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Advanced 3D Model Metadata for Design Configuration Management – A Use Case in Barrier Functions

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ABSTRACT

In building design and function, walls, slabs, and other partitions (members) may serve various functions, which may not be readily evident to all stakeholders or facility users. Building walls and slabs typically serve a structural function, for the vertical and lateral force resisting systems. Additionally, building walls and slabs may serve non-structural functions, with a common architectural function being a fire rated barrier. Non-structural partitions may only serve a function for occupancy/space usage, but in some cases the partition could serve other functions, like a fire partition or barrier.

To support advancements in Building Information Modelling (BIM), advanced 3D modelling software has become commonplace. Modern 3D modelling software has the capability to identify typical standard features, but also the availability of user-defined attributes as metadata for any given model object/element. Utilizing metadata for model objects provides rich context for design rendering/viewing/reviewing, drawing output, procurement, and quality requirements, as well as 4D modelling to support schedule development. This paper presents a use-case for discrete metadata documentation specific to complex requirements for barrier functions in nuclear power plants.

BACKGROUND

Traditional design practice communicates the function, performance, or requirements through design drawings, and other support documentation, calculations, programs, and reports, often termed "contract documents." Current code requirements or practice may also dictate physical labelling or stencilling on the wall or partition as shown in Figure 1, allowing occupants, facility users/owners, or future construction personnel to understand the function without reference to the design documentation. Traditional practice relied on documentation, either on paper/pdf and/or physically in-place on the structure.

Figure 1 - Example Code Required Partition Wall Labelling

As functional requirements increase, providing explicit, discretized correlation of functional and performance characteristics to individual members has increasing importance. In nuclear power plants (NPP), walls, slabs, and other partitions (members) have numerous functional and performance characteristics, far exceeding the demands of typical buildings. For example, NPP members may serve structural functions, but also serve as a functional barrier to compartmentalize or protect from hazards, such as fires, tornadoes, hurricanes, aircraft, high energy line break (HELB), radiation, security, and flooding. Further, the structural performance may dictate different performance requirements (i.e., safety classification or seismic category), depending on the safety classification of the Structures, Systems, or Components (SSC) the member supports or protects.

Each different type of function, safety classification, or seismic category may impose different code or regulatory requirements dictating code, material, performance, and/or quality demands. Without discrete information, it can be challenging to understand the functional requirements of different SSC. Figure 2 provides an example of walls and an associated door in which the functional requirements may not be obvious.

Figure 2 – Example Walls and Door without Obvious Functional Requirements

WORKFLOW

Where substantial additional functional requirements of SSC exist, documenting the requirements in a discretized database becomes more critical to ensure accuracy and quality, and to improve efficiency of the project delivery. In a Building Information Modelling (BIM) Software and process, custom attribute fields can be created to capture requirements stored within the software's database. Such attributes assigned by element/object can be exported via reports and opened in a common spreadsheet editor and input/data can be added on the spreadsheet in the respective requirements field. Once the input is complete the spreadsheet can be imported into the BIM software. This methodology will efficiently assign requirements to the element and store it to the 3D model, as discussed in Bonasera and Marohl (2025). An example of requirements captured in a 3D Model structural element is illustrated in Figure 3.

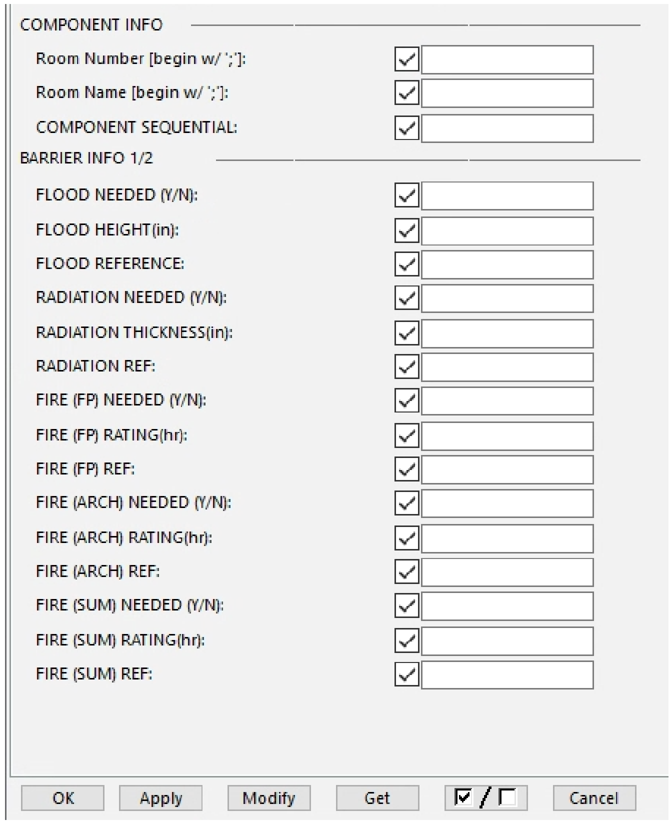

Figure 3 – Example Custom User Defined Attributes (Subset Only)

However, not all users have access to 3D modelling software, nor do all users have the necessary skillset to use a 3D modelling software. Different members of a design team will perform different functions, necessitating different resources and knowledge. This paper distinguishes the design team based upon role as follows:

- “3D Modeler” – Inputs and outputs data into the 3D model
- “Data Owner” – Specifies data to be input to 3D model and reviews the data in the 3D model, either within the model, or the output contract documents (i.e. drawings)

The 3D Modeler has access to native 3D modelling software that allows modelling objects natively in the 3D model, and can populate all metadata within the 3D modelling software. The 3D Modeler can also export reports and import files into the 3D model. The Data Owner is specifying the design, requirements, or properties that the model needs to reflect or capture, such as an architect or engineer. In many instances, a Data Owner may not have access to, or knowledge about, a 3D modelling software. To facilitate automated data population into the 3D model, as well as overall “ownership” of the data that is populated, a workflow that has been successfully implemented is shown in Figure 4, where the 3D Modeler outputs a spreadsheet, allowing population of metadata to 3D model objects by the Data Owner. Once complete, the 3D Modeler imports the data into the 3D model. In this way, the Data Owner in essence directly populates the information into the model, without requiring access to the software or skills necessary to do so in the native application.

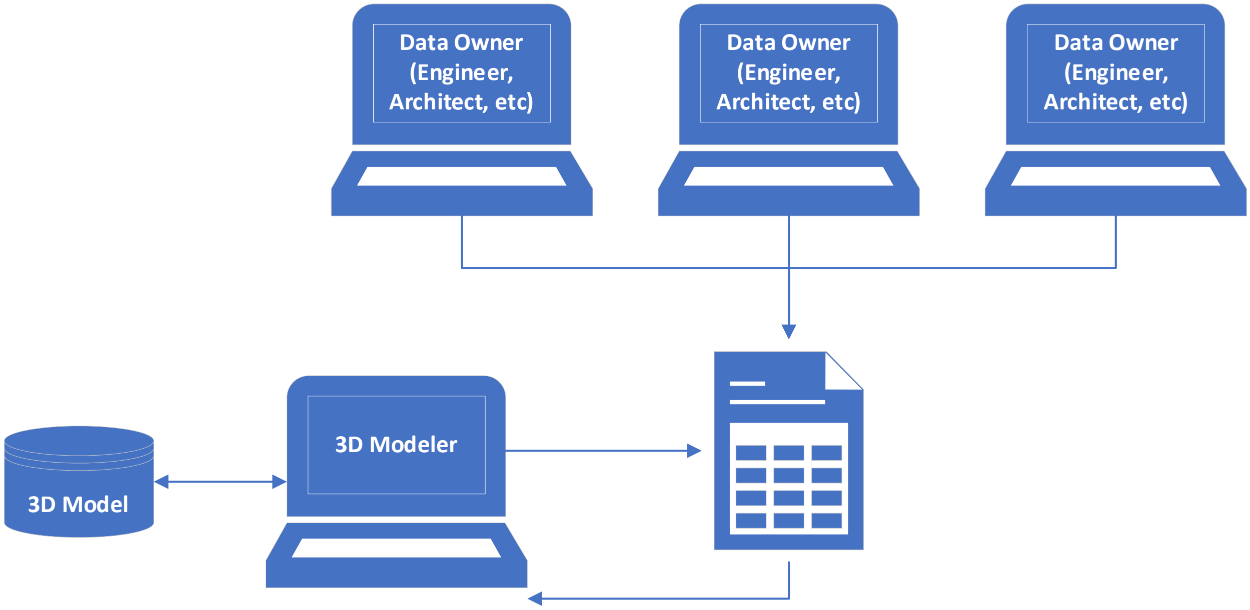

Figure 4 - Workflow for Non-3D Model User Data Ownership

Ownership of data is a novel concept, vs ownership of design scope or division of responsibility. Ownership of data allows for higher confidence in the output contract documents compared to workflows where a team member provides markups, comments, sketches, or other material to a 3D Modeler which then requires interpretation of the information and then manual translation into the 3D model. True ownership of data requires some level of control, and the workflow described herein allows for direct population of the data into the data into the 3D model, which is then reviewed as an output later.

DATA UTILIZATION

Various use-cases for metadata output can be conceived to aid the designer, the constructor, the procurer, the owner, or the occupant. The designer may benefit considering a streamlined document review cycle, in which the Data Owner has already directly populated the information into the model, allowing the drawing reviews to occur easily and seamlessly. The constructor may benefit by understanding functional, quality, and construction requirements as part of the 4D model and schedule planning. The procurer may benefit by allowing quantities output from the model to correlate more directly to purchasing specifications and requirements, where quantities in the model are correlated to their functional requirements, and thereby their procurement specifications. The owner could benefit by virtual walkthroughs of their facility, weighing options during design, or potentially even virtual reality renderings of functional requirements within the physical space, in lieu of physical tagging. The direct benefit to the designer is presented in the use case in this paper.

Consider a use case of masonry walls in a nuclear power plant. A masonry wall in an NPP can serve many different purposes, including structural, architectural, or barrier functions (e.g. fire, radiation, HELB, internal flood). Each function could necessitate different performance, material, or quality requirements. Other related characteristics could be dictated by the functional requirements, such as the types of commodities (e.g. pipe, raceway, duct) that can be attached or supported by the wall, or what type of seals are required in any penetrations through the wall. Since these functional requirements can vary from building-to-building, and within a building room-to-room, and even within rooms from wall-to-wall, tracking and communicating the requirements of specific walls can be challenging.

The challenge of tracking functional requirements can be more complex when rooms, enclosures, or vestibules exist that are not full-height, such as that shown in Figure 2, which can be cumbersome and complicated to display clearly on 2D drawings. Often the solution may be a tabular solution identifying the requirements for each numbered wall, communicated to a drafter via markup. An alternative solution presented in this use case is identifying the data in the 3D model as metadata, which reports out to a drawing. Figure 5 presents an example of how specifying functional barrier requirements in 3D model user defined attributes can report out for use.

WALL NAME	FIRE	FLOOD	RADIATION	AIRCRAFT IMPACT	TORNADO MISSILE	HIGH ENERGY LINE BREAK
W101	-	-	N	N	N	N
W102	2 HR	-	N	N	N	N
W103	2 HR	-	N	N	N	N
W104	-	-	Y	N	N	N
W201	3 HR	-	N	N	N	N
W202	3 HR	-	N	N	Y	Y
W203	3 HR	Y	Y	N	N	Y
W204	3 HR	-	Y	N	N	Y
W301	3 HR	-	Y	N	N	Y
W302	3 HR	-	N	N	N	N
W303	3 HR	-	N	N	N	N
W304	3 HR	-	Y	Y	Y	Y

Figure 5 – Example Barrier Functions Reported from 3D Model User Defined Attributes

In the example shown in Figure 5, a spreadsheet is output from the 3D model providing each row with the ‘Wall Name’ column populated, and each other column is populated by a Data Owner responsible for the information in their column. The column data may be controlled through spreadsheet review protections on editing specific columns, by file user to provide additional control for data ownership if desired. Once the Data Owner has populated the necessary column data, the spreadsheet is imported back into the 3D model, and formal contract documents can export directly from the 3D model. The data may also be used within the 3D model or model viewing software, to filter and see the different barriers performing specific functions.

More traditional uses benefit from the same approach. Consider a material take-off for the same set of masonry walls. In an NPP, what can be commonplace material take-off work in other applications, can become relatively complex based upon the varying functional requirements. Figure 6 provides an example of what a typical material take-off could like for the set of masonry walls.

Example Material Take-Off From BIM Software						
WALL NAME	**WALL LENGTH (FT)**	**WALL THICKNESS (FT)**	**WALL HEIGHT (FT)**	**WEIGHT**	**MATERIAL**	**f'm (psi)**
W101	12.0	0.64	8.9	Normalweight	C90	2,150
W102	12.0	0.64	5.7	Normalweight	C90	2,150
W103	12.0	0.64	5.7	Normalweight	C90	2,150
W104	16.4	0.97	10.1	Normalweight	C90	2,150
W201	16.4	0.97	9.1	Normalweight	C90	2,150
W202	16.4	0.97	7.9	Normalweight	C90	2,150
W203	16.4	0.97	8.9	Normalweight	C90	2,150
W204	31.7	0.97	16.4	Normalweight	C90	2,150
W301	16.4	0.97	9.5	Normalweight	C90	2,150
W302	31.6	0.97	16.4	Normalweight	C90	2,150
W303	16.4	0.97	11.5	Normalweight	C90	2,150
W304	23.4	0.97	10.1	Normalweight	C90	2,150

Figure 6 – Typical Masonry Wall Material Takeoff

Consider now however that three of the walls have identified different performance requirements. Perhaps a different fire rating or weight has necessitated use of lightweight concrete, as shown in Figure 7. Due to this change in design, the required material purchased would be different. Tracking and outputting through the 3D model data allows discrete specification of the different information for quantities, as well as tracking and scheduling installation.

Example Material Take-Off From BIM Software						
WALL NAME	**WALL LENGTH (FT)**	**WALL THICKNESS (FT)**	**WALL HEIGHT (FT)**	**WEIGHT**	**MATERIAL**	**f'm (psi)**
W101	12.0	0.64	8.9	Normalweight	C90	2,150
W102	12.0	0.64	5.7	**Lightweight**	C90	2,150
W103	12.0	0.64	5.7	Normalweight	C90	2,150
W104	16.4	0.97	10.1	Normalweight	C90	2,150
W201	16.4	0.97	9.1	**Lightweight**	C90	2,150
W202	16.4	0.97	7.9	**Lightweight**	C90	2,150
W203	16.4	0.97	8.9	Normalweight	C90	2,150
W204	31.7	0.97	16.4	Normalweight	C90	2,150
W301	16.4	0.97	9.5	Normalweight	C90	2,150
W302	31.6	0.97	16.4	Normalweight	C90	2,150
W303	16.4	0.97	11.5	Normalweight	C90	2,150
W304	23.4	0.97	10.1	Normalweight	C90	2,150

Figure 7 – Example Updated Material Take-Off with Lightweight Masonry

Consider further that each function may result in the wall having a different safety classification, such as non-safety related/commercial grade, augmented quality, or nuclear safety related. Each individual barrier function, as well as potentially structural function, could result in a more restrictive safety classification being applied. Figure 8 provides an example of how the same material take-off might look with safety classification updated. Although the safety class may not change the material, it likely would affect the quality requirements the supplier and constructor would need to satisfy in the work, as well as potentially the retention of records in fabrication, delivery, construction, and operation.

Example Material Take-Off From BIM Software						
WALL NAME	WALL LENGTH (FT)	WALL THICKNESS (FT)	WALL HEIGHT (FT)	WEIGHT	SAFETY CLASS	f'_m (psi)
W101	12.0	0.64	8.9	Normalweight	Non-Safety Related	2,150
W102	12.0	0.64	5.7	Lightweight	Non-Safety Related	2,150
W103	12.0	0.64	5.7	Normalweight	Augmented Quality	2,150
W104	16.4	0.97	10.1	Normalweight	Augmented Quality	2,150
W201	16.4	0.97	9.1	Lightweight	Non-Safety Related	2,150
W202	16.4	0.97	7.9	Lightweight	Non-Safety Related	2,150
W203	16.4	0.97	8.9	Normalweight	Augmented Quality	2,150
W204	31.7	0.97	16.4	Normalweight	Nuclear Safety Related	2,150
W301	16.4	0.97	9.5	Normalweight	Augmented Quality	2,150
W302	31.6	0.97	16.4	Normalweight	Nuclear Safety Related	2,150
W303	16.4	0.97	11.5	Normalweight	Nuclear Safety Related	2,150
W304	23.4	0.97	10.1	Normalweight	Nuclear Safety Related	2,150

Figure 8 – Example Updated Material Take-Off with Safety Classification

Finally, Figure 9 and Figure 10 present an additional complexity introducing radiation barrier requirements. In this example, some of the radiation barriers will require the material weight to be updated from normalweight concrete to heavyweight concrete. This change could result in various other changes to the design, however the example presented here is simplified.

Example Material Take-Off From BIM Software						
WALL NAME	WALL LENGTH (FT)	WALL THICKNESS (FT)	WALL HEIGHT (FT)	WEIGHT	SAFETY CLASS	RADIATION BARRIER
W101	12.0	0.64	8.9	Normalweight	Non-Safety Related	NO
W102	12.0	0.64	5.7	Lightweight	Non-Safety Related	NO
W103	12.0	0.64	5.7	Normalweight	Augmented Quality	NO
W104	16.4	0.97	10.1	Normalweight	Augmented Quality	YES
W201	16.4	0.97	9.1	Lightweight	Non-Safety Related	NO
W202	16.4	0.97	7.9	Lightweight	Non-Safety Related	NO
W203	16.4	0.97	8.9	Normalweight	Augmented Quality	YES
W204	31.7	0.97	16.4	Normalweight	Nuclear Safety Related	YES
W301	16.4	0.97	9.5	Normalweight	Augmented Quality	YES
W302	31.6	0.97	16.4	Normalweight	Nuclear Safety Related	NO
W303	16.4	0.97	11.5	Normalweight	Nuclear Safety Related	NO
W304	23.4	0.97	10.1	Normalweight	Nuclear Safety Related	YES

Figure 9 – Example Updated Material Take-Off with Radiation Barrier Requirements

Example Material Take-Off From BIM Software						
WALL NAME	WALL LENGTH (FT)	WALL THICKNESS (FT)	WALL HEIGHT (FT)	WEIGHT	SAFETY CLASS	RADIATION BARRIER
W101	12.0	0.64	8.9	Normalweight	Non-Safety Related	NO
W102	12.0	0.64	5.7	Lightweight	Non-Safety Related	NO
W103	12.0	0.64	5.7	Normalweight	Augmented Quality	NO
W104	16.4	0.97	10.1	Normalweight	Augmented Quality	YES
W201	16.4	0.97	9.1	Lightweight	Non-Safety Related	NO
W202	16.4	0.97	7.9	Lightweight	Non-Safety Related	NO
W203	16.4	0.97	8.9	Heavyweight	Augmented Quality	YES
W204	31.7	0.97	16.4	Normalweight	Nuclear Safety Related	YES
W301	16.4	0.97	9.5	Heavyweight	Augmented Quality	YES
W302	31.6	0.97	16.4	Normalweight	Nuclear Safety Related	NO
W303	16.4	0.97	11.5	Normalweight	Nuclear Safety Related	NO
W304	23.4	0.97	10.1	Heavyweight	Nuclear Safety Related	YES

Figure 10 – Example Updated Material Take-Off with Weight Updated for Radiation Barrier

Ultimately, the various specifications will direct the procurement and installation requirements, based upon the contract documents (i.e. specifications and drawings). The example case presented in the material take-offs shows that significant variation can occur in a complex design. Ultimately, the goals will be to ensure the installation meets all of the requirements, while minimizing cost and schedule. To do so, discretized tracking of requirements is important to avoid overspecification for the walls that have lesser requirements, providing a discrete set of requirements for each wall. To perform such discretization of specifications, by wall, a 3D model with metadata is the ideal solution.

CONCLUSION

This paper provides a description of a use case for documenting the functional and performance requirements of individual walls, slabs, and partitions in a 3D model database as part of the BIM process. In the use case provided, it is demonstrated how the functional and performance characteristics of a wall, in this case a masonry wall, can be complex, with many different variations depending on intent and location within the NPP. The use case demonstrates that designing and tracking the variations require a detailed mechanism to do so and recommends a 3D model as an appropriate tool for tracking the variations in functional and performance requirements.

The recommended use of a 3D model to identify functional and performance requirements allows ownership of the data in the model through a spreadsheet export and import workflow, as well a viewing and filtering the 3D model, and automated output into contract documents. The use case is presented as an example, to demonstrate the benefits realized in specifying, tracking, and developing contract documents utilizing 3D model metadata.

REFERENCES

Bonasera, M, and Marohl, M (2025). *Data Management and Interface for General 3D Model Users,* 28th International Conference on Structural Mechanics in Reactor Technology, Toronto, Canada, August 10-15, 2025.