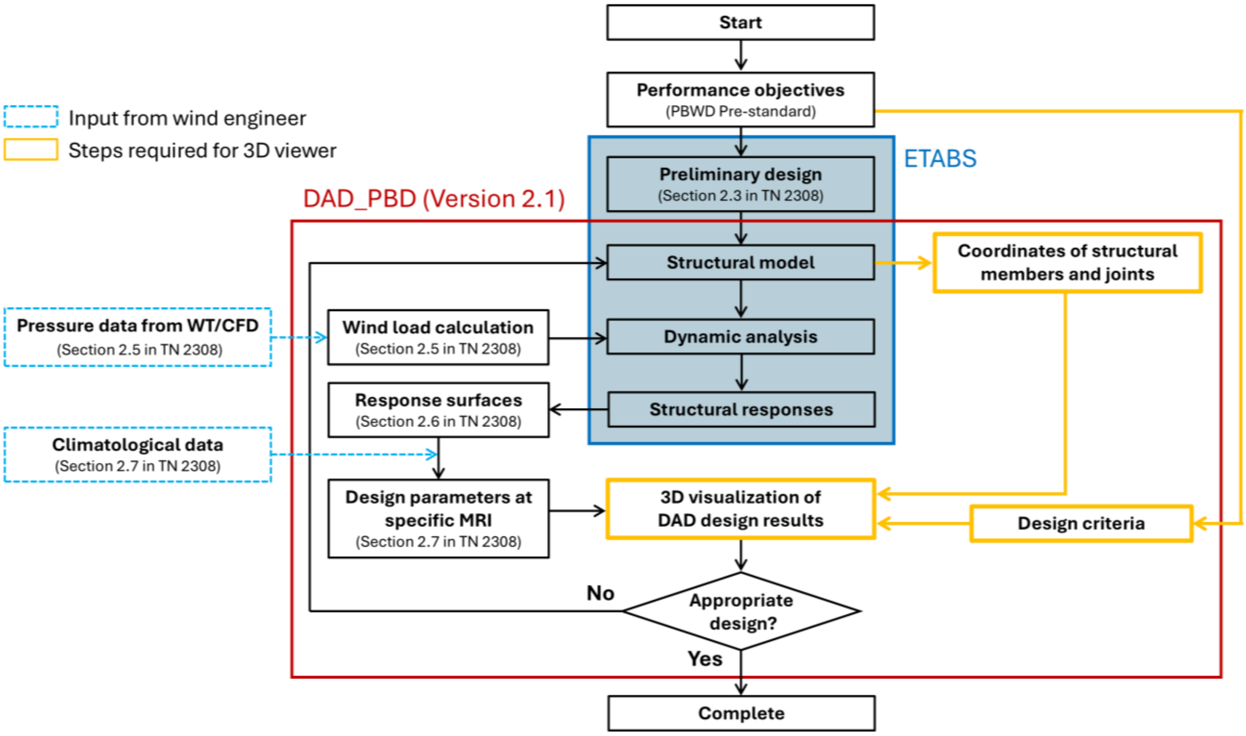


Fig. 1. Process diagram for DAD_PBD v2.1.

2.2. Required Software and Packages

The software and Python packages required for DAD_PBD v2.0 remain applicable to DAD_PBD v2.1. Below is the list of required software and Python packages:

- Structural/dynamic analysis software: CSI ETABS [5]
- Python programming language and packages: NumPy [12], h5py [13], SciPy [14], Matplotlib [15], Pythonnet [16], openpyxl [17], and pandas [18]

For more detailed instructions, users are advised to refer to Section 2.2 of NIST Technical Note (TN) 2308 [10].

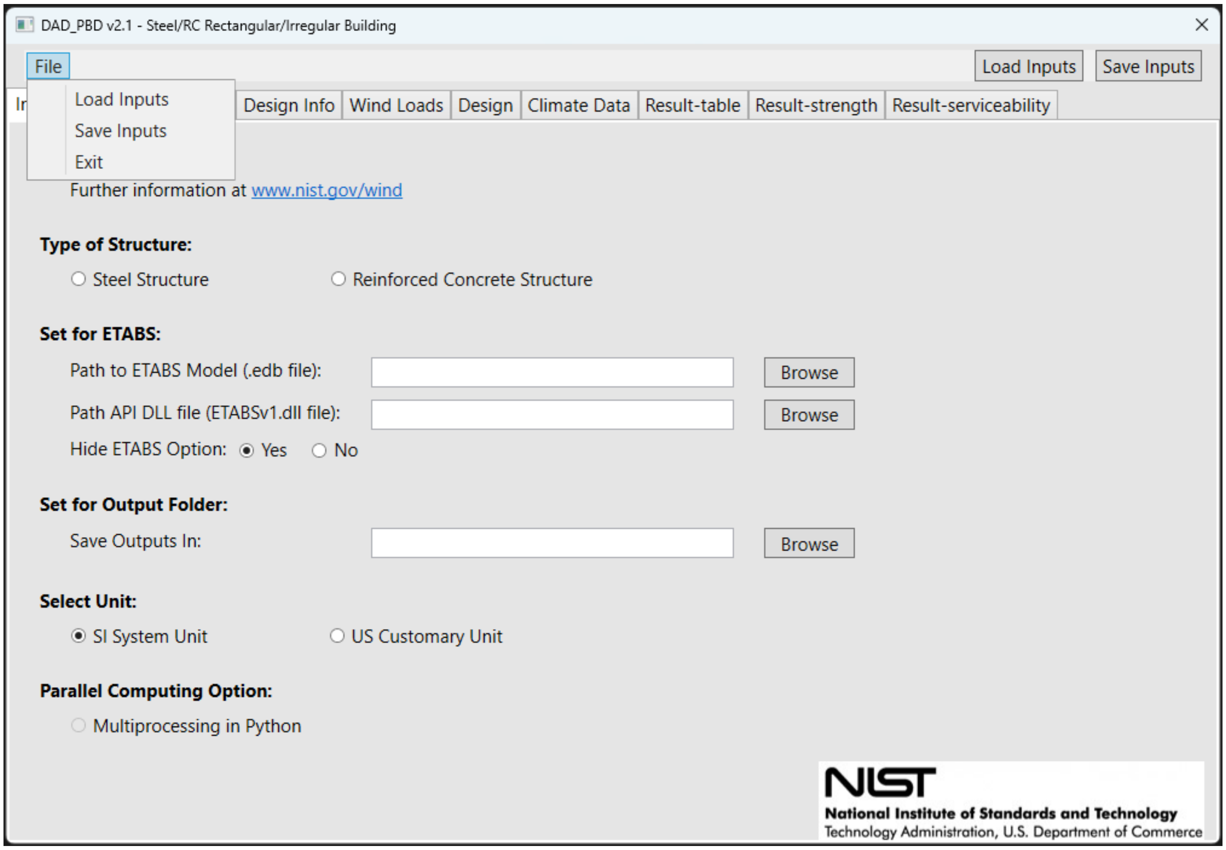
2.3. Getting Started

2.3.1. Initialization

The user should install and execute the DAD_PBD.exe (version 2.1) file, which is freely available for download at http://nist.gov/wind. Upon launching the DAD_PBD v2.1, the program will automatically load the Python dll file from the default directory path. If the program cannot locate the Python dll file, a pop-up window will prompt the user to manually select the directory in which it is located.

The user can input analysis data by loading an input text file. Using the **Load Inputs** button on the top right corner (or under the 'File' menu), the user can locate the input text file (.txt) saved previously during the analysis. For further details on the input text file, refer to Section 2.4.1 of NIST TN 2308 [10].

In DAD_PBD v2.1, a menu bar was added above the tabs, as shown in Fig. 2. The current version only includes the 'File' button, which populates the **Load Inputs**, **Save Inputs**, and **Exit** buttons. Additional menus with further features can be added as the DAD_PBD continues to be updated. In addition, the default name of the input text file is dynamically updated to reflect the date the user accesses the software. For example, the default name would be 'Input_DAD_20250417.txt' if the input text file were to be created on April 17th, 2025. The default name was 'Input_DAD_01012023.txt' in v1.0 and 2.0, regardless of the date.



Further information at www.nist.gov/wind

Type of Structure:

○ Steel Structure ○ Reinforced Concrete Structure

Set for ETABS:

Path to ETABS Model (.edb file):
Path API DLL file (ETABSv1.dll file):
Hide ETABS Option: ● Yes ○ No

Set for Output Folder:

Save Outputs In:

Select Unit:

● SI System Unit ○ US Customary Unit

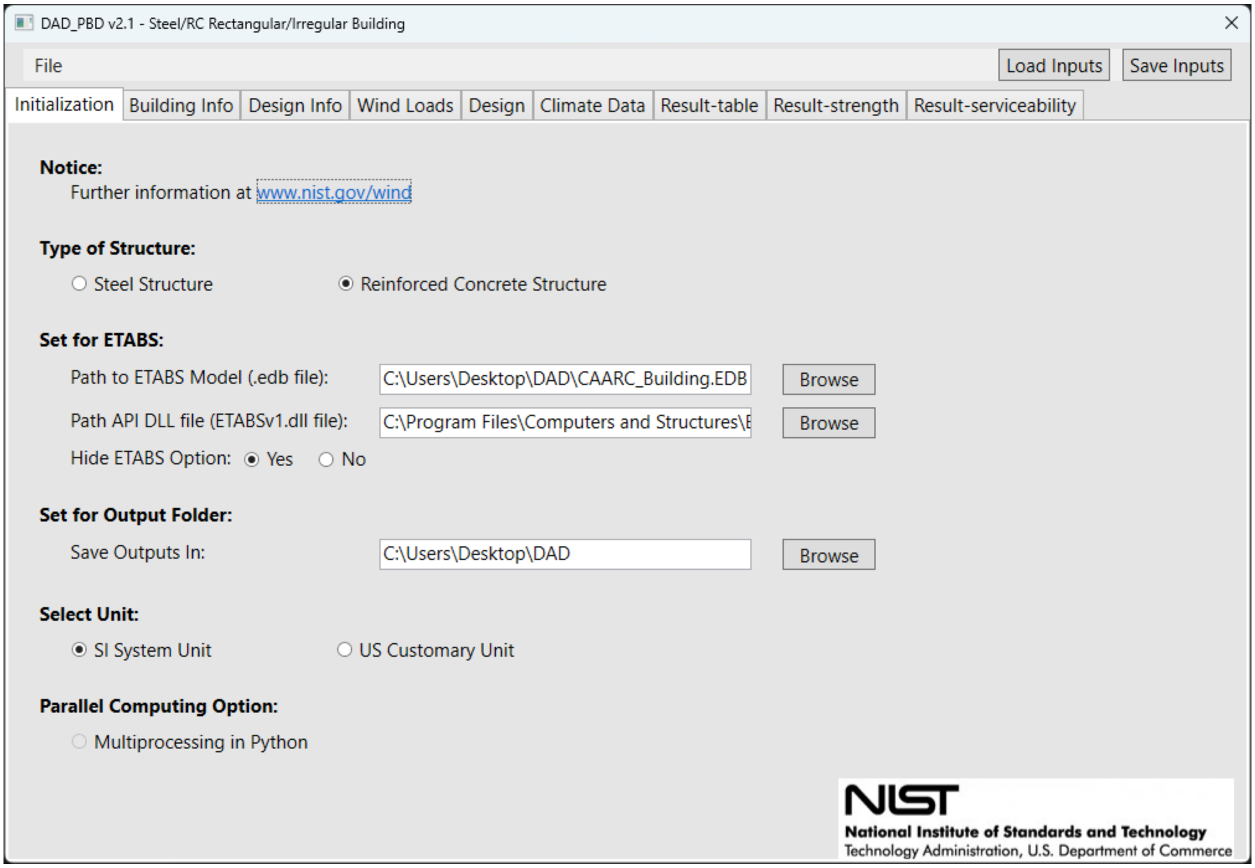
Parallel Computing Option:

○ Multiprocessing in Python

Fig. 2. File menu and subsequent buttons.

If the input text file is unavailable, the inputs can be manually entered. However, the user must ensure that the inputs are consistent with those from the analysis, or an error message will be prompted. To enter the input manually, the user should follow the steps below. As mentioned above, the following items outline only the necessary steps for opening the 3D viewer:

1. In the ‘Initialization’ tab under the ‘Type of Structure’ panel, the type of structure must be selected. Users should choose the **Steel Structure** radio button for steel-framed buildings and the **Reinforced Concrete Structure** for RC buildings (see Fig. 3).
2. The users must specify the ETABS model file (with .edb extension) in the ‘Path to ETABS Model (.edb file):’ field, and designate the folder where all analysis outputs and figures are saved after completing the DAD analysis in the ‘Save Outputs In’ field (see Fig. 3 for example). Note that these file paths can be entered manually or selected using the **Browse** buttons.
3. The preferred unit system must be selected. Two unit systems are available for DAD_PDB: SI and US customary units. The force and length are in kilo-Newtons or Newtons (kN or N) and meters (m), respectively, for SI units, and kip (1000 lbf) and feet (ft), respectively, for US customary units. The user must select the preferred unit system. Make sure to choose the same unit system used for the analysis.



Notice:
Further information at www.nist.gov/wind

Type of Structure:
○ Steel Structure ● Reinforced Concrete Structure

Set for ETABS:
Path to ETABS Model (.edb file): C:\Users\Desktop\DAD\CAARC_Building.EDB
Path API DLL file (ETABSv1.dll file): C:\Program Files\Computers and Structures\E
Hide ETABS Option: ● Yes ○ No

Set for Output Folder:
Save Outputs In: C:\Users\Desktop\DAD

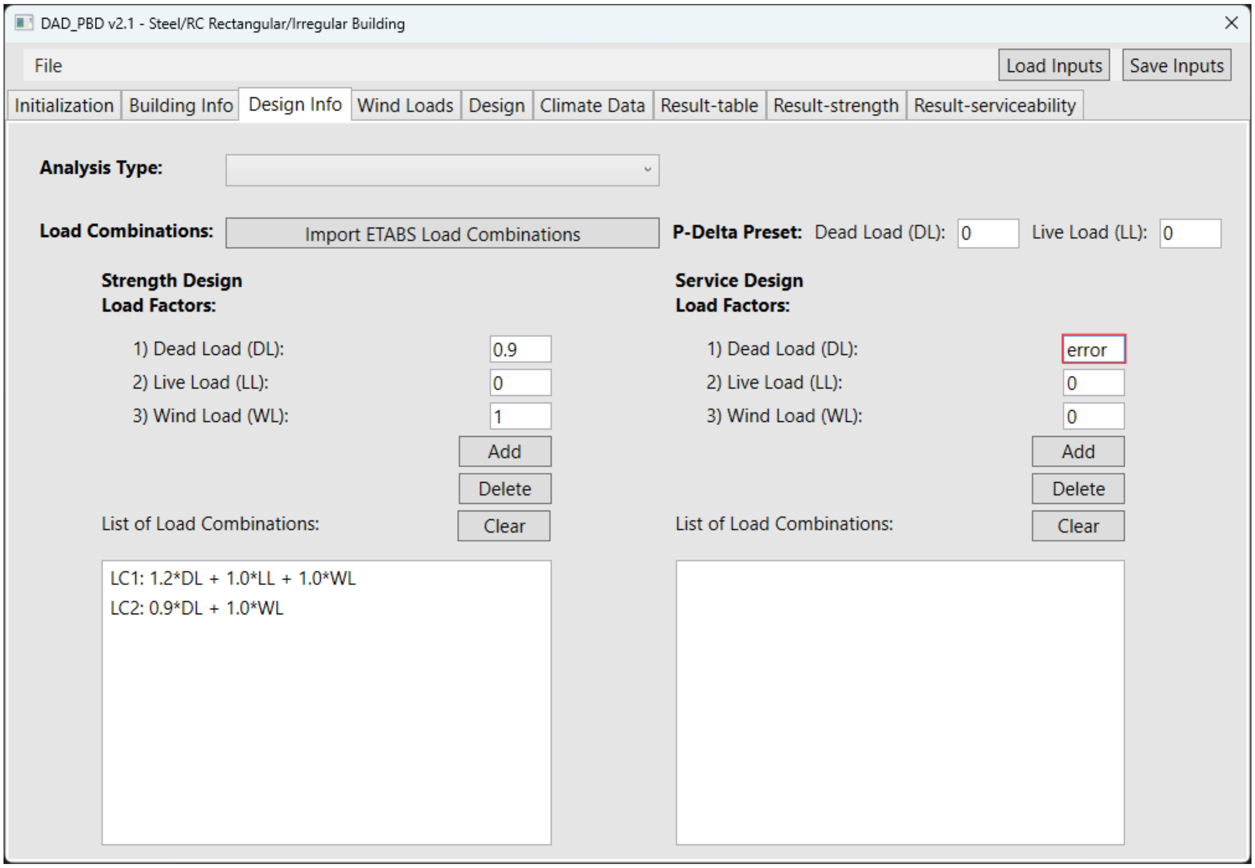
Select Unit:
● SI System Unit ○ US Customary Unit

Parallel Computing Option:
○ Multiprocessing in Python

Fig. 3. Initialization graphical user interface of DAD_PBD.

4. In the ‘Design Info’ tab, the users must populate the strength load combinations by entering the load factors and clicking the **Add** button. The load factors shown in Fig. 4 will populate the load combination of 0.9DL + 1.0WL, where DL is the dead load, LL is the live load, and WL is the wind load. To delete a previously added load combination, the user can click the load combination to remove and press the **Delete** button. The **Clear** button removes all load combinations in the list. Since the 3D viewer in the current version (v2.1) is limited to visualizing strength design results, such as the Demand-to-Capacity Index (DCI), the load combinations for serviceability are unnecessary. The users must ensure that the same load combinations used in the analysis are populated.

   Note that the GUI interaction for input boxes was updated in DAD_PBD v2.1. Only numbers should be entered for numerical input boxes, such as the ‘Dead Load and ‘Wind Loads’. If a non-numeric value is entered, the input box will be highlighted in red, as shown in Fig. 4, indicating an incorrect input format. By default, zero is entered for all numerical input fields.



Analysis Type:

Load Combinations:

P-Delta Preset: Dead Load (DL): 0 Live Load (LL): 0

Strength Design Load Factors:

1) Dead Load (DL): 0.9
2) Live Load (LL): 0
3) Wind Load (WL): 1

List of Load Combinations:

LC1: 1.2*DL + 1.0*LL + 1.0*WL
LC2: 0.9*DL + 1.0*WL

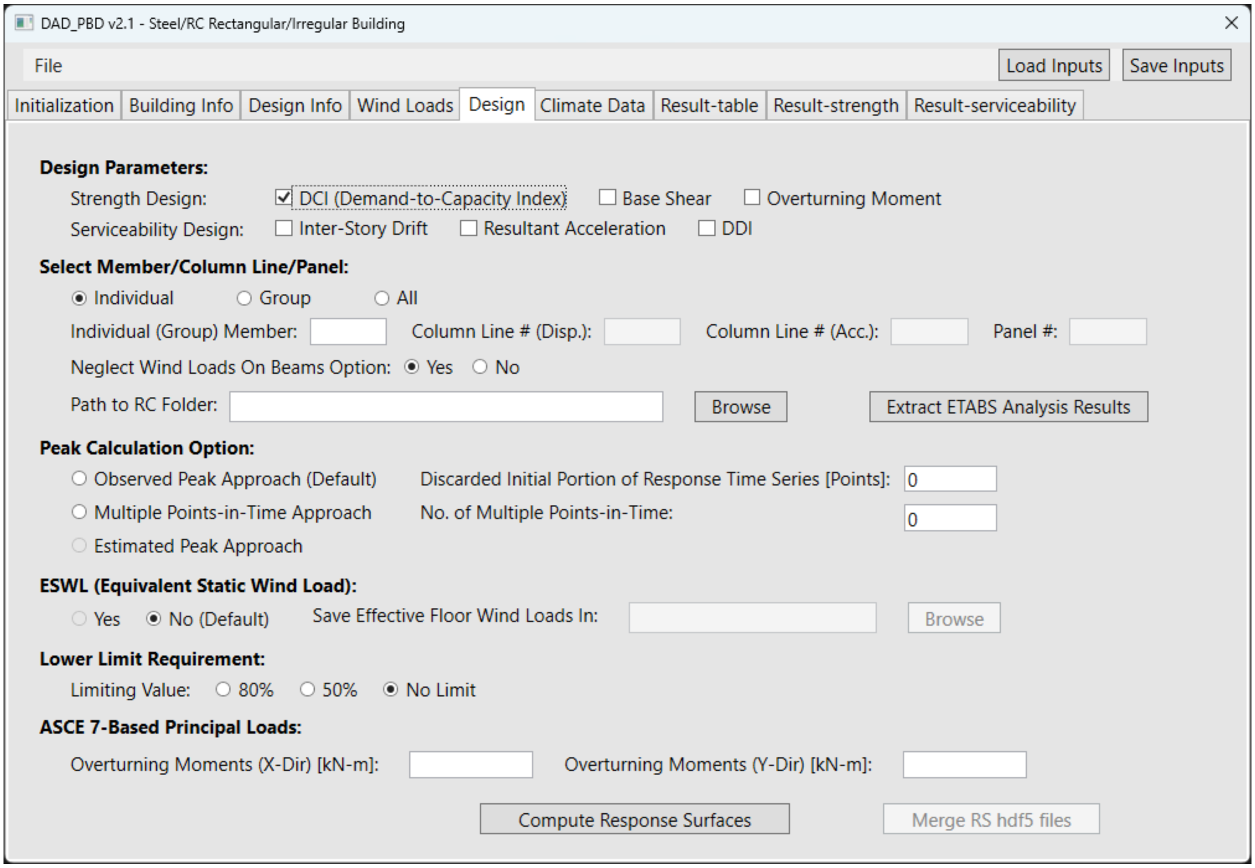
Service Design Load Factors:

1) Dead Load (DL): error
2) Live Load (LL): 0
3) Wind Load (WL): 0

List of Load Combinations:

Fig. 4. Populating load combinations under ‘Design Info’ tab.

5. Under the ‘Design’ tab, the ‘DCI (Demand-to-Capacity Index)’ box must be checked. No other inputs are necessary (see Fig. 5).



Design Parameters:
Strength Design: ☑ DCI (Demand-to-Capacity Index) ☐ Base Shear ☐ Overturning Moment
Serviceability Design: ☐ Inter-Story Drift ☐ Resultant Acceleration ☐ DDI

Select Member/Column Line/Panel:
● Individual ○ Group ○ All
Individual (Group) Member: Column Line # (Disp.): Column Line # (Acc.): Panel #:
Neglect Wind Loads On Beams Option: ● Yes ○ No
Path to RC Folder:

Peak Calculation Option:
○ Observed Peak Approach (Default) Discarded Initial Portion of Response Time Series [Points]: 0
○ Multiple Points-in-Time Approach No. of Multiple Points-in-Time: 0
○ Estimated Peak Approach

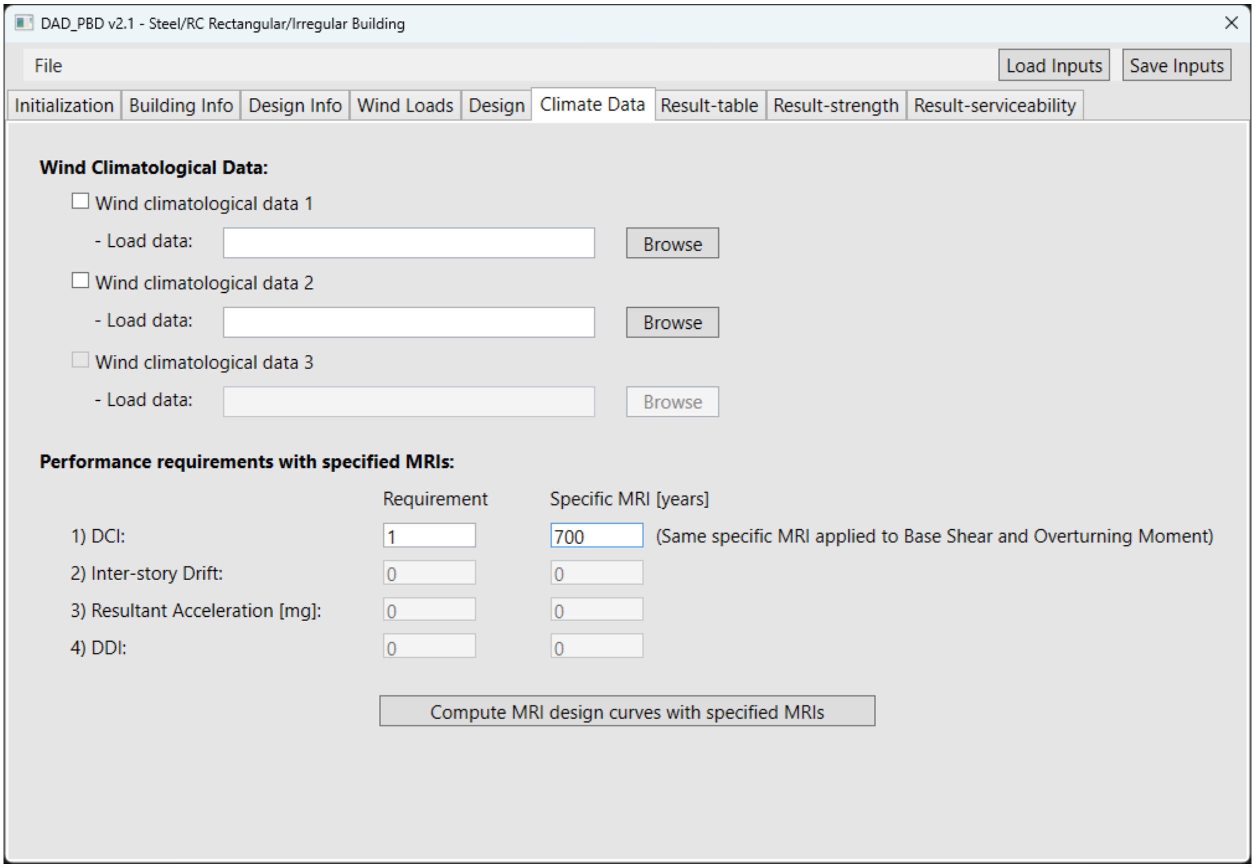
ESWL (Equivalent Static Wind Load):
○ Yes ● No (Default) Save Effective Floor Wind Loads In:

Lower Limit Requirement:
Limiting Value: ○ 80% ○ 50% ● No Limit

ASCE 7-Based Principal Loads:
Overturning Moments (X-Dir) [kN-m]: Overturning Moments (Y-Dir) [kN-m]:

Fig. 5. Necessary design parameter inputs under ‘Design’ tab.

6. Under the ‘Climate Data’ tab, the users must enter the DCI requirement and the specific MRI under the ‘Performance requirements with specific MRIs’ panel (see Fig. 6). The DCI requirement is generally one, but it can exceed unity when material nonlinearity is considered in the design. For more detailed instructions on DCI requirements, refer to the PBWD pre-standard [2].



Wind Climatological Data:

☐ Wind climatological data 1
- Load data:

☐ Wind climatological data 2
- Load data:

☐ Wind climatological data 3
- Load data:

Performance requirements with specified MRIs:

	Requirement	Specific MRI [years]	
1) DCI:	1	700	(Same specific MRI applied to Base Shear and Overturning Moment)
2) Inter-story Drift:	0	0	
3) Resultant Acceleration [mg]:	0	0	
4) DDI:	0	0	

Fig. 6. Necessary inputs under ‘Climate Data’ tab.

2.4. Reading Structural Data from ETABS Model for 3D Viewer

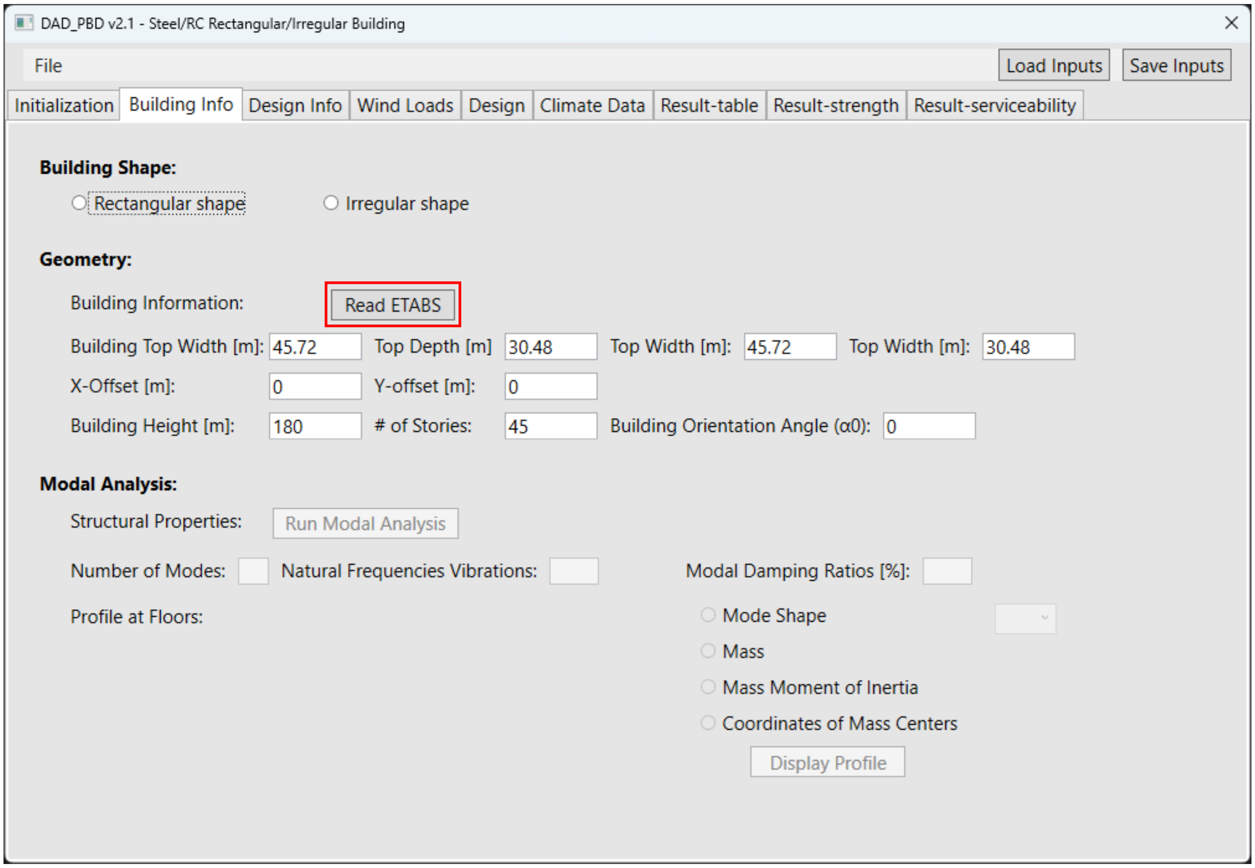
Once all inputs are correctly entered, the next step is to extract the Cartesian coordinates of the structural members in the ETABS model. Under the ‘Geometry’ panel in the ‘Building Info’ tab, the user must click the **Read ETABS** button (red box in Fig. 7), which opens the ETABS model in ETABS and directly imports the building geometry. During this process, the program also reads the coordinates of the ETABS model and saves them in a Hierarchical Data Format (HDF5) file (i.e., ‘Frame_Joint_Coord.hdf5’). The file also contains the type of frame, unique name, and story level of each structural member. Table 1 presents a summary of the data contained in the HDF5 file. As defined in the NIST TNs 2293 [8] and 2308 [10], structural members consist of beams, braces, and columns for steel buildings. For RC buildings, shear walls and link beams are included in addition to beams, braces, and columns. Although the geometry and dimensions of the buildings can be manually entered, clicking the **Read ETABS** button is necessary for the program to generate the ‘Frame_Joint_Coord.hdf5’ file that will be used to render 3D objects in the 3D viewer. Note that the building shape selection is not needed for the 3D viewer, as the building models are generated using the coordinates of each structural element.

Table 1. Data summary of Frame_Joint_Coord.hdf5 file.

Variables	Structure Type[a]	Description
JointNumber	Steel/RC	List of strings with ETABS joint Unique Name
JointX, JointY, JointZ	Steel/RC	Array of X, Y, Z (JointX, JointY, JointZ) coordinates of joints
UniqueName	Steel/RC	List of strings with ETABS frame member Unique Name
FrameType	Steel/RC	Type of frame member (e.g., column, beam, brace)
Point1X, Point1Y, Point1Z	Steel/RC	Array of X, Y, Z (Point1X, Point1Y, Point1Z) coordinates of the starting point in each structural element
Point2X, Point2Y, Point2Z	Steel/RC	Array of X, Y, Z (Point2X, Point2Y, Point2Z) coordinates of the end point in each structural element
PierName_SW	RC	List of strings with pier labels of shear walls
Story_SW	RC	List of strings with story names of shear walls
PointX_SW, PointY_SW, PointZ_SW	RC	2D array ($n \times 4$)[b] of X, Y, Z (PointX_SW, PointY_SW, PointZ_SW) coordinates of the shear wall vertices
SpandrelName_LB	RC	List of strings with spandrel labels of link beams
Story_LB	RC	List of strings with story names of link beams
PointX_LB, PointY_LB, PointZ_LB	RC	2D array ($n \times 4$)[b] of X, Y, Z (PointX_LB, PointY_LB, PointZ_LB) coordinates of the link beam vertices

[a] Only variables associated with the structure type will be generated. For example, any variables related to the shear wall and link beam will not be included in the HDF5 file.

[b] The size of the 2D array is ($n \times 4$), where n is the number of shear walls and link beams, and 4 represents the four vertices of a rectangle. The current DAD_PBD can only model rectangular-shaped shear walls and link beams.

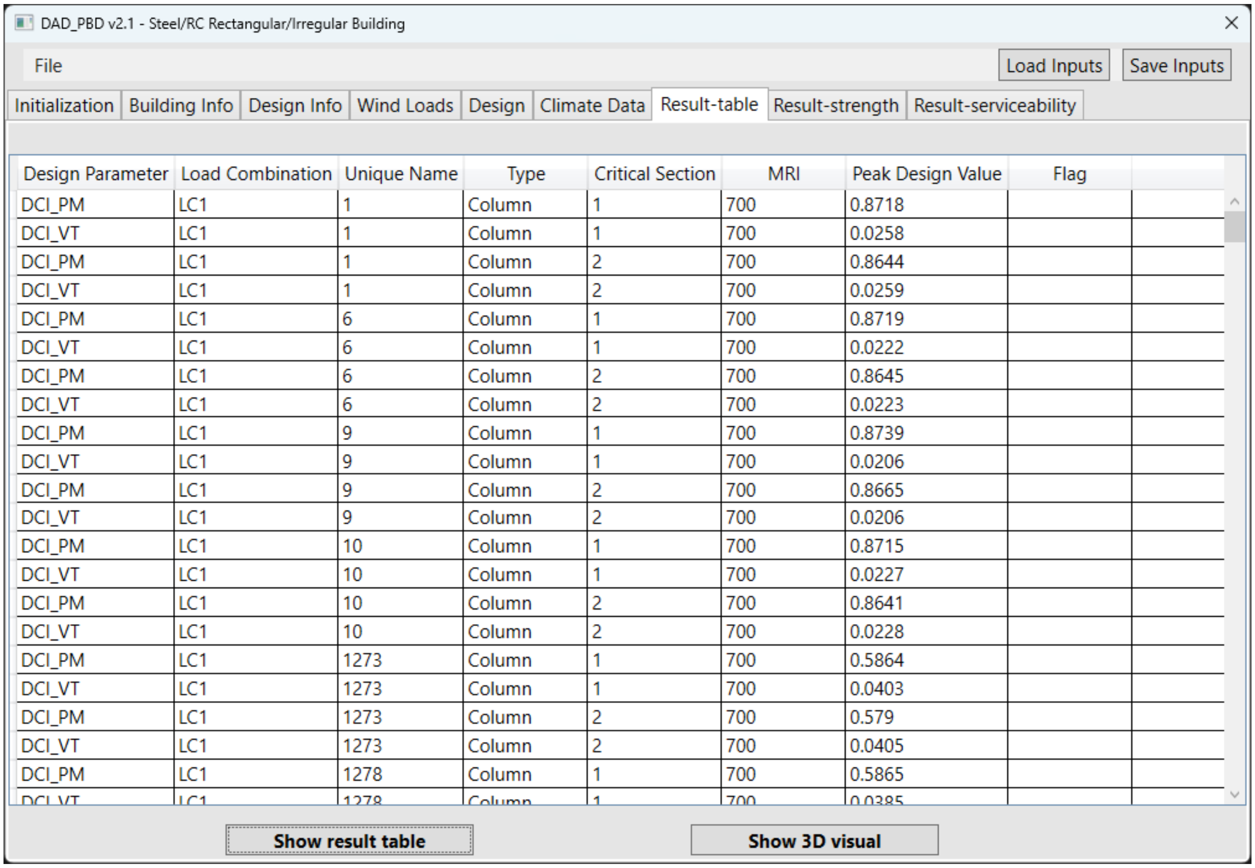


Building Top Width [m]: 45.72
Top Depth [m] 30.48
Top Width [m]: 45.72
Top Width [m]: 30.48
X-Offset [m]: 0
Y-offset [m]: 0
Building Height [m]: 180
# of Stories: 45
Building Orientation Angle (α0): 0

Fig. 7. Read ETABS button under ‘Building Info’ tab.

2.5. Result Table

Before opening the 3D viewer, the analysis result table in the ‘Result-table’ tab must be loaded, as the 3D viewer depends on the result data to calculate the maximum DCI values (see Section 2.6 for more details). Thus, the **Show 3D viewer** button will be grayed out (i.e., disabled) if the table has not been loaded. Given that all the prerequisite DAD analysis is complete, and data is stored in the correct folder, the result table can be loaded by clicking the **Show result table** button. The users must ensure that the ‘Selected_Members_Info.hdf5’ and ‘DesignParameters_MRI.hdf5’ files are saved in the ‘Output’ folder. For RC buildings, the ‘ResponseSurface.hdf5’ is also required. Figure 8 shows an example UI of the ‘Result-table’ tab, populating DCI values of all structural members for all load combinations and all critical sections. For detailed calculations of DCI and further information on HDF5 files, refer to NIST TN 2308 [10].



Design Parameter	Load Combination	Unique Name	Type	Critical Section	MRI	Peak Design Value	Flag
DCI_PM	LC1	1	Column	1	700	0.8718	
DCI_VT	LC1	1	Column	1	700	0.0258	
DCI_PM	LC1	1	Column	2	700	0.8644	
DCI_VT	LC1	1	Column	2	700	0.0259	
DCI_PM	LC1	6	Column	1	700	0.8719	
DCI_VT	LC1	6	Column	1	700	0.0222	
DCI_PM	LC1	6	Column	2	700	0.8645	
DCI_VT	LC1	6	Column	2	700	0.0223	
DCI_PM	LC1	9	Column	1	700	0.8739	
DCI_VT	LC1	9	Column	1	700	0.0206	
DCI_PM	LC1	9	Column	2	700	0.8665	
DCI_VT	LC1	9	Column	2	700	0.0206	
DCI_PM	LC1	10	Column	1	700	0.8715	
DCI_VT	LC1	10	Column	1	700	0.0227	
DCI_PM	LC1	10	Column	2	700	0.8641	
DCI_VT	LC1	10	Column	2	700	0.0228	
DCI_PM	LC1	1273	Column	1	700	0.5864	
DCI_VT	LC1	1273	Column	1	700	0.0403	
DCI_PM	LC1	1273	Column	2	700	0.579	
DCI_VT	LC1	1273	Column	2	700	0.0405	
DCI_PM	LC1	1278	Column	1	700	0.5865	
DCI_VT	LC1	1278	Column	1	700	0.0385	

Fig. 8. Example UI of the 'Result-table' tab after loading the table.

2.6. Three-Dimensional Viewer

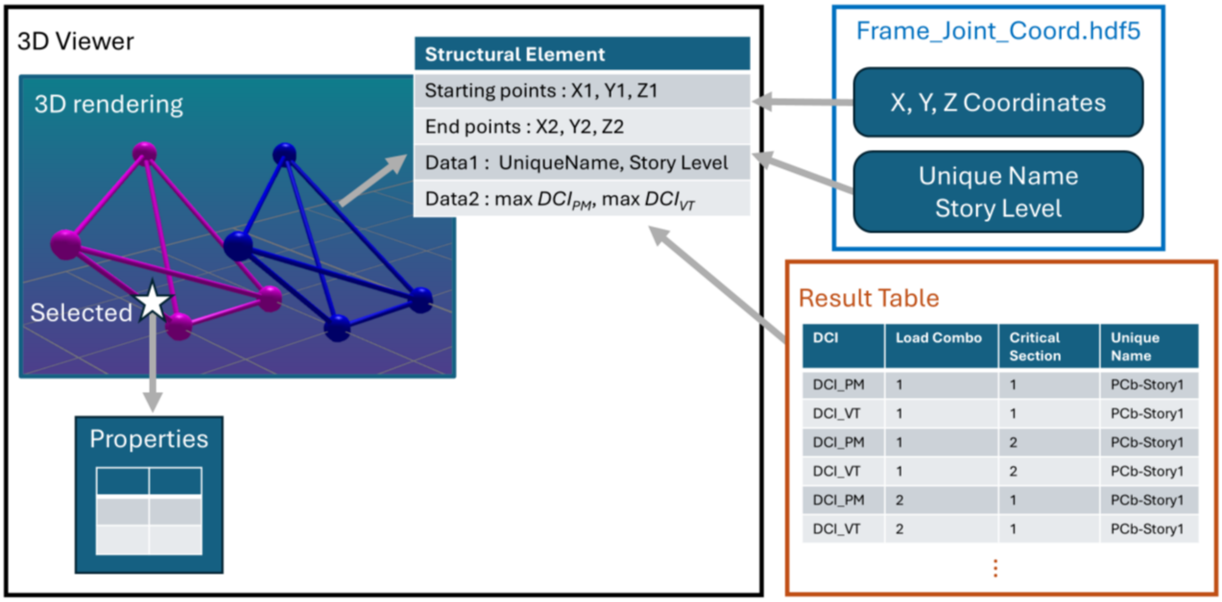
For the 3D viewer, DAD_PBD v2.1 adopted the Helix-Toolkit (https://github.com/helix-toolkit), an open-source .NET library that creates clickable nodes, wires, and simple 3D objects and associates them with properties (i.e., data). The HelixViewport3D component provides many other advanced features suitable for a 3D viewer application, including navigation, a floor grid, a User Coordinate System (USC) to indicate orientation, and a view cube.

To replicate the ETABS model and display the design results in the 3D viewer, the software employs the following steps:

1. The software retrieves design results from the result table and identifies the maximum DCI_{PM} and DCI_{VT} values for each structural member. The result table provides DCI_{PM} and DCI_{VT} values for each load combination at each critical section. For example, a shear wall with two critical sections and two load combinations will have four DCI_{PM} and four DCI_{VT} values. Only the maximum values among these are selected and used for visualization.
2. The software reads the 'Frame_Joint_Coord.hdf5' file to retrieve the joint and structural element information (e.g., name, frame type, coordinates) extracted from ETABS (see Section 2.4). The joints and structural members are rendered in the 3D viewer using the physical geometry points (i.e., x-, y-, z-coordinates of joints and structural elements).

3. Each element's unique name, story level, and maximum DCI_{PM} and DCI_{VT} data are stored as associated properties.
4. The maximum DCI_{PM} and DCI_{VT} are rendered onto the structural members as colors for user evaluation.
5. The associated properties are shown in the property table when the element is selected.

Figure 9 shows a schematic diagram of how 3D objects are rendered and properties assigned to each structural element.



DCI	Load Combo	Critical Section	Unique Name
DCI_PM	1	1	PCb-Story1
DCI_VT	1	1	PCb-Story1
DCI_PM	1	2	PCb-Story1
DCI_VT	1	2	PCb-Story1
DCI_PM	2	1	PCb-Story1
DCI_VT	2	1	PCb-Story1

⋮

Fig. 9. Schematic diagram of 3D object rendering and property assignments.

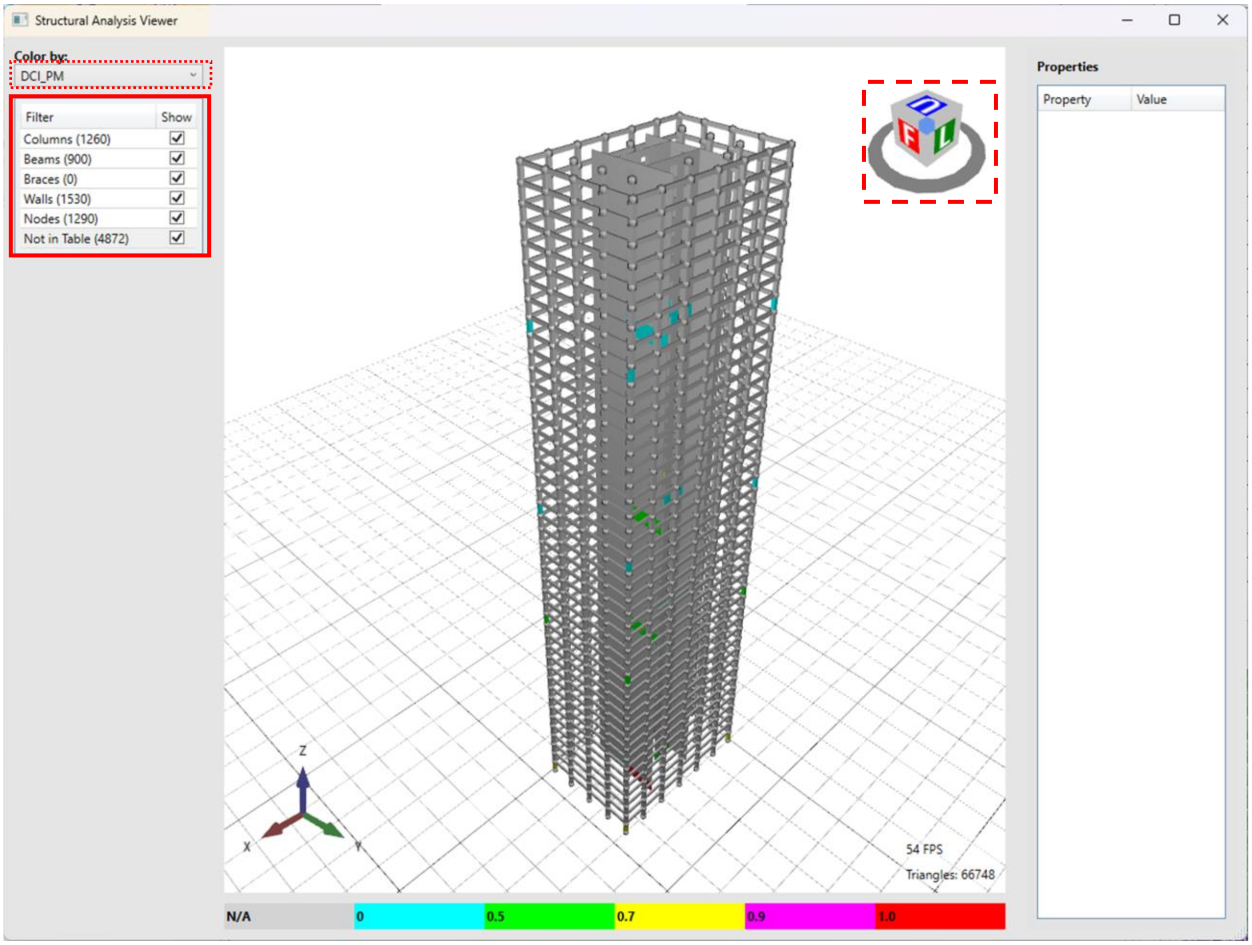
To launch the 3D viewer, the user is required to click the **Show 3D visual** button, upon which a separate window displaying the 3D model of the building will be opened. Figure 10 presents an example of the 3D viewer displaying a reinforced concrete (RC) building featuring a central shear wall system (more examples are presented in Section 3). The joints (i.e., nodes) are shown by spheres; beams by rectangular tubes; columns by square tubes; braces by circular tubes; and shear walls, including link beams, by rectangular planes. In the top left corner, a filtering system is implemented (red box in Fig. 10). By unchecking the box under the 'Show' column, the user can hide the structural members from the viewer for better visibility. The number in parentheses next to each structural member type represents the total number of elements associated with that member type. For example, the labels 'Column (1260)' and 'Walls (1530)' indicate that the model contains 1260 columns and 1530 shear walls (including link beams). For clarity, a single structural member in ETABS can consist of multiple elements.

Since DAD_PBD enables users to perform analyses on selected members, a 'Not in Table' option has been added to allow users to hide all members not included in the results table. By unchecking this box, users can view the building model only with selected members (see Fig. 11). Members labeled as 'Not in Table' are shown in gray to indicate they were not selected for analysis, while selected members appear in a color corresponding to their DCI values as defined by the color bar at the bottom of Fig. 10. The color scale was intentionally matched with the one used for the Demand-to-Capacity Ratios (DCRs) in ETABS to convey consistent messaging. The red-colored member indicates that the DCI value exceeds the performance requirement and needs to be redesigned.

To facilitate intuitive rotation and navigation of the 3D building model, a feature similar to that found in ETABS has been implemented. Users can zoom in and out of the model by scrolling the mouse wheel, pan the view by clicking and dragging the mouse while holding down the scroll wheel, and rotate the model by clicking and dragging with the right mouse button. Additionally, a cube-like navigation tool, commonly referred to as a ViewCube, is provided for quick access to different viewing angles (highlighted by a red dashed box in Fig. 10). When the user hovers over the ViewCube, interactive hotspots are activated, as indicated by blue highlights at its corners. Clicking a specific hotspot allows the user to switch to a corresponding view. For instance, selecting the face labeled 'U' displays a 2D top view, while selecting a corner activates the associated isometric view.

Two design parameters are available to view in the 3D viewer: DCI from axial and flexural forces (DCI_{PM}) and DCI from shear and torsional forces (DCI_{VT}), which can be chosen using the dropdown menu (dotted red box in Fig. 10) under 'Color by'. For detailed calculation of DCI, refer to NIST TNs 2293 [8] and 2308 [10].

In the bottom-right corner of the 3D viewport, the Frames Per Second (FPS) and the total number of triangles used to render the building model are displayed, enabling users to monitor performance and identify potential rendering lags. A higher FPS generally results in smoother and more fluid motion when navigating the building model. In 3D graphics, most objects are ultimately rendered as a mesh of triangles, the simplest polygon that can define a surface in 3D space. Buildings with more complex shapes or additional structural elements require more triangles, which can slow down rendering, especially in real-time or interactive applications. For building models containing an excessively high number of triangles, users may experience noticeable lag in the 3D viewport; therefore, it is recommended to disable the display of certain structural elements to improve performance. Notice the total number of triangles used to render all the components is 66748 in Fig. 10. However, the number of triangles reduces to 1388 when the 'Not in Table' members are turned off in Fig. 11. Turning off the nodes is also suggested as rendering curved-shaped objects, such as spheres, requires many meshes. For reference, the number of triangles reduces to 35788 when the nodes are hidden.



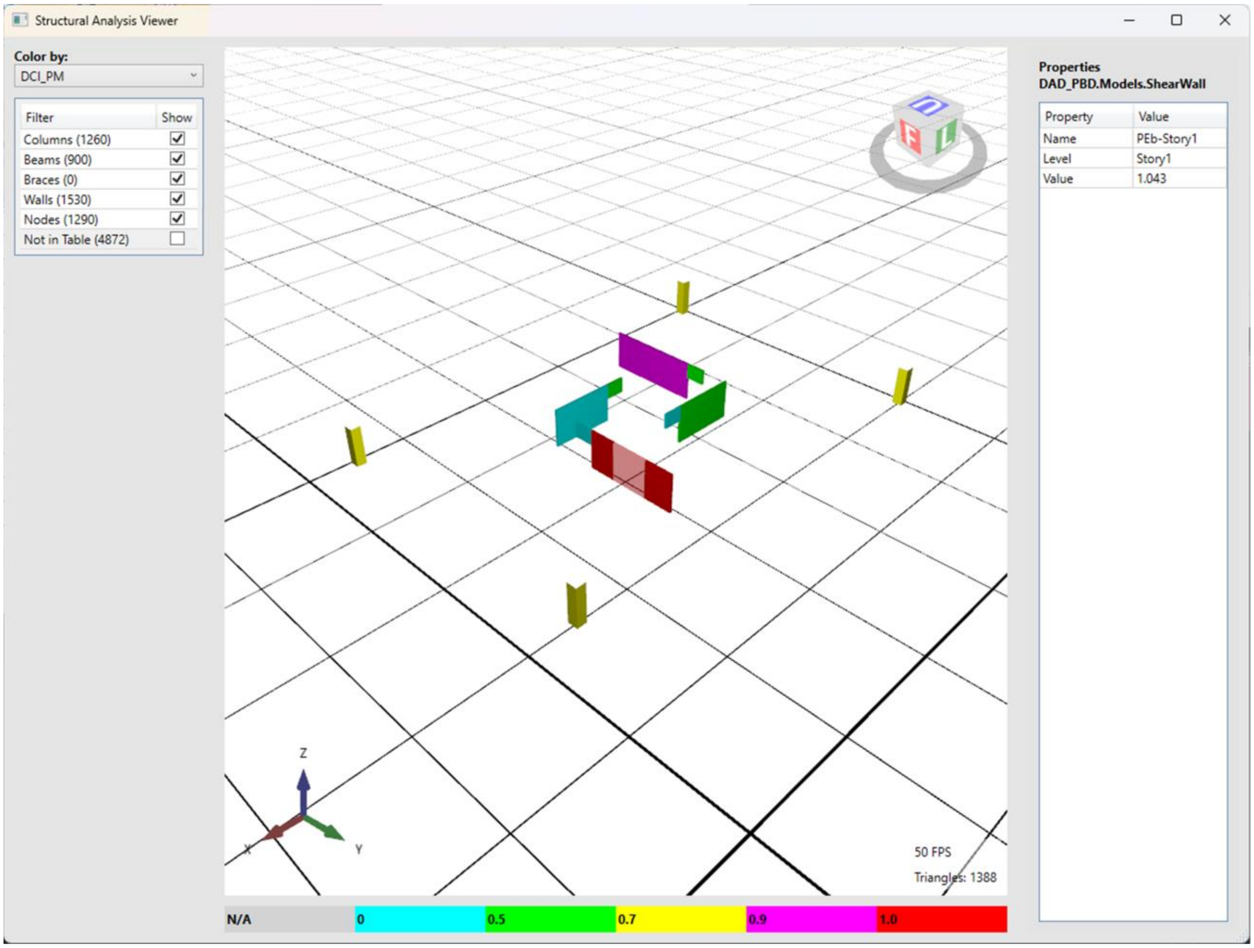
Color by: DCI_PM

Filter	Show
Columns (1260)	☑
Beams (900)	☑
Braces (0)	☑
Walls (1530)	☑
Nodes (1290)	☑
Not in Table (4872)	☑

Property	Value

Fig. 10. Three-dimensional viewer window.

Each structural element is selectable, and upon selection, its associated properties and DAD analysis results are displayed in the properties window. The user can view the DCI result in a text format in the property table by left-clicking the member. The selected element will be shown as partially transparent, and the associated DCI value will be shown in the property table on the right side of the window. As shown in Fig. 11, the DCI_{PM} value, name, and the story level of one of the first-story shear walls are populated in the property table. Members with DCI values exceeding unity, which signify inadequate design, are highlighted in red within the 3D viewer to alert the user and prompt potential redesign. It is important to note that the DCI values displayed in the table and the corresponding color represent the maximum DCI across all load combinations and critical sections. For members that were not analyzed, indicated by a gray color, a default value of -1.0 will be shown in the property table.



Color by: DCI_PM

Filter	Show
Columns (1260)	☑
Beams (900)	☑
Braces (0)	☑
Walls (1530)	☑
Nodes (1290)	☑
Not in Table (4872)	☐

Properties
DAD_PBD.Models.ShearWall

Property	Value
Name	PEb-Story1
Level	Story1
Value	1.043

N/A	0	0.5	0.7	0.9	1.0

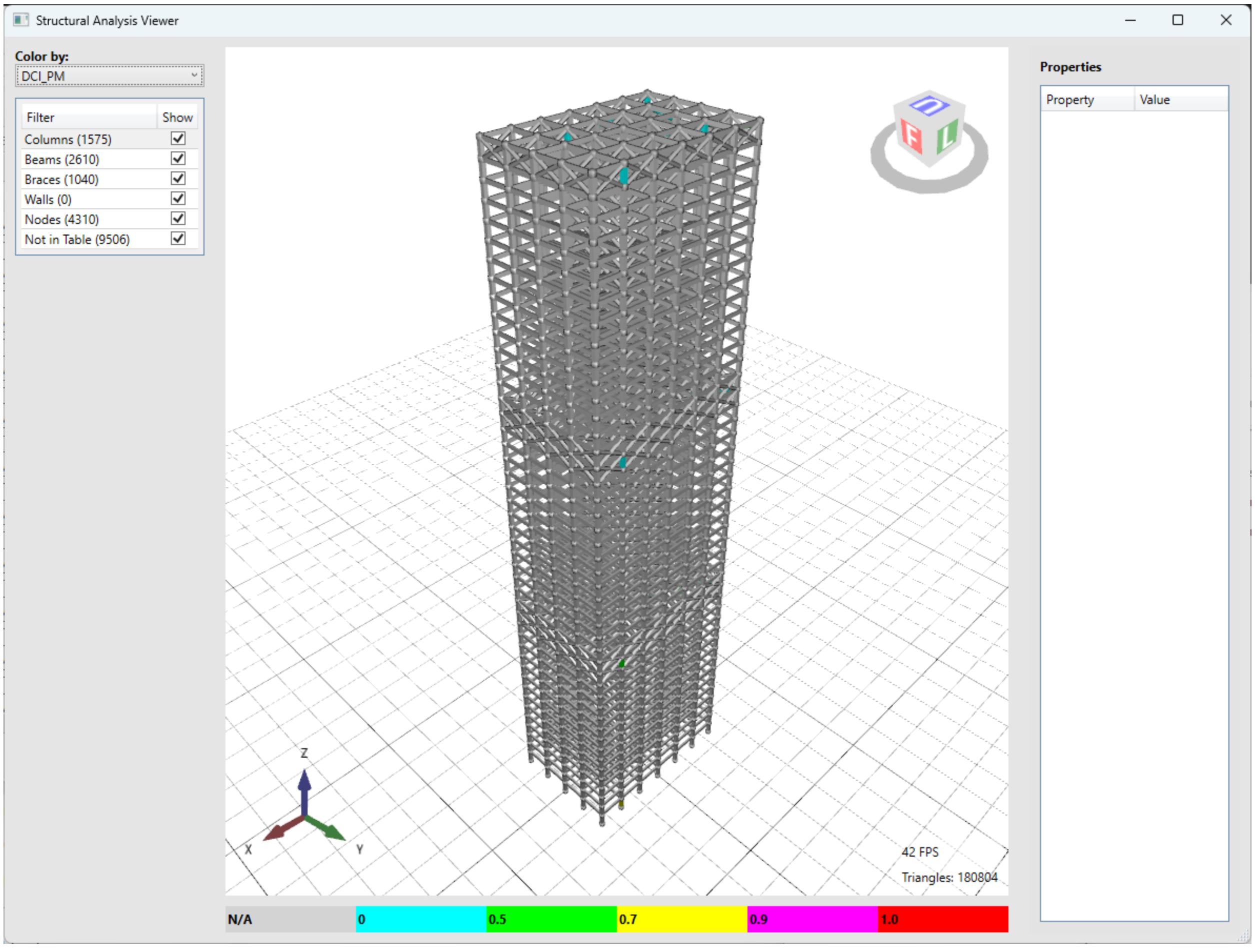
Fig. 11. 3D view of the first-story shear walls and columns, and DCI_{PM} value of the selected shear wall shown in property table.

3. Visualization Example

In this section, the visualization of three design examples is presented: (1) rectangular steel structure, (2) rectangular RC structure, and 3) tapered RC structure. The (1) and (2) examples leverage the same buildings and results from the design examples presented in NIST TNs 2293 [8] and 2308 [10], respectively. Both buildings are representations of a 45-story Commonwealth Advisory Aeronautical Research Council (CAARC) building [19] with different structural systems. The tapered building is a 100-story RC building designed based on the tapered building model from the Tokyo Polytechnic University Aerodynamic Database [20]. Analysis was not performed on the tapered building, and arbitrary values are used solely for visualization purposes.

3.1. Rectangular Steel Structure

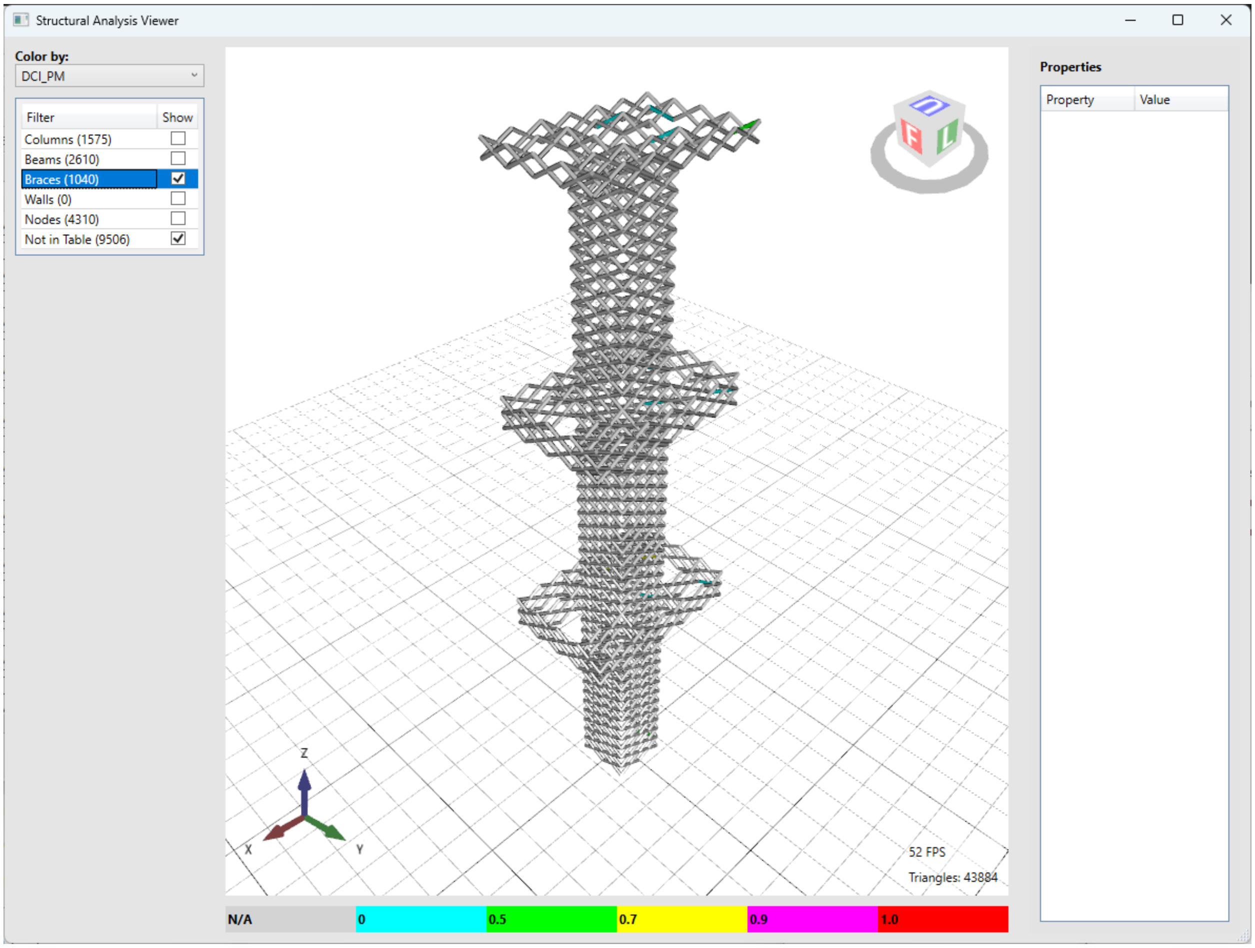
Figure 12 shows the 3D viewer window of the rectangular-shaped CAARC steel building. The building has a belt truss system with an outrigger and an inner core brace system, which are obscured in the initial view. The braces can be seen by turning off the columns, beams, and nodes (see Fig. 13). Notice that the number next to 'Walls' is zero, indicating no shear walls in this steel building design example.



Color by: DCI_PM

Filter	Show
Columns (1575)	☑
Beams (2610)	☑
Braces (1040)	☑
Walls (0)	☑
Nodes (4310)	☑
Not in Table (9506)	☑

Fig. 12. Initial view of the rectangular-shaped CAARC steel building.



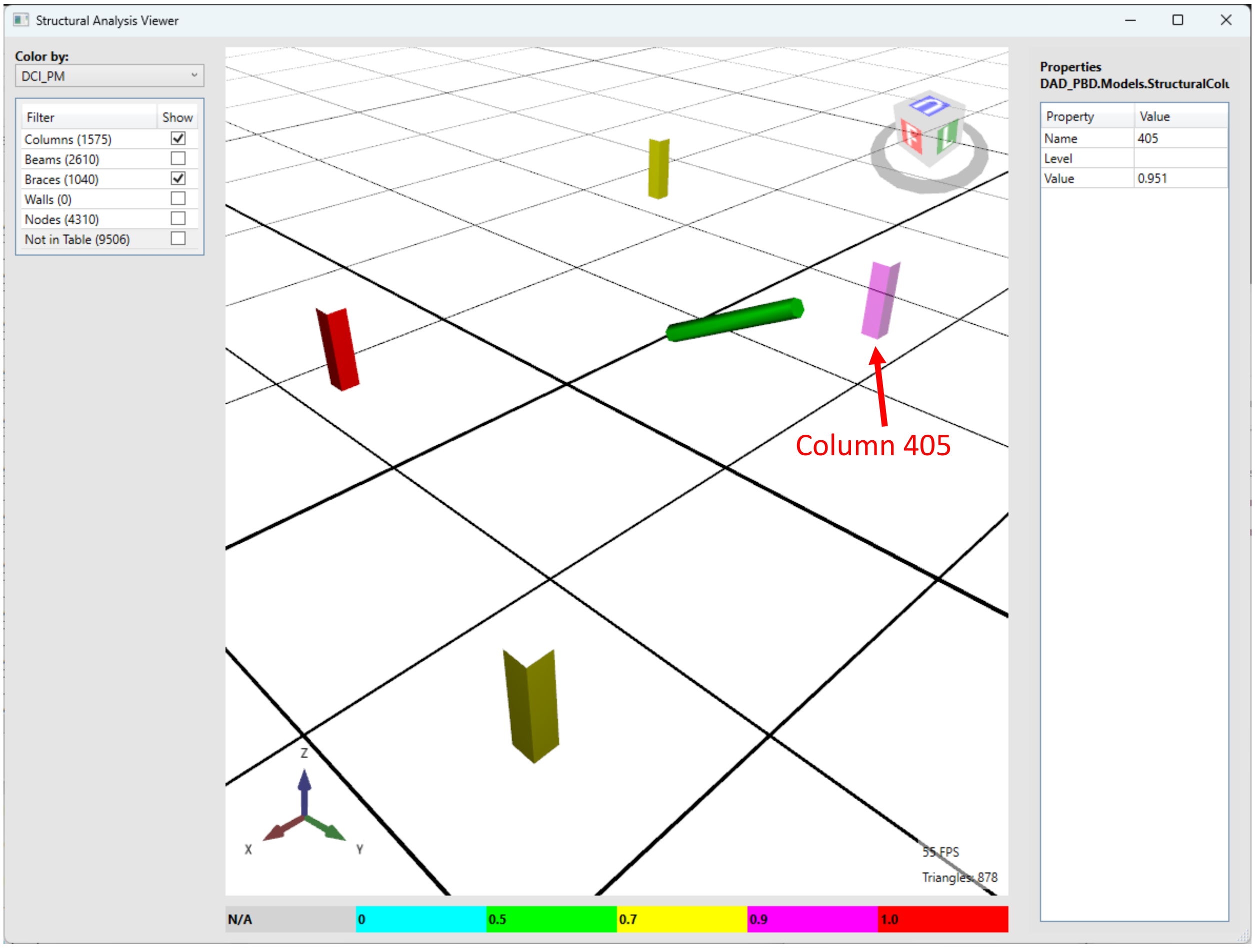
Color by: DCI_PM

Filter	Show
Columns (1575)	☐
Beams (2610)	☐
Braces (1040)	☑
Walls (0)	☐
Nodes (4310)	☐
Not in Table (9506)	☑

Property	Value

Fig. 13. 3D view of brace system of rectangular-shaped CAARC steel building.

Figures 14 and 15 exhibit the 3D views of the first-story columns and braces, displaying the DCI_{PM} and DCI_{VT} results, respectively. As shown in the property table, the DCI_{PM} value of Column 405 is 0.951 (Fig. 14), which corresponds to the magenta color. The DCI_{VT} value of Column 990 shows 0.012 (Fig. 15), corresponding to the cyan color.



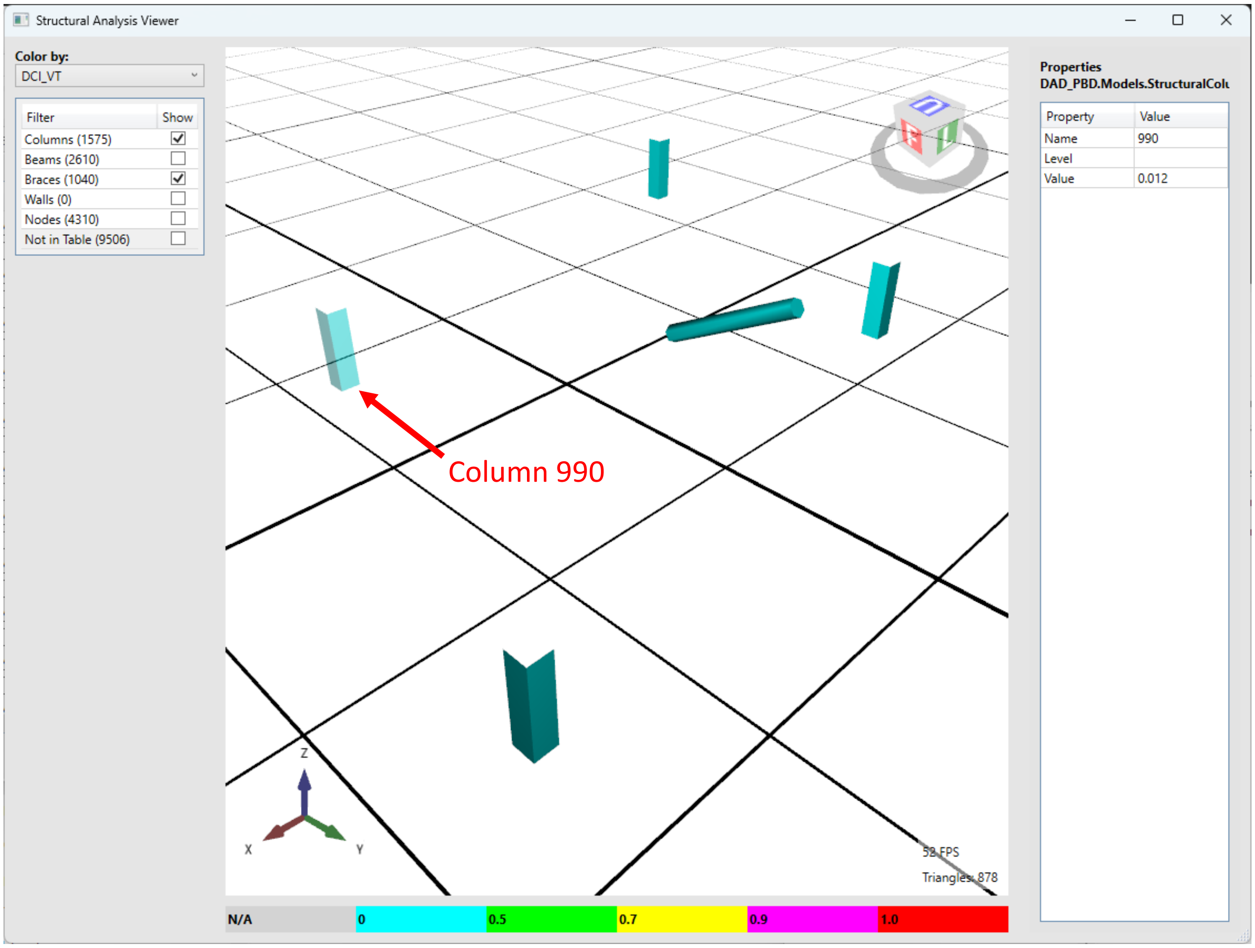
Color by: DCI_PM

Filter	Show
Columns (1575)	☑
Beams (2610)	☐
Braces (1040)	☑
Walls (0)	☐
Nodes (4310)	☐
Not in Table (9506)	☐

Properties
DAD_PBD.Models.StructuralCol

Property	Value
Name	405
Level	
Value	0.951

Fig. 14. 3D view of the first-story columns and braces, and *DCI$_{PM}$* value of Column 405 shown in property table.



Color by: DCI_VT

Filter	Show
Columns (1575)	☑
Beams (2610)	☐
Braces (1040)	☑
Walls (0)	☐
Nodes (4310)	☐
Not in Table (9506)	☐

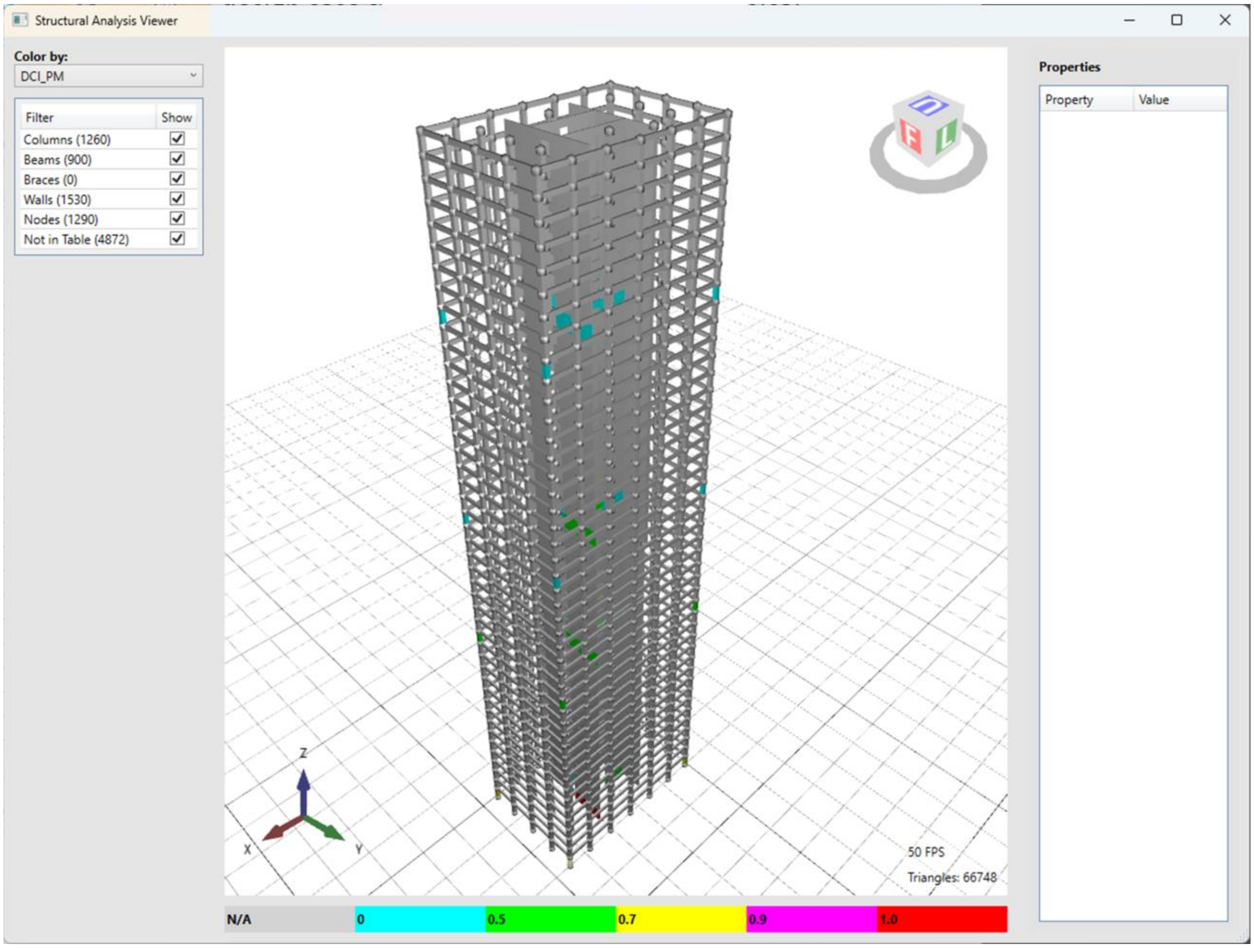
Properties
DAD_PBD.Models.StructuralColu

Property	Value
Name	990
Level	
Value	0.012

Fig. 15. 3D view of the first-story columns and braces, and DCI_{VT} value of Column 990 shown in property table.

3.2. Rectangular RC Structure

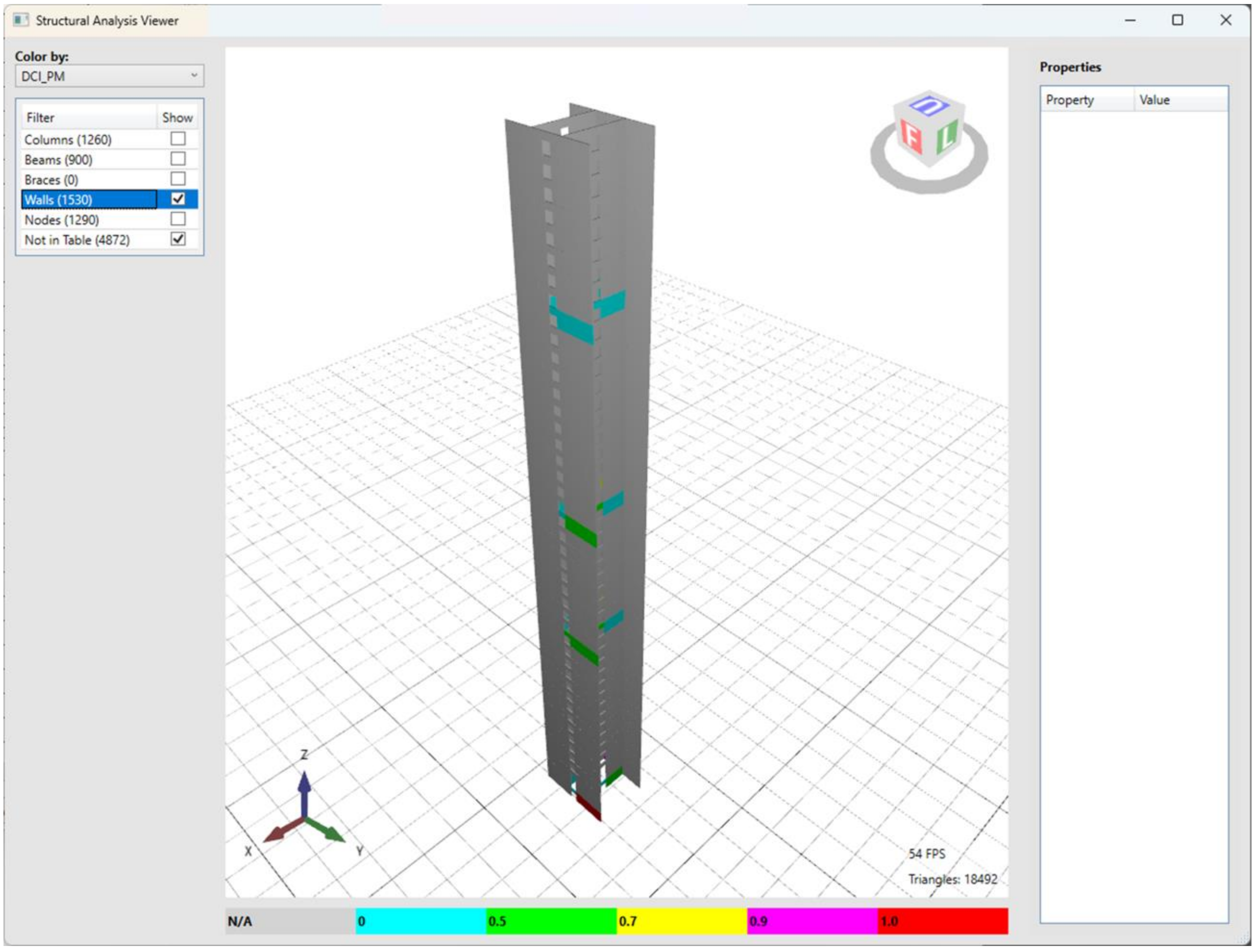
Figure 16 illustrates the 3D viewer window of the rectangular-shaped CAARC RC building, featuring an RC shear wall system at the center. Figure 17 presents the model with only the shear walls visible, achieved by disabling the display of columns, beams, and nodes. Note that the number next to ‘Braces’ is zero, indicating no braces in this building design example. Refer to Section 2.6 for examples of DCI values of the RC building.



Color by: DCI_PM

Filter	Show
Columns (1260)	☑
Beams (900)	☑
Braces (0)	☑
Walls (1530)	☑
Nodes (1290)	☑
Not in Table (4872)	☑

Fig. 16. Initial view of the rectangular-shaped CAARC RC building.



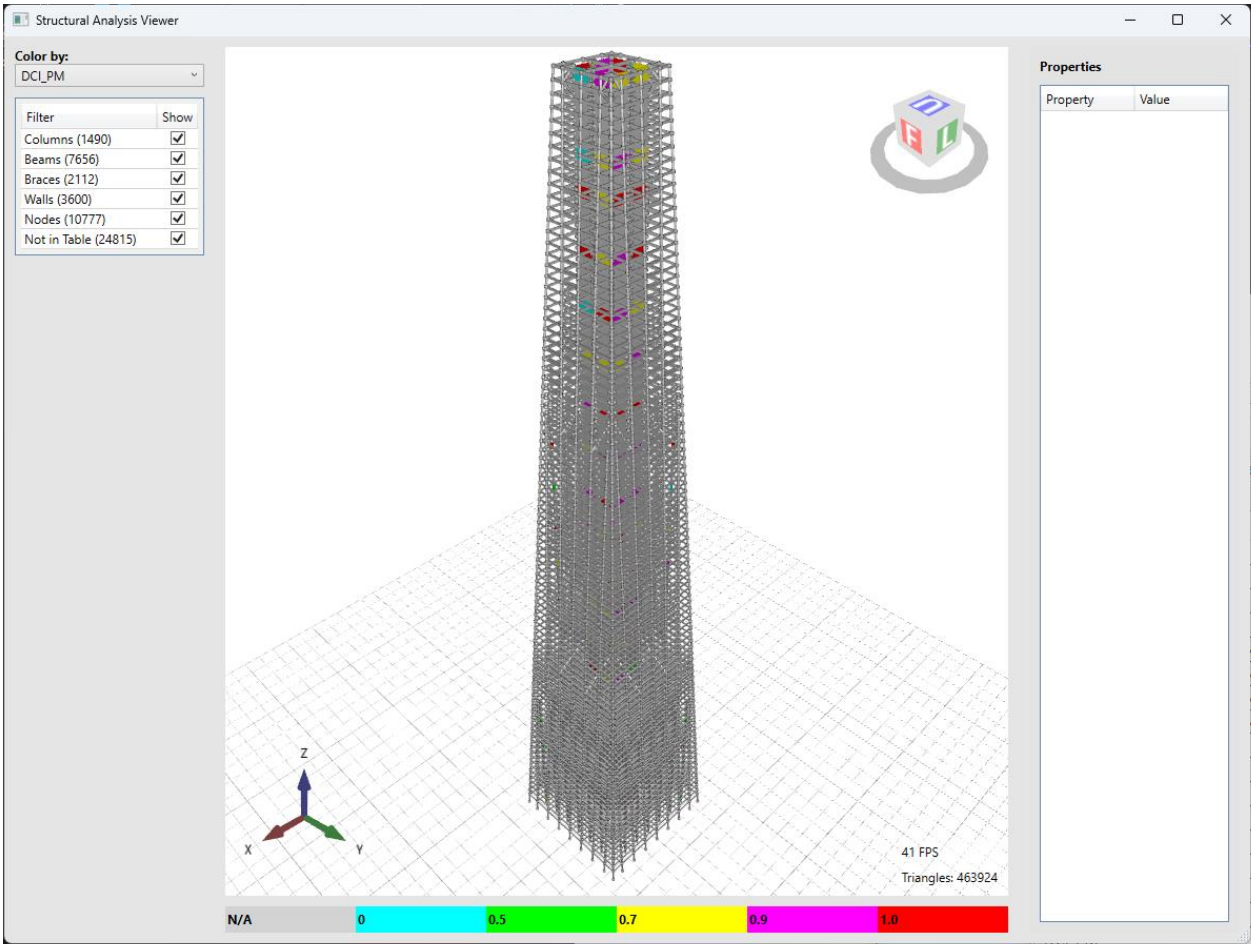
Color by: DCI_PM

Filter	Show
Columns (1260)	☐
Beams (900)	☐
Braces (0)	☐
Walls (1530)	☑
Nodes (1290)	☐
Not in Table (4872)	☑

Fig. 17. 3D view of shear wall system of rectangular-shaped CAARC RC building.

3.3. Tapered RC Structure

Figure 18 shows the 3D viewer window of the tapered RC building with an outrigger brace and shear wall system in the center. It is worth noting that the total number of triangles is nearly 464000, as shown in the bottom right corner of the viewing window. Due to the large number of meshes required for rendering, a temporary decrease in FPS (down to as few as one frame per second) may occur when navigating the building model. Figure 19 presents the shear walls with arbitrary DCI results across different floors and the bracing system of the tapered building by disabling the display of columns, beams, and nodes.



Color by: DCI_PM

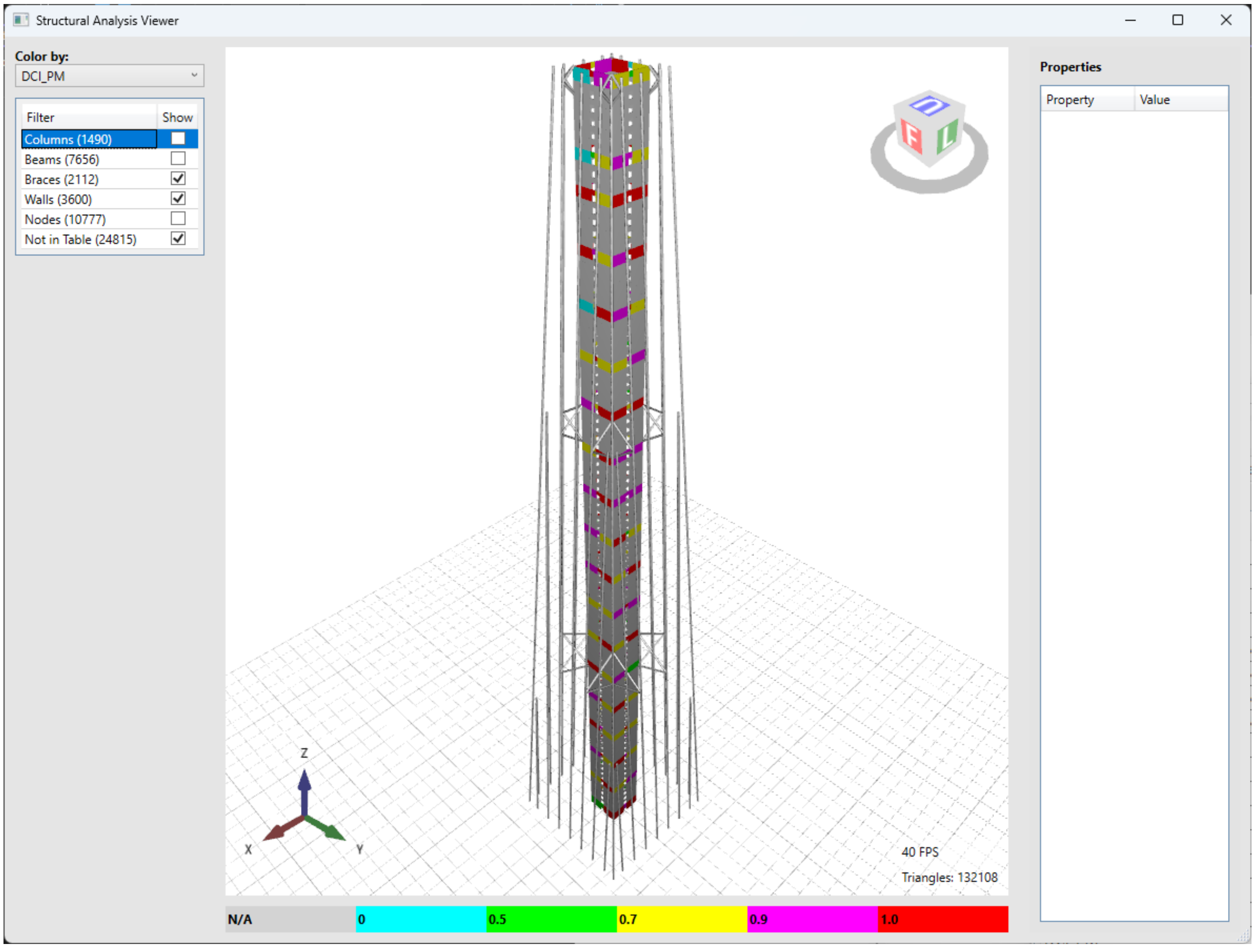
Filter	Show
Columns (1490)	☑
Beams (7656)	☑
Braces (2112)	☑
Walls (3600)	☑
Nodes (10777)	☑
Not in Table (24815)	☑

Property	Value

41 FPS

Triangles: 463924

Fig. 18. Initial view of tapered RC building.



Structural Analysis Viewer

Color by:
DCI_PM

Filter	Show
Columns (1490)	☐
Beams (7656)	☐
Braces (2112)	☑
Walls (3600)	☑
Nodes (10777)	☐
Not in Table (24815)	☑

Properties

Property	Value

40 FPS
Triangles: 132108

Fig. 19. 3D view of shear wall and outrigger brace system of tapered RC building.

4. Future Work

The DAD_PBD version 2.1 is the first edition to include a 3D viewer feature, leaving opportunities for future enhancements. The following suggested improvements to the user interface (UI) and 3D viewer are aimed at improving user-friendliness in the process of reviewing design results:

1. In the current version, only DCI values (e.g., DCI_{PM}, DCI_{VT}) are available for display. However, a 3D view of serviceability design results (e.g., inter-story drift, acceleration, DDI) could be introduced in future updates.
    a. Like for the structural members with associated DCI values, the maximum inter-story drift and acceleration relative to the serviceability requirements can be assigned to all nodes.
    b. By utilizing node coordinates, panels could be rendered on the exterior faces of the building to represent the DDI results.
2. The property table for structural members could be enhanced to display more detailed information, rather than just one ultimate DCI value. For example, displaying the internal force combination (e.g., axial forces and moments) corresponding to the DCI value would assist users in optimizing member sizes more effectively.
3. As demonstrated in Section 3.3, buildings with complex shapes or numerous structural elements can slow down the 3D viewport, negatively impacting the navigation feature. Improving the real-time rendering process is another necessary enhancement.
4. The current DAD_PBD displays the structural members in arbitrary shapes (e.g., beams in rectangular tube, columns in square tube). The future version could include structural members with the actual cross-sectional dimensions. Additionally, the connection type between the structural members, such as fixed end and partial end fixity, can be shown in future versions, as the connection elements are critical in nonlinear analysis.
5. Similar to ETABS, displaying the deformed shapes, dynamic modes, and shear and moment diagrams for members would also be a great enhancement to the 3D Viewer.
6. In addition to the modifications discussed in Section 2.3.1, the software could be further refined by incorporating more UI error messages to notify users of input errors.
7. The current version uses a text file format for saving and loading input variables, which is considered outdated and inconvenient. A suggested improvement would be to switch to the JavaScript Object Notation (JSON) format, a widely used text-based format for data storage and exchange.

References

[1] Yeo D (2010) Database-Assisted Design for Wind: Concepts, Software, and Example for High-Rise Reinforced Concrete Structures. (National Institute of Standards and Technology, Gaithersburg, MD), Technical Note (NIST TN) 1665.

[2] ASCE (2023) – *Prestandard for Performance-Based Wind Design V1.1* (American Society of Civil Engineers, Reston, VA). https://doi.org/10.1061/9780784484739

[3] Rhee DM, Sisson S, Carmen B, Mashnad M, Yeo D (2024) Database-assisted-design facilitating performance-based tall building design. (Institution, Birmingham, UK), Series Database-assisted-design facilitating performance-based tall building design Document http://dx.doi.org/10.2139/ssrn.4994381

[4] Park S, Yeo D (2018) Database-assisted Design and Equivalent Static Wind Loads for Mid- and High-rise Structures: Concepts, Software, and User's Manual. (National Institute of Standards and Technology, Gaithersburg, MD), Technical Note (NIST TN) 2000. https://doi.org/10.6028/NIST.TN.2000

[5] CSI (2020) ETABS Analysis and Design of Building Systems. Berkeley, California: Computers and Structures Inc.

[6] Saini DS, Alipour A, Shafei B (2022) Database-Assisted Design of High-Rise Steel Structures Using ETABS Software: User's manual of DAD_ETABS version 1.0. (National Institute of Standards and Technology, Gaithersburg, MD), NIST Grant/Contractor Report (GCR) NIST GCR 22-035. https://doi.org/10.6028/NIST.GCR.22-035

[7] Sisson S, Mashnad M, Yeo D (2022) Evaluation of DAD_ETABS Procedure and Software for the Design of High-Rise Steel Buildings for Wind. (National Institute of Standards and Technology, Gaithersburg, MD), Technical Note (NIST TN) 2236. https://doi.org/10.6028/NIST.TN.2236

[8] Rhee DM, Yeo D, Pingree S, Sisson S, Heumann E, Mashnad M (2024) Database-Assisted Design: Performance-Based Approach for Dynamically Sensitive Steel Structures. (National Institute of Standards and Technology, Gaithersburg, MD), Technical Note (NIST TN) 2293. https://doi.org/10.6028/NIST.TN.2293

[9] StructurePoint (2023) SpColumn v10.10. Design and investigation of reinforced concrete column sections. Libertyville, Illinois: StructurePoint.

[10] Rhee DM, Yeo D, Mashnad M, Carmen B, Clay C (2024) Database-Assisted Design: Performance-Based Approach for Dynamically Sensitive Steel and Reinforced Concrete Structures. (National Institute of Standards and Technology, Gaithersburg, MD), Technical Note (NIST TN) 2308. https://doi.org/10.6028/NIST.TN.2308

[11] ASCE (2022) *ASCE/SEI 7-22 – Minimum Design Loads and Associated Criteria for Buildings and Other Structures* (American Society of Civil Engineers, Reston, VA). https://doi.org/10.1061/9780784415788

[12] Harris CR, Millman KJ, van der Walt SJ, Gommers R, Virtanen P, Cournapeau D, Wieser E, Taylor J, Berg S, Smith NJ, Kern R, Picus M, Hoyer S, van Kerkwijk MH, Brett M, Haldane A, del Río JF, Wiebe M, Peterson P, Gérard-Marchant P, Sheppard K, Reddy T, Weckesser W, Abbasi H, Gohlke C, Oliphant TE (2020) Array programming with NumPy. *Nature* 585(7825):357-362. https://doi.org/10.1038/s41586-020-2649-2

[13] Collette A (2013) *Python and HDF5* (O'Reilly, Sebastopol, CA).

[14] Virtanen P, Gommers R, Oliphant TE, Haberland M, Reddy T, Cournapeau D, Burovski E, Peterson P, Weckesser W, Bright J, van der Walt SJ, Brett M, Wilson J, Millman KJ, Mayorov N, Nelson ARJ, Jones E, Kern R, Larson E, Carey CJ, Polat I, Feng Y, Moore EW, VanderPlas J, Laxalde D, Perktold J, Cimrman R, Henriksen I, Quintero EA, Harris CR, Archibald AM, Ribeiro ANH, Pedregosa F, van Mulbregt P, Contributors S (2020) SciPy 1.0: fundamental algorithms for scientific computing in Python. *Nature Methods* 17(3):261-272. https://doi.org/10.1038/s41592-019-0686-2

[15] Hunter JD (2007) Matplotlib: A 2D graphics environment. *Computing in Science & Engineering* 9(3):90-95. https://doi.org/10.1109/Mcse.2007.55

[16] Pythonnet (2022) Python.NET documentation. Available at https://pythonnet.github.io/pythonnet/.

[17] openpyxl (2024) openpyxl - A Python library to read/write Excel 2010 xlsx/xlsm files. Available at https://openpyxl.readthedocs.io/en/stable/.

[18] pandas (2024) pandas documentation. Available at https://pandas.pydata.org/docs/.

[19] Melbourne WH (1980) Comparison of measurements on the CAARC standard tall building model in simulated model wind flows. *Journal of Wind Engineering and Industrial Aerodynamics* 6(1-2):73-88. https://doi.org/10.1016/0167-6105(80)90023-9

[20] Tanaka H, Tamura Y, Ohtake K, Nakai M, Kim YC (2012) Experimental investigation of aerodynamic forces and wind pressures acting on tall buildings with various unconventional configurations. *Journal of Wind Engineering and Industrial Aerodynamics*. https://doi.org/10.1016/j.jweia.2012.04.014