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Upgrading BIM Processes in a Structural Design Office

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BIM A+ European Master in Building Information Modelling

Master Dissertation
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RESUMO

A metodologia BIM permite auxiliar os engenheiros estruturais no desenvolvimento integrado da certificação de um projeto estrutural, reduzindo erros e aumentando a ligação entre as vertentes de engenharia e arquitetura. De igual forma, BIM permite que engenheiros estruturais, desenhadores e responsáveis pela execução melhorem a qualidade do projeto estrutural e a cooperação entre profissões. Embora exista investigação teórica sobre a importância dos processos BIM na indústria de engenharia estrutural, existe uma lacuna no que respeita à discussão sobre a implementação dos processos BIM de forma prática.

Este trabalho pretende apresentar como atualizar de forma prática os processos de trabalho num escritório de projeto para lidar com os novos desafios e inovações no campo de BIM com objetivo de aumentar a produtividade interna do trabalho em diferentes usos de BIM na fase de projeto. Além disso, é almejado definir novas estratégias reestruturado esses processos para serem mais integrados, digitalizados e com maior controlo da qualidade da produção, permitindo assim aumentar a eficiência do trabalho e reduzindo ao tempo despendido.

Dessa forma, esta dissertação forneceu uma estrutura para atualizar um processo BIM na fase de projeto de forma os usos de BIM desejados, dentro do escritório de design Newton, através da revisão do modelo interno de BIM, com biblioteca de objetos, e modificando esses objetos de forma a atender às necessidades da fase de projeto. Além disso, foram revistos os processos de modelação e projeto utilizados de forma a automatizar algumas tarefas repetitivas para que os projetistas disponham de mais tempo produtivo.

Palavras-chave: Building Information Modeling (BIM), Dimensionamento estrutural, template BIM, Biblioteca de objetos, Manual de modelação).

ABSTRACT

BIM software supports structural engineers in developing integrative allocation of structural design certification, reducing errors, and increasing the association between engineering and architecture departments. BIM allows structural engineers, detailers, and fabricators to improve structural design and association among professions. Even though much research discussed the importance of BIM processes in the structural engineering industry theoretically, there was a lack of research that discussed the implementation of BIM processes in practical aspects.

This work intends to provide practical upgrading for work processes in a Design office to deal with new BIM challenges and implementation for new BIM innovations to increase the work productivity for the desired BIM uses within a company in the Design stage. Also, define new strategies to re-engineer these processes to be more integrated and digitalized with controlling the production quality, increasing the work efficiency, and save more time.

Therefore, this dissertation has provided upgrading framework for the BIM process in the design stage to achieve the desired BIM uses for Newton design office through revising the internal BIM template with objects library and modify them to cover the design stage needs. Also, revise the used modelling and design processes and automate some repetitive tasks so designers can use their productive time more wisely.

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Keywords: Building Information Modelling (BIM), Structural Design, BIM Template, Object libraries, Modelling Manual.

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1. INTRODUCTION

1.1. General remarks and scope

Over the past decades, the introduction and implementation of Building Information Modelling (BIM) into processes with the support of technological tools has developed and transformed the Architecture, Engineering, and Construction (AEC) industry, introducing new approaches to the Design Stage. It has, furthermore, established new types of collaboration among stakeholders, from the very first stages of the project until the end of its lifecycle (Eastman, C.M, Teicholz, P.Sacks, R. and Liston, 2018) In addition, it has been proven that BIM tools and BIM workflows significantly increase design productivity, reduce construction waste, and improve connectivity in facility operations (B Succar et al., 2016).

BIM has contributed to increasing the digitalization of the AEC processes addressing its low productivity growth over time, seeking more efficiency and revenues for the industry (Mihindu and Arayici, 2008). With BIM, all data has a direct or indirect relationship, creating a database representing a digital project copy. Regardless, the design process and the insertion of information with BIM tools are still broadly hand operated. The desire to respond to the clients effectively and optimize the design and construction workflows has generated new data management tools.

The development of new BIM processes and implementation of BIM tools according to the desired uses of companies is a feasible way to achieve custom automatization, increase work productivity. Also, it has been a goal of researchers and companies for a more integrated design process. Therefore, several graphical programming tools for design have arisen. Dynamo, the visual programming tool for Autodesk Revit, has proven suitable for approaching BIM design workflow, reducing labour time, increasing quality assurance, and supporting software interoperability. Especially inside structured Companies, where BIM is already implemented in the day-to-day workflow, Dynamo effectively automates repetitive tasks. Companies are always looking for possibilities to simplify, optimize and improve their processes. They want to reduce, especially labour-intensive tasks. Visual programming application into BIM tools like Revit gives new opportunities to create, manage, and check geometrical and no-geometrical information in the digital model.

Moreover, BIM software enables architects, designers, engineers, modellers, Building Information Modelling (BIM) coordinators, and BIM managers to create BIM models and analyse intelligent data to improve design and construction. BIM has developed a transformation in the engineering industry. Information is the core of any process that improves productivity, providing several benefits compared to the traditional 2D CAD process. Productivity in modelling is directly connected to the BIM Templates quality used in projects. Also, it can help to increase efficiency when working in software, and the company will benefit from consistency across projects. The templates save much time by having predefined standards.

1.2. Objectives

This work intends to provide practical upgrading for work processes in a Design office to deal with new BIM challenges and implementation for new BIM innovations to increase the work productivity for the desired BIM uses within a company in the Design stage. Also, define new strategies to re-engineer these processes to be more integrated and digitalized with controlling the production quality, increasing the work efficiency, and save more time.

In order to accomplish the main objective, it is required to revise the internal BIM objects library and the used Revit template and modify them to cover the design stage needs. Also, revise the used modelling and design processes and automate some repetitive tasks so designers can use their productive time more wisely using Dynamo scripts that allow user to achieve the desired BIM uses.

It is also intended to create procedures manual for the modelling tasks to support modellers in increasing the production quality of structural models with high accuracy level. Also, facilitate coordination and collaboration at design and drawings production stages and create a BIM model suitable to be exported to other structural analysis software.

1.3. Partnership for the dissertation

This work was developed in close connection with Newton - Consultores De Engenharia Lda, an international engineering company that has been using and improving its BIM methodology for over 10 years to provide structural design and project management services. Newton facilitated the conditions to work side-by-side with the company to define the needs and identify the problems related to this subject. The colleagues involved were a vital asset to criticize and validate this work, improving its initial status.

1.4. Dissertation structure

Besides the introduction, the other four chapters structure this work. The second chapter comprehends a literature review about the topics considered essential to support the development of the work, mainly involving building information modelling in the structural design phase.

The following chapter, “Upgrading Newton Framework”, diagnosed the framework of the used BIM template and discussed the improvement structure for all factors that affect the modelling workflow. In addition, it clarifies the upgrading structure for Newton internal Revit families by implementing Uniclass 2015 and Omniclass classification systems for efficient specification, scheduling, and cost estimation. Additionally, it illustrates upgrading the used materials with their parameters to achieve the desired BIM uses. Also, it discusses the procedure of applying a new naming convention for all Revit families. it highlights the importance of applying a database system to store the information of Revit families. Moreover, describes exporting the IFC model by mapping the Revit elements with IFC shared parameters. This IFC development aims to increase the quality of the exported IFC model. Additionally, (Modelling technical manual) discussed, improving the current a technical modelling guide manual for Newton BIM uses. This manual discusses the procedures of modelling structural elements (Foundations, slabs, beams, columns, and walls) to facilitate coordination and collaboration at design and drawings production stages and create a better BIM model by improving the interoperability with software outside its standard workflow.

Chapter 4, “Automating Newton tasks”, registers the development of the proposed digital solutions using Dynamo scripts to automate some repetitive tasks parallel to Newton's core design workflow so designers can use their productive time more wisely. This chapter is divided into three Dynamo scripts. The first one, section 4.2 (Formwork), discussed the Dynamo script to read the information from the concrete structural Revit model and use the information to make calculations and produce the result of the formwork quantity take-off directly to the Revit, simultaneously create a 3D model for the formwork elements in an independent Revit template. Additionally, section 4.3 (Footing Insulation) discussed the automation process of calculating the quantity take-off of the footing insulation from the structural BIM model and creating a 3D model. Moreover, section 4.4 (Splitting VL elements at levels) developed a Dynamo script to split all the VL elements for the 3D Revit model. Thus, once the VL elements and the levels are selected, all selected VL elements will split in the Revit model.

Lastly, the conclusion, embedded in chapter 5, states the results of the developed work, and indicates further developments for the specification to reach a higher level of digitalization, quality, and productivity for the desired work.

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2. LITERATURE REVIEW

This chapter presents an in-depth view of the main subjects related to building information modelling in the structural design phase. Initially, some aspects of BIM are discussed, such as BIM uses that can serve the structural design. Then, works on information management are introduced, like standards, commonly used BIM tools, methods, and issues are presented.

2.1. BIM

BIM is a process and platform used in the construction industry. Nowadays, BIM is used in many projects and is a requirement on contracts. An ordinary meaning of BIM is "a digital representation of physical and functional characteristics of a facility and a shared knowledge about a facility forming a reliable basis for decisions during its life-cycle; defined as existing from earliest conception to demolition" (BuildingSMART, 2017). There is a general cognizance that BIM is a 3D design. Therefore, a BIM model has multi-dimensional information on itself. BIM is a system for initiating and organizing all the knowledge on the building objects during the construction project phases, including initiating, planning, construction, closure, facilities management, and demolition. The result of this mechanism is the BIM model and the digital description of all conditions of the developed resource. Many people assume BIM as a prominent design allocation and advance establishment (Autodesk, 2017). After the handover, the real value can be figured out when the manager or the person who owns the stocks gets all the correct knowledge. Above all, BIM integrates much independent information on the model in which items are connected to associated knowledge like manuals, specifications, and warranty details. This feature permits the owner or the facilitator to organize the items effectively and correctly. BIM connects all the knowledge about various parts of building design at the same point. Thus, BIM allows everyone to reach the information for any purpose, e.g., to integrate various ways of design to be more effective, to collaborate for effective building design. In this way, the risk associated with unknowns and missing data about the building is reduced, and the cost of change is minimized.

2.2. BIM in Structural design

BIM software supports structural engineers in developing integrative allocation of structural design certification, reducing errors, and increasing the association between engineering and architecture departments. BIM allows structural engineers, detailers, and fabricators to improve structural design and association among professions. The BIM model is a building prototype and ensures the designer realizes failures and clashes before building the actual structural design (Autodesk, 2017). BIM can also create integrated design projects and can act as a dominant material as a management tool. Structural designers confront many advantages of BIM in various forms, as the model can be consistently updated for achieving integrated design. BIM also changes the form of how one manages and see the items. It increases the impact on building design, structural design, and engineering analysis. BIM makes possible the reduction in design efforts, minimizes errors and changes, and develops cost-effective designs and increases production quality. It ensures better results both in design and construction (AutodeskAEC, 2017).

2.3. Structural Deliverables in pre-BIM context

According to Portuguese law, as an example, the deliverables for structural design projects are consist of

- Calculation notes and justifications according to applicable law.
- Drawings Plan views and cross-sections at adequate scales that represent:
    - The position with dimensioning of the structural elements, such as (beams, columns, slabs including openings, walls, etc.).
    - The cross-sectional Information of all elements (before finishing application).
    - The level of unfinished superior surfaces of beams, walls, slabs.
    - Location and size of openings in structural elements (e.g., for plumbing).
    - The development of columns through their height, with a clear indication of lower/upper levels.
    - Details of all elements of the structure that show their shape/constitution and allow their construction without doubts or ambiguities at the scales 1:50, 1:20, 1:10 or higher.
- Quantity take-off for materials and works to be conducted. Corresponding budgeting as well.
- Technical specifications for the conduction of all works (general and specific).

2.4. Model uses

The conceptual background of Model Uses has been covered by BIM Excellence (Bilal Succar, 2020). Model Uses describe and verify the Information Requirements that need to be delivered as 3D digital models. As a Knowledge Block, Model Uses form part of a more significant modular language that connects information requirements with System Units, Defined Roles, and Competency Items.

The following BIM uses the most commonly used in Design offices to achieve the desired deliverable of the 3D BIM model.

- Quantity Take-Off (QTO): A Model Use representing how 3D models are used to calculate the number of used elements, objects, and building materials to generate Cost Estimates.
- Cost Estimation: A Model Use representing how 3D models are used to generate feasibility studies and compare different budgetary options.
- Design Authoring: A Model Use represents developing Generative Models or Parametric Models for design exploration, design communication and design iteration purposes. Design authoring is a crucial BIM activity leading to model-based 2D Documentation, 3D Detailing and other model-based deliverables.
- 2D Documentation: A Model Use representing how 2D Drawings are extracted from information-rich 3D models. 2D Documentation typically includes 2D plans, 2D sections, 2D elevations and 2D details.

- 3D Detailing: A Model Use representing how three-dimensional details are extracted from information-rich 3D models. 3D Detailing typically include hybrid 2D-3D annotated views
- Structural Analysis: A Model Use representing how 3D models are used to analyse the behaviour of the structural system. Structural analysis typically includes studying the effects of static/dynamic loads on buildings and how building design can be subsequently optimized.

2.5. Naming Convention

2.5.1. Spelling

According to NBS object standards, the BIM object has applied spellings that consider the approach taken by the origin resource. For instance, NBS uses the Oxford English Dictionary (OED) as the default spelling guide. It is essential to follow a consistent approach to spelling when it uniformly comes to scheduling information.

2.5.2. Composition

BIM object Name shall consist of alphanumeric characters without text formatting (a-z, A-Z, 0-9). Also, it is limited to a maximum of 75 characters. In addition, the naming fields shall use only the dash character (-) within phrases and the underscore character (_) as a delimiter. Information within each field is to be Pascal Case (capitalized first letters for words and no spaces). No spaces or other punctuation shall be used. Naming conventions should be spontaneous so that information can be found and recovered. For example, spaces and punctuation are not helpful in the digital age, and special characters may mean different things and commands in different software packages. In this way, it facilitates the ability to provide search functionally and interactions with other databases. The BIM object and file name must be unique to avoid duplication of information and aid in exporting information and its interpretation.

2.5.3. Abbreviations

The BIM object and file name must be unique to avoid duplication of information and aid in exporting information and its interpretation.

2.5.4. Naming fields

The naming fields shall be consisting of BIM object the originator, source, material, and type. NBS recommended to organize the naming fields as follow:

<Originator>_<Source>_<Material>_<Subtype>_<Differentiator>

2.6. Classification systems

Implementation of classification systems on the internal elements libraries is essential for efficient specification, scheduling, and cost estimation. This classification system allows the used BIM objects to be identified, described, and well organised within the BIM environment. In addition, the classification system facilitates the searching, sorting, extracting, and analysing of the data. Using a unified classification system ensures consistency and reduces ambiguity. Also, it allows the user to collect and compare data across several projects.

2.6.1. Uniclass 2015

Uniclass can categorize information for costing, briefing, CAD layering when preparing specifications or other production documents. Also, it is open, accessible, and compliant with ISO 12006-2 ease integrations with and translations to other classification schemes in the future.

Uniclass provides:

- a unified system to classify all elements relate to the construction industry.
- A flexible numbering system to adapt to future requirements for classification.
- A synonyms database that allows users by using standard terminology to find the required classification.

The suite of Uniclass 2015 tables is generally hierarchical and permits a venture to be characterized from the broadest see to the foremost nitty-gritty. The Complexes table portrays ventures in general terms. Moreover, it can be thought of in terms of the arrangement of an Activity. Complexes classifications can be broken down as groupings of Entities, Activities and Spaces/locations depending on the specific utilize (Delany, 2019).

In Uniclass 2015, The locations / Spaces and Activities tables could be used to describe Entities. Also, it can be described by systems tables as figured in Figure 1. Thus, the main starting point for detailed design and construction is entities.

Elements are the primary Entity's architectural components, such as walls, structural columns, and floors. Other requirements in entities like ventilation or heating are considered as functions. Also, the Elements table consists of Functions, so it is named Elements/ functions, which are described in more detail by Systems, which contain Products.

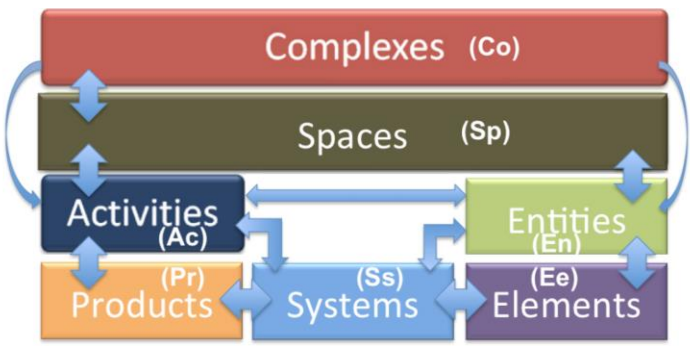

Figure 1-Tables and their relationships used in Uniclass 2015.

- Complexes can generally describe a project, such as a private house with a garden and garage, rail networks and airports.

- Entities are separate things in the project, such as buildings and bridges. However, they present the places where the different activities occur.

- The Activities table describes what user activities are contained in the complex, entity, or space. It also includes project management, surveys, operation and maintenance, and services.

- Spaces are provided in buildings for different activities to take place. In some cases, a space is only proper for one activity. The term location is more relevant for linear entities such as transport corridors than space for dividing the project into appropriate sections.

- Elements are the primary building components (floors, walls, and roofs) or the main structural components like a bridge (foundations, piers, deck). While Functions are the provided and managed building services.

- Systems are collections of products that could be one or more are collected to describe an element or a function (Delany, 2019).

Uniclass codes consist of either four or five pairs of characters. The four following pairs represent groups, sub-groups, sections, and objects. Each group of codes has Up to 99 items. The figure below shows the Uniclass division into groups, sub-groups, sections, and objects.

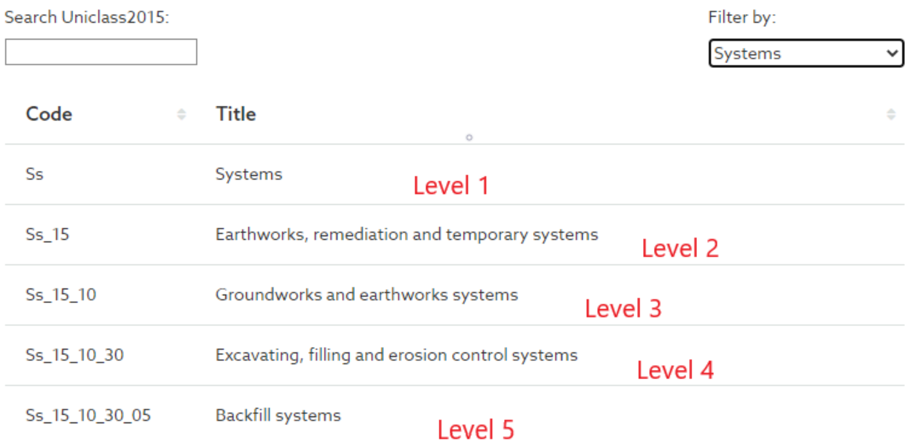

Figure 2-Uniclass divisions

2.6.2. Omniclass

This study also classified using the Omniclass, the currently used classification system in the US construction industry based on ISO 12006-2 (Organization of Information about building Works – Framework for Classification). Also, OmniClass is supported by CSI (Construction Specifications Institute) and CSC (Construction Specifications Canada).

OmniClass contains many features of legacy systems that it includes, while developing the subject matter to support the BIM requirements and the AEC industry integrated processes. OmniClass has become an essential demand within the developing field of product search and comparison. It supports the requirement in BIM format for highly detailed product information. In addition, it can normalize and categorize detailed attributes/properties and processes developed and supported by the National BIM Standard and Integrated Project Delivery.

Omniclass is developed to provide a standardized source for information classification throughout the facility's entire life cycle from conception to demolition or reuse. It can be used for organizing, sorting, and retrieving information and deriving relational computer applications.

The advantages of Omniclass:

- it incorporates other systems currently in use as the basis of many of its tables such as MasterFormat for work result table, UniFormat for elements table and EPIC for structuring products.

- its implementation in computer technology (primarily relational or object-oriented databases), using that to relate information from variety of perspectives and to produce reports from all perspectives.

OmniClass is a faceted classification that can classify from various perspectives. It has fifteen tables; each table describes a different aspect of construction information as shown in the following figure.

OmniClass 2006-2013
Table 36 - Information
Table 23 - Products
Table 41 - Materials
Table 33 - Disciplines
Table 34 - Organizational Roles
Table 35 - Tools
Table 32 - Services
Table 31 - Phases
-
Table 11 - Construction Entities by Function
Table 12 - Construction Entities by Form
-
Table 13 - Spaces by Function
Table 14 - Spaces by Form
Table 21 - Elements (Includes Designed Elements) (Uniformat)
-
Table 22 - Work Results (MasterFormat)
Table 49 - Properties
-

Figure 3- Omniclass tables

The most useful Omniclass codes for contractors to create a work breakdown structure (WBS) are:

Table 22- Work Results. This table defines the deliverables required under or by the contract documents. This document is usually known as the Contractual Work Breakdown Structure and describes what the contractor must deliver or create to have completed the project. While the WBS defines WHAT needs to be done, the next level deeper is the cost and resource loaded CPM schedule. This schedule tells us HOW (the sequence of activities or the workflow) and WHEN the work will be done, established by the early and late start and finishes dates, calculated by the forward and backwards pass.

Table 41- Materials. This table contains a list of bulk materials usually purchased by the truck, trailer, tank, or rail car volumes. These will most likely be used if a contractor has set up their concrete batch plant or asphalt plant rather than used for most construction sites.

Table 23- Products. This table contains almost 7,000 “products” used in the construction process. Again, these can be broken down into a more refined set of codes.

2.7. IFC – Model Exchange

Interoperability is a crucial feature for exchanging and (re)data in new generation applications for planning, construction, analysis, management, collaboration, and communication. Among such data, an essential source of information about the built environment is Building Information Models (BIMs). The effective interoperability of such data would bring significant advantages. These would involve many scopes. First, the collaboration among different practitioners involved in building design, construction, and management. Second, the exchange and reuse of the data among diverse stakeholders and through time. Third, the integration with other data sets, including different formats, for various use cases.

OpenBIM is a new general methodology for Designing, construction, and operating of buildings according to open standards. Despite the used software, the openBIM approach supports open cooperation, transparency for all project partners. IFC is considered the primary standard for information exchange in openBIM (BIM Corner, 2021).

The "Industry Foundation Classes" or IFC is an open, standardized, digital, and interoperability solution for coordination between different BIM software or hardware devices for all the built environments. It is a generic, neutral data format. IFC presents descriptions for all object element types used in the construction industry and stores those descriptions in a data file.

BuildingSMART International delivered the IFC schema specifications to achieve its goal by promoting the openBIM. The IFC schema specification identifies the usage, construction, operation of the facility or installation. Also, it can describe the physical elements of buildings, the manufacturing way of the products. In addition, it can provide more structural and energy analysis models, work schedules, and cost breakdowns.

The IFC file format facilitates information transmission from one party to another for a specific business transaction, which reduces the information loss during this information exchange between software, increasing productivity and enhancing communication. Also, it can be used to archive project information during different phases (the design, procurement, and construction) or archive for long term purposes in the "as-built" phase (BuildingSMART website, 2021).

BuildignSMART regularly set the updates to develop the IFC definitions. The IFC schema is steadily growing. The current version is IFC 4, issued in 2013 (the prior releases were marked as 1.0, 1.5, 1.51 and then 2x, 2×2, 2×3).

MVD (Model view definition) enables a specific information exchange requirements which given at specific stage of the project that determines the usage of the IFC file. It is used to exchange specialized models with their specific graphics and contents to fulfil planners needs. For instance, information about the supporting building elements could be used for a specialized model for structural planning. (Autodesk, 2018). BuildingSMART listed MVDs available in Revit as follows:

- *IFC4, Model Reference View* provides a specific IFC file for coordination and quantity determination.
- *IFC4, Design Transfer View* provides an IFC model to import and edit in specific BIM software.
- *IFC2x3, COBie 2.4 Design Deliverable* which the UK government requires for their level 2 BIM for collaboration on public sector work.
- *IFC2x3 Coordination View* provided the IFC model for the coordination exchange between the building industry disciplines.

2.8. Revit software review

2.8.1. Revit template

Revit Template is essential at the beginning of any new project to ensure that this project is consistent with other company projects. The template provides a reliable way to ensure that the project follows the suitable collection of features, settings, and office standards.

The quality of the Revit template used in projects significantly affects the Revit productivity, including industry and organization standards. Also, the template can increase Revit working efficiency, which leads to more consistency across different company projects.

The main goal of templates is to save much time for the company. Revit users do not need to adapt the project settings for each new project to be compatible with company standards with the predefined templates.

Templates are different according to the design purposes, which could be personalized for a specified type of project and will contain all the necessary standards and information used in this special task. Therefore, many checklists were developed for different template purposes. The checklist is not a rigid list of points that the BIM manager must include but a list of things that should be considered when creating a template. Thus, a BIM manager should choose only those elements that will best fit the purpose of a given Revit template.

2.8.2. Object families

Revit Libraries are the Revit objects / families' databases that include all the geometrical and non-geometrical information of the objects. The Revit libraries consist of three types of libraries:

- The first library is the system Revit library, which is pre-made by Autodesk and has a limitation in the library customization and can be saved inside the Revit template such as "walls, floors".

- The loadable Revit families, which can be created from scratch by the user, can be saved as (.rft) independent files and can be inserted in the project directly from ready-made families such as "Structural Columns, Structural Framing."

- The in-place families can be created from scratch by the user like the loadable families, but those families can be created only for specific projects and cannot be saved outside the project file.

Revit software allows families creators to make realistic and accurate families and import existing libraries from other creators, websites, and software. Revit families could be developed as parametric families with geometrical and non-geometrical information, which allows the user to modify the given libraries by updating predefined parameters such as *length*, *thickness* or *number* when using (array) order.

By this method, the family parameters define the Revit library's geometry. Each combination of the parameters can be saved as a family type, and each instance of a type can also contain other variations. For example, a concrete rectangular column is a Family. It has types defining different dimensions, and the actual building model has instances of the types placed in the building where parameters based on instances can define each concrete rectangular column uniquely.

2.8.3. Revit parameters

Project parameter allows users to add a new information to a specific Revit category for a specific project. This parameter is visible in schedules but cannot be used in tags. Also, it is not shared with any external file. There are no limits to creating new project parameters in the project. However, it is recommended to keep it to a minimum because it leads to a heavy Revit file due to increasing its size and become more challenging to maintain the unnecessary data inside the model.

Shared parameters have the same uses as project parameters with some differences. The main difference is that the shared parameter can be created for various Revit families. Also, it can be used in schedules, tags, and exported as ODBC (Open Database Connectivity). In addition, shared parameters can be stored in an external text file (.TXT file) to host the shared parameters information. Also, the values of the shared parameters applied in a specific family or project are not automatically applied to other families using the same shared parameter.

Global parameters can be created for multiple objects from different categories, not just a specific category.

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3. UPGRADING NEWTON’S FRAMEWORK

This chapter focuses on an in-depth view of upgrading Newton framework through the customization of the BIM template to serve Newton projects such as industrial facilities, houses, and multi-story buildings. This study has been developed to update the Newton template to be compatible with the desired BIM uses. In addition, saving more time working with BIM software and follow the company standard, which serves the Portuguese and the European markets.

The focus of the development is this dissertation will be targeting procedures that will power Newton's performance regarding to the following BIM uses:

- Setting up the model for structural analysis.
- Extracting quantity take-off.
- Drawing generation.

3.1. Diagnosis of the existing Template framework

The BIM uses related to structural designs as described before are part of the work scope of the study firm, Newton - Consultores De Engenharia Lda. As a structural design office with a consistent background in using BIM, Newton saw the possibility of adding value to its business model by upgrading the used template with its object contents to be prepared for ever more demanding client’s requirements.

The methodology applied to diagnose the existing workflow and discuss the dissertation development was based on weekly meetings (in-person and video calls) with the company representative and the dissertation supervisors. In addition, the Zoom platform was used to hold online meetings. In addition, A communication channel on the WhatsApp platform was established at the very beginning of the dissertation development, enabling information exchange through messages daily. Furthermore, a Common Data Environment (CDE) was also set up on OneDrive, allowing data sharing between the Newton team and the author of the dissertation. Finally, it is worth highlighting that the total availability and commitment of the Newton team were crucial for this work achievement.

Newton customized its own template using Revit Autodesk software from many years. It has been delivering the BIM uses very correctly in many ways, the quantity take-off, the drawing generation, and the structural analysis. The goal is to upgrade the used template and its contents to be compatible with different client's requirements without decreasing the productivity of a fully trained and operational staff.

There is a general template for the Newton project start. However, even Newton has delivered several projects with more information requirements and many parameters; as shown in table 1, the general template is not yet prepared for comprehensive information requirements, which may be required according to EIR. Therefore, this work intended to make the template easier for the designers to achieve information requirements without having more work.

3.1.1. Diagnosis of existing Newton objects

This study focuses on the structural elements (Structural column, Structural framings, Walls, Floors, and Structural foundations) and diagnoses their parameters. The following table 1 diagnoses the structural column and the structural framing families as an example according to multiple factors to study the information needed to be developed.

Newton Families	Dimensions	Material	IFC Parameters	Naming convention	Classification Systems	Elements Specifications
Structural Column	x	x	N/A	N/A	N/A	N/A
Structural Framing	x	x	N/A	N/A	N/A	N/A
Structural Foundations	x	x	N/A	N/A	N/A	N/A
Floors	x	x	N/A	N/A	N/A	N/A
Walls	x	x	N/A	N/A	N/A	N/A

Table 1– Diagnosis of the information of Newton Families

3.2. The development of Newton Template framework

This study agrees that the Newton office will develop its BIM template to automate some procedures, which will improve quality and productivity, save time, and reduce errors and rework. Also, applying naming convention for the template and its objects.

In addition, Newton will manage its BIM objects library and specification database in compliance with the classification system Uniclass 2015, Omniclass, and the NBS object standards. Both classification systems and standards are indispensable for the intended increase of automatization, allowing the link between different sources of construction data and assuring its interoperability among different digital tools. Moreover, creating new IFC parameters to better export the model in IFC format.

Revit Template is dynamic; it will be developed continuously with new improvements to adjust it for updated workflows and standards. It is the BIM manager responsibility to create and update the template and its contents. Autodesk releases a new Revit version every year. Therefore, the BIM manager should check and run some tests for the template whenever there is a significant update for the software or a new version.

In this workflow, Newton will be able to use any Revit version from Revit 2021. However, the Revit 2021 template will be upgraded to a specific version when a new project starts.

This study used the checklist of items to update on the Revit template which included to the datasets of the book *Increasing Autodesk Revit Productivity for BIM Projects* (F Roberti, D Ferreira, 2021) to be as a guide to upgrade the Newton template according to the latest Revit 2021 specifications. This checklist has many features that suitable for structural design uses.

3.2.1. Implementation of naming convention

This study has developed to apply the metadata requirements for Newton BIM objects, views, and sheets according to NBS National BIM Library, including naming convention for objects, properties, values, and materials. Before applying NBS standards on Newton Revit template and its contents, the template contents were stored in the Portuguese language. Then, they were translated to the English language to follow the NBS standards and be opened more on all the European markets.

Table 2 and Table 3 show as the example for families naming convention, the applied naming convention for structural column objects library.

Families Updated Naming	Families Old Naming
Nw_Column_RC_Circular	**NW-Pilares Circulares**
Nw_Column_RC_Rectangular	**NW-Pilares em Betão Armado**
Nw_Column_Steel_Circular	**CHS-Circular Hollow Section-Column**
Nw_Column_Steel_HEB	**NW-Pilares Metálicos**
Nw_Column_Steel_RectangularHollowSection	**RHS-Rectangular Hollow Section Column**
Nw_Column_Steel_SquareHollowSection	**SHS-Square Hollow Section-Column**

Table 2– Example of Newton families Naming Convention

NW	**Newton Office**	**Originator**
Column	**Object Type**	**Source**
RC	**Object Material**	**Material**
Rectangular	**Object Section**	**Subtype**

Table 3–Diagnosis for families Naming Fields

3.2.2. General settings

The template general settings discuss the fundamental configuration.

- **Browser Organization**

The Browser Organization tool is crucial to enhance the modelling productivity because of the ability to optimize the way of views and sheets organization to be suitable for Newton's workflow. The Browser Organization tool is classified into three divisions, as follows:

- Browser Organization – Views
- Browser Organization – Schedules
- Browser Organization – Sheets

In this section, the project browser did not have many changes. The existing Newton template was suitable for the structural deliverable according to the Portuguese market and the desired BIM uses. The browser organization depends on the company needs, the working team usage, and the project base.

The Views has been organized differently to serve Newton BIM uses, with translating all the Portuguese expressions to the English language and applying new naming conventions according to NBS standards.

Also, for schedules, sheets, and legends, no changes were applied. The existing Newton template covered all the company requirements. Therefore, the changes were applied only for the naming convention and translation for all schedules, legends, and sheets. In addition, some new schedules were created to achieve better BIM uses and save more time.

The existing Newton template has many schedules that serve the QTO BIM use. The template schedules have been created to calculate the quantities of the elements and show their information, also calculate the materials take-off. In addition, the template has many sheets to serve the drawing generation BIM use by creating sheets that able to extract the structural plans at different levels, sections, elevations, and details for different structural elements.

- **Snaps**

Object snap is essential for adding or editing any element, as it will display the snap point symbol. The settings of object snap could be changed according to a specific workflow. Also, it could allow the user to change the condition of any specific snap order to fit a specific workflow. In addition, the object snap shortcuts could help in increasing template productivity. Snaps decided to be as Revit default without applying any changes.

- **Project Information**

Project information is helpful to specify any information about the project, such as (Organization name, Organization description, building name, and Author). In addition, project Information can be customized according to company requirements by creating a new project parameter or shared parameters and adding them to the system family "Project Information".

For the Newton Template, new project parameters shown in figure 4 were developed and added to the project information to be accessible by just picking on the project information such as (Model name, Model number, Designer, and Checker).

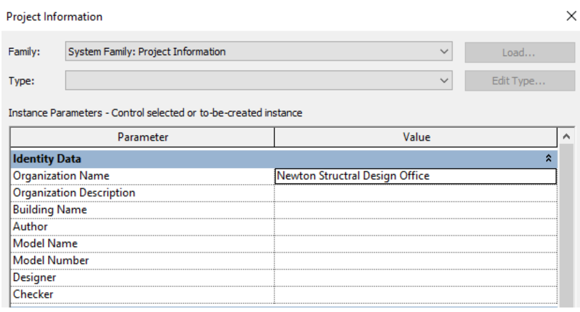


Figure 4- Project Information in Newton Template

- **Template parameters**

The study kept the existing project parameters for Newton and created new parameters to fulfil the company needs, such as the project information parameters discussed before. While it did not develop any new global parameters and mostly depended on the shared parameters to achieve the desired development.

In addition, four shared parameters groups shown in Table 4 were created to fulfil Newton requirements. Each group contains different shared parameters which can be used in various projects. All those shared parameters are stored in Newton template and in an external text file under the name "NewtonSharedParameters". The following table shows the created shared parameters with their shared parameter groups, and the uses of each shared parameter will be illustrated in the further sections. It's BIM manager responsibility to add or modify the template parameters.

Parameter Group	Classification system	Dynamo parameters	IFC	Material specifications
BIM Object Name	x			
NBS Description	x			
NBS Reference	x			
OmniClass Description	x			
OmniClass Number	x			
OmniClass Version	x			
Uniclass Version	x			
Uniclass EF Description	x			
Uniclass EF Number	x			
Uniclass Pr Description	x			
Uniclass Pr Number	x			
Uniclass Ss Description	x			
Uniclass Ss Number	x			
Formwork Area		x		
Insulation Area		x		
IFC Export As			x	
IFC Export Type			x	
Exposure Class				x

Table 4- Newton created shared parameters

- **Project Units**

Project units can be defined by discipline, which can automatically adjust all the projects without any need for any other input from the user. Newton Project units were developed according to the International System of Units (SI) (ISO 80000-1:2009), to fulfil European market requirements.

3.2.3. Views and Sheets

- **Starting page – splash screen**

The splash screen is the main page where the project's primary information should be included.

Newton starting page shown in Figure 5 is developed as a view template to include Newton logo, Project photo and information about project and model which contains:

- The project’s name.
- Date of creation.
- The used Revit template.
- The used Revit version.
- The project code.
- The client name.
- The design stage.
- The Revision number.
- The model’s name.
- The modeler.
- The project manager.
- The BIM Coordinator.
- The project Team members

Figure 5– Newton Starting page

- **Title Block**

The title block has the same principles as the starting page which has relevant information about the project and sheet. New title blocks were proposed to Newton representative to produce a new sheet frame that follows ISO 7200 standards. However, we found after discussion that the current one is better for Newton work, the clients' requirements, and the Portuguese market.

ISO 7200 has provided two samples for title block; the first one in Figure 6 is in compact form, provides maximum space for factual content of document. Its dimension is 180 x 27 mm, contains five optional data fields.

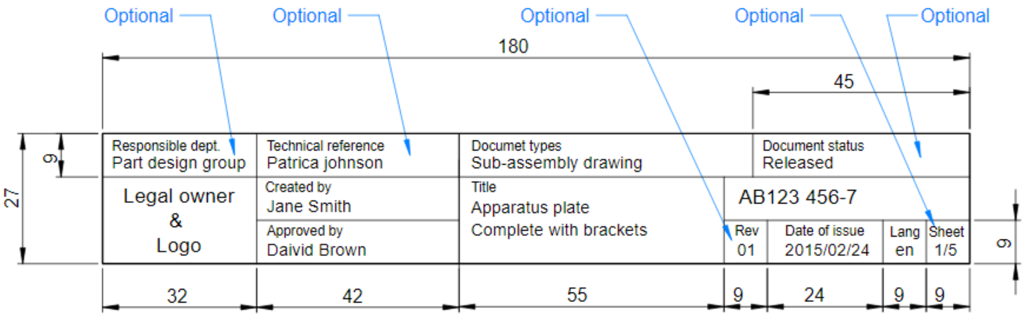


Figure 6– ISO Standard title block1

The second in Figure 7 is a title block with person name fields on additional line, provides larger space for legal owner field and free area in upper right-hand corner for classification, key words, etc. Its dimension is 180 x 36 mm, contains six optional data fields.

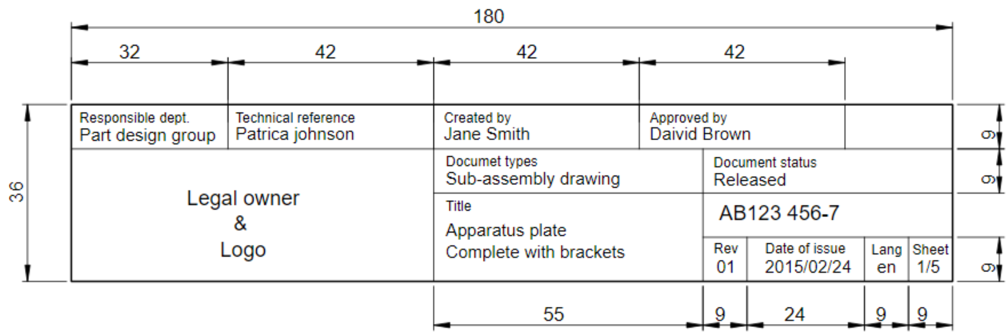


Figure 7– ISO Standard title block 2

While the existing title block in the Newton template has its information in the Portuguese language with a different arrangement for the data fields as shown in the following figure.

Figure 8– Newton title block

3.2.4. Graphic standards

Graphic standards cover the primary settings that control the Revit graphics, which directly affects the productivity and consistency across the discipline drawings.

- **Line patterns**

Line patterns combine just two characters (Dash – Dot) with specific dimensions and blank spaces.

According to Newton requirements and usage, this study is developed to create new line patterns Figure 9 and store them in the Newton template according to ISO128-20. Also, a naming convention is applied for each line style to identify its formation. For instance, line type “NW_Dash_1.0mm” refers to a line type for Newton company consists of a Dash with length 1.00 mm, then a blank space, then another Dash with length 1.00 mm and so on.

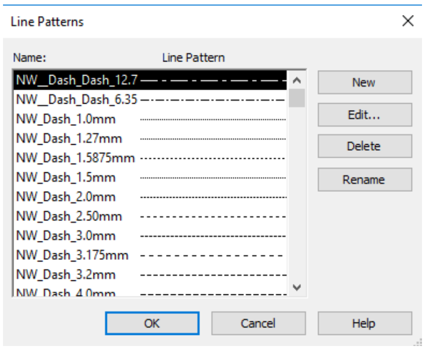
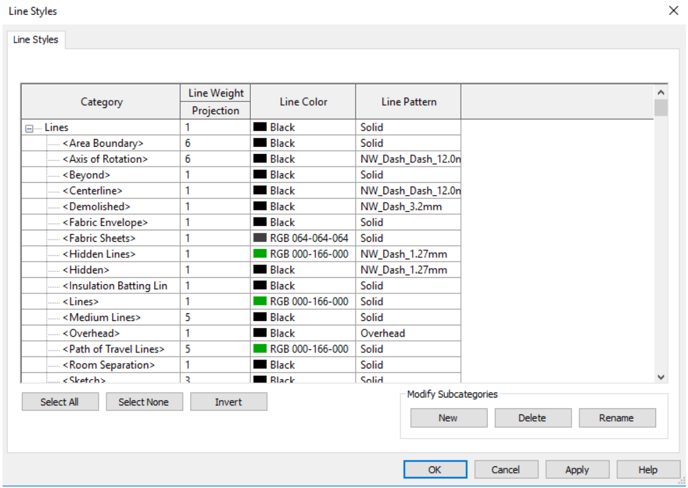


Figure 9– Newton Line Types

- **Line Styles**

Line styles consist of line patterns, line weights, and colours. Revit classifies the line styles to hard-coded or system line styles category, which has <> and cannot be renamed or deleted, shown in Figure 10. The other line style category can be created, renamed, and deleted by the user. For both line style categories, the user can modify the line weight, colour, and pattern.

This study modified some line patterns and line wights for some line style system categories in Figure 11. Also, created new line styles with their weight, colour and pattern for future uses to fulfil the company requirements.



Category	Line Weight Projection	Line Color	Line Pattern
Lines	1	Black	Solid
<Area Boundary>	6	Black	Solid
<Axis of Rotation>	6	Black	NW_Dash_Dash_12.0n
<Beyond>	1	Black	Solid
<Centerline>	1	Black	NW_Dash_Dash_12.0n
<Demolished>	1	Black	NW_Dash_3.2mm
<Fabric Envelope>	1	Black	Solid
<Fabric Sheets>	1	RGB 064-064-064	Solid
<Hidden Lines>	1	RGB 000-166-000	NW_Dash_1.27mm
<Hidden>	1	Black	NW_Dash_1.27mm
<Insulation Batting Lin	1	Black	Solid
<Lines>	1	RGB 000-166-000	Solid
<Medium Lines>	5	Black	Solid
<Overhead>	1	Black	Overhead
<Path of Travel Lines>	5	RGB 000-166-000	Solid
<Room Separation>	1	Black	Solid
<Sketch>	3	Black	Solid

Figure 10– Line styles system category

Category	Line Weight Projection	Line Color	Line Pattern
NW_Dash_Dot_2.0mm	1	Black	NW_Dash_Dot_2.0mm
NW_Dash_Dot_3.0mm	1	Black	NW_Dash_Dot_3.0mm
NW_Dash_Dot_3.5mm	1	Black	NW_Dash_Dot_3.5mm
NW_Dash_Dot_4.0mm	1	Black	NW_Dash_Dot_4.0mm
NW_Dash_Dot_4.7625	1	Black	NW_Dash_Dot_4.7625
NW_Dash_Dot_6.35mm	1	Black	NW_Dash_Dot_6.35mı
NW_Dash_Dot_9.525mm	1	Black	NW_Dash_Dot_9.525n

Figure 11– New Newton Line Styles

- **Fill Patterns**

Fill patterns control the appearance of the objects' surfaces and the cut areas. Revit divided the parts into two categories (Drafting and Model), where the user can create, edit, delete, and rename the patterns. The main difference between the two categories is that the Drafting represents the cut areas of the model elements without concerning the scale factor. On the other hand, the Model category defines model elements and their surfaces, and it scales with the model, so if the view scale changes, the pattern scale changes accordingly.

In addition, patterns could be imported from the AutoCAD pattern file or created directly in Revit. This study reviewed the patterns from the existing template, filtered them according to Newton's uses, added some new patterns according to ISO 128-50, and applied the naming convention as shown in Figure 12.

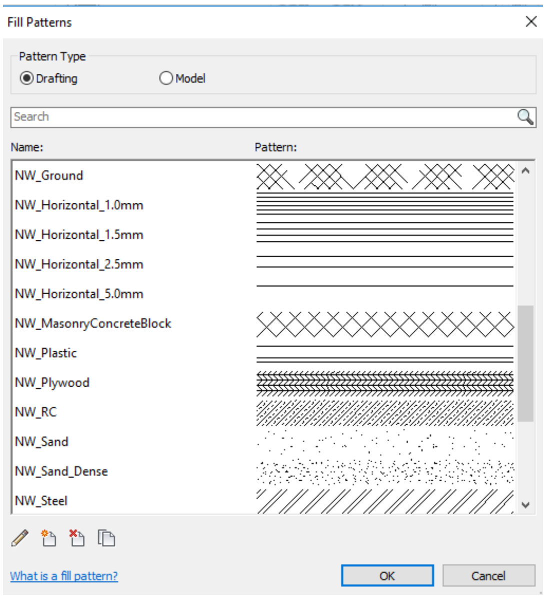


Figure 12– Newton Patterns

3.2.5. View Templates

View Templates are a combination of properties that can be managed and applied to specific views. The assigned views will use the same view settings and keep consistency across construction documentation sets by applying this specific view template.

After creating a view template, the user can modify the view template parameter to assign the desired view template and apply its view properties. Figure 13 shows the created view templates in Newton template.

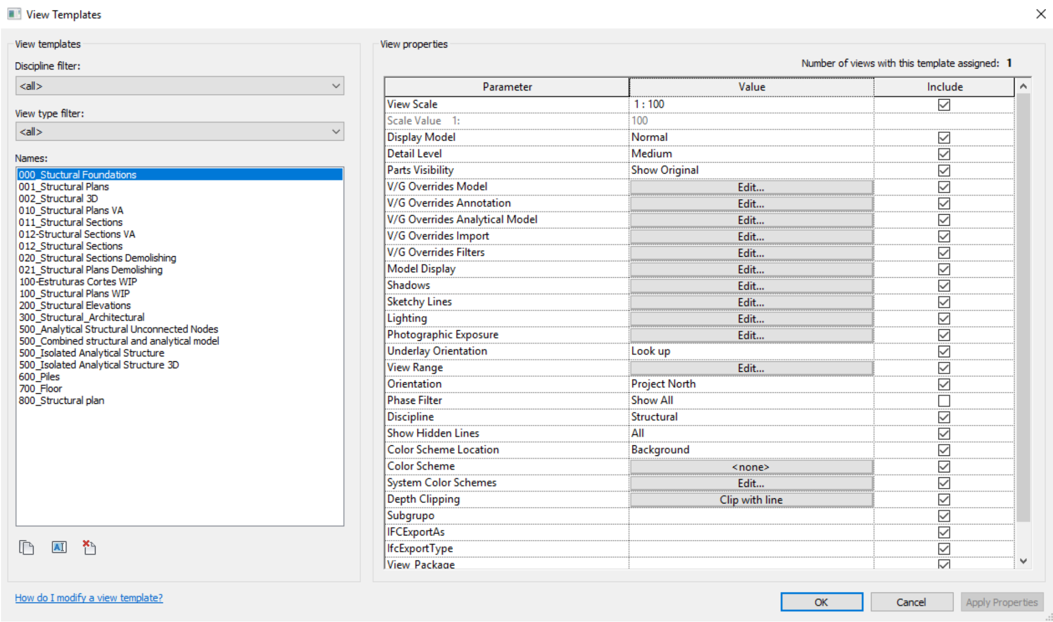


Figure 13– Newton View Templates

- **Filters**

Filters allow the Revit user to override the visibility and the graphical representation of elements by selecting one or more categories in the filter and defining the filter rules.

This study is developed to create new filters with their rules to fulfil Newton's needs and increase the Revit work productivity. For instance, the following filter showed in Figure 14 represents the column filtration by selecting the structural columns category and applying the filtering rule to search for the family name containing the word "column" in the structural column category. Also, at the same way of column filtration, new filters were created by selecting the structural family category and applying the filtering rule to search for the family name of (Beams, concrete walls, floors). In addition, new filters were created to make a filtration for rebars by their diameters. The BIM manager can create different filters by setting filters rules regarding the desired use of the filter for future developments.

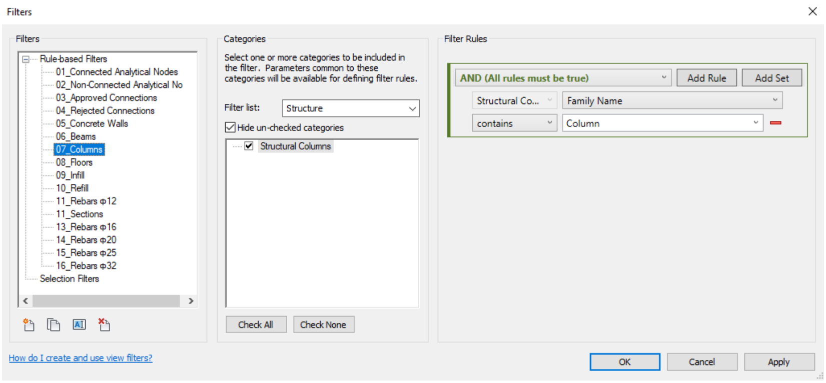


Figure 14– Newton Filters

- **Phases**

Phases are used to fulfil the project's requirements that need to be represented on different stages, such as refurbishment projects, which impact the deliverables and the coordination processes. The phases feature allows the user to track the phase elements that are new, Demolished, Temporary, and Existing, as well as to control the different views of the project.

Phases features allow the user to define different phases according to the project process in “Project Phases” tab. This study defined four phases according to apply to Newton projects as shown in Figure 15:

- Existing: Elements were created in an earlier phase and continue to exist in the current phase.
- Demo: Elements were created in an earlier phase and demolished in the current phase.
- New Construction: elements were created in the current view.
- Final: Final delivery of the project.

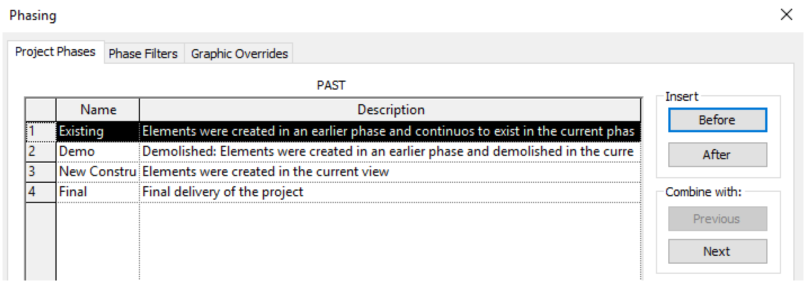


Figure 15– Newton Project Phases

In addition, Revit allows users to create different combinations to control phases visibility. Also, apply colour coding to define how objects will be represented at the different four states as shown in Figure 16:

- Existing: Elements that exist in the view phase.
- New: Elements modelled in the view phase.
- Demolished: Existing elements already demolished in the particular phase.
- Temporary: New elements are demolished in the same phase.

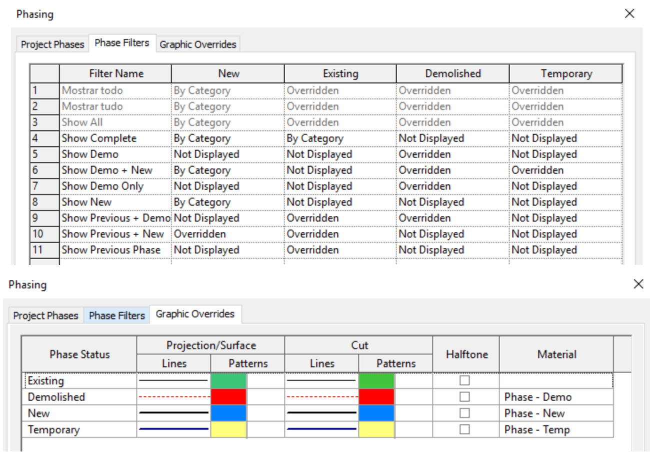


Figure 16– Newton Project Phases

Moreover, a new schedule is created as shown in Figure 17 to allow the user to control the phases feature by choosing from the dropdown list the desired level, phase, and phase filter. This Revit schedule will facilitate the management of phases through the project creation lifetime, which will increase the productivity of Revit.

<000_Phases Creation>

A	B	C	D	E	F
Associated Le	Type	View Name	Title on Sheet	Phase	Phase Filter
000- Level 0_G	Structural Plan	000- Level 0_Grid Coordination	Level 0_Structural Plan_Grid Coordination	New Construction	Show All
000- Level 0_G	Structural Plan	001_Exisiting	Level 0_Structural Plan_Exisiting	Existing	Show All
000- Level 0_G	Structural Plan	002_Demo	Level 0_Structural Plan_Demolition	Demo	Show Previous + Demo
000- Level 0_G	Structural Plan	003_NewConstruction	Level 0_Structural Construction_Phase 1	New Construction	Show Previous + New
000- Level 0_G	Structural Plan	004_Final	Level 0_Structural Construction_Final	Final	Show Complete
010_Level 1_G	Structural Plan	010_Level 1_Grid Coordination	Level 1_Structural Plan_Grid Coordination	New Construction	Show All
010_Level 1_G	Structural Plan	011_Exisiting	Level 1_Structural Plan_Exisiting	Existing	Show All
010_Level 1_G	Structural Plan	012_Demo	Level 1_Structural Plan_Demolition	Demo	Show Previous + Demo
010_Level 1_G	Structural Plan	013_NewConstruction	Level 1_Structural Construction_Phase 1	New Construction	Show Previous + New
010_Level 1_G	Structural Plan	014_Final	Level 1_Structural Construction_Final	Final Existing Demo New Construction Final	Show Complete
Level_02_Roof	Structural Plan	Level_02_RoofPlan	Planta Estrutural da Cobertura		None

Figure 17– Newton Schedule for controlling phases feature

3.2.6. Revit IFC Exporter settings

While Newton used to use IFC 2x3 to export their IFC models, this study is developed using IFC 4 format for better representation of complex geometries. It is essential to map all Revit families to a specific IFC class and IFC type before exporting the model to the IFC format. This mapping allows the element type to be well-identified across different software.

In this section, the exporting settings of IFC are modified according to the desired MVD which is essential to define the IFC's content and structure and should be coordinated and chosen according to the BIM uses. In this study, "IFC 4 Design Transfer View" is the default MVD for the Newton template as shown in Figure 18.

Design Transfer View aims to support the transfer of model data to be used for further design, analysis, estimating and facility management tasks. While Reference View aims to support the coordination of the planning disciplines; architecture, structural analysis and building services, especially to support clash detection and resolution of issues resulting from geometry.

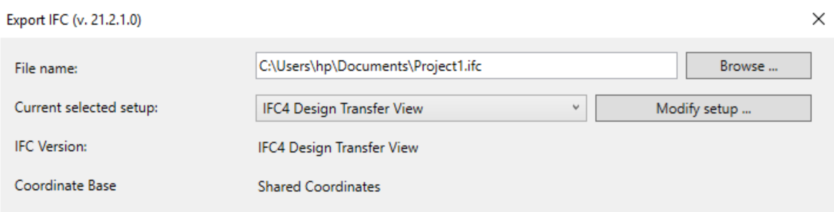


Figure 18– Export IFC setting

3.2.7. Objects library development

- **Classification improvement**

This study has developed a BIM object library complying with NBS Object Standards and a specification database for these objects. It classifies the objects using an internal classification based on the Uniclass2015 system, having the same classification code/index in both object library and specification database, which confers linking them. The choice for Uniclass relies on the coverage of this classification system, comprising products, systems, activities, among other categories, and the fact that it is developed by the leading BIM specification institution in the UK, one of the countries with the highest levels of BIM adoption in the world (Kassem & Succar, 2017). Moreover, an internal movement in Portugal to establish a national classification system based on Uniclass has directed the firm to stick to NBS standards. The challenge is that intelligence is needed to recognize the data, understand the semantically meaning, and then check the consistency of that information.

Besides classifying the internal BIM object library using Uniclass 2015 system, this study also classified using the Omniclass. The Omniclass classification system's primary purpose is to add value to the Newton office that its internal libraries are compatible with US projects requirements, allowing Newton to fulfil clients' requirements outside Europe.

The study has developed to apply the Uniclass 2015 and Omniclass classification systems in Newton internal library using Revit families. Firstly, with a collaboration with the Newton team, all the Revit families for Newton projects have been collected, identified, and classified according to the element's structural usage. Then, the work is implemented to the used elements, divided according to Revit usage classification (Structural Columns, Structural Framing, Structural Foundations, Floors, and Walls).

From NBS official website, all Uniclass classification tables and Omniclass tables were downloaded in .xlsx format, and each element in each table has its number parameter and description parameter. The Uniclass 2015 tables are:

- Uniclass Table EF for Elements / Functions.
- Uniclass Table Pr for Products.
- Uniclass Table Ss for Systems.

And the used Omniclass tables are:

- Table 21 for Elements (Included design elements).
- Table 23 for products.

This study collects all Newton families manually in one Excel sheet. It classifies each family according to the used three Uniclass 2015 tables (EF, Pr, and Ss) and the used two Omniclass tables (21&23). The Annexes attached in this dissertation contain the full table contains the modified Newton families.

In the Newton Revit template, new shared parameters as showed in Figure 19 are created for classification and NBS specifications. Those shared parameters are stored in (.txt) external file, and the user can browse the file's location to insert it in the Revit project.

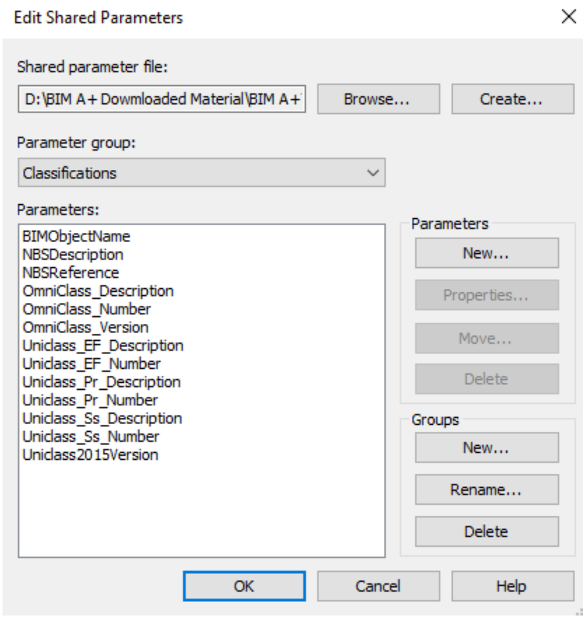


Figure 19– Classification shared parameters

The classification shared parameters for each Newton Revit family were added as a "Type" parameter, not an "Instance", to apply the classifications to all family elements. Also, the following figure describes that all parameters were added under the "Data" group with read only value not to be modified by the user.

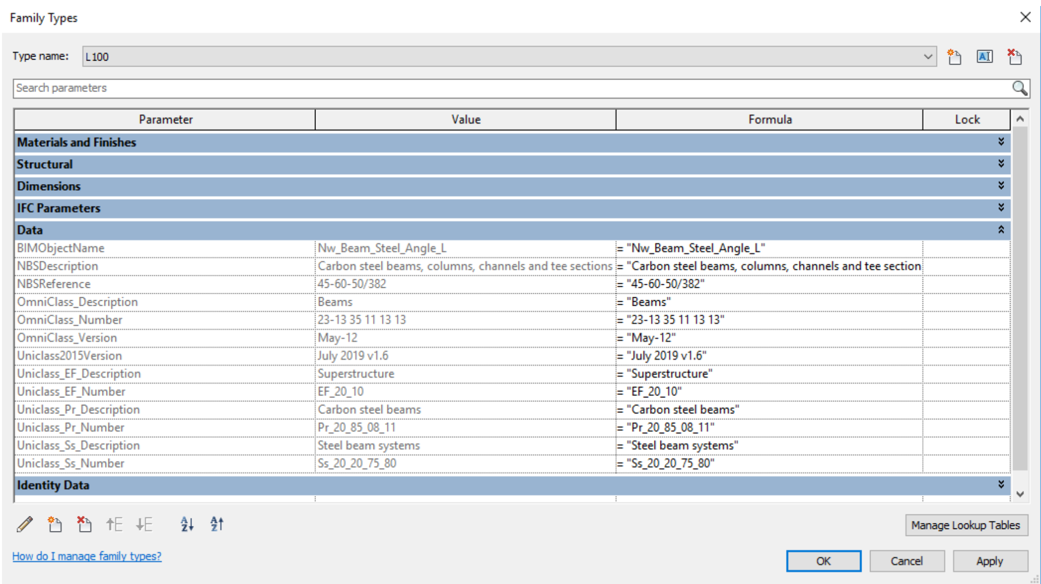


Figure 20– Read only Classification parameters in Data group

Some structural elements are products with unified specifications and dimensions, such as the steel sections (IPE, HEB and angels) and the precast concrete elements, which have their specifications from the producer and could be classified as a product according to the used classification system.

While other elements are not considered products, such as cast in situ concrete elements, which are cast in the site under a supervision without pre-ordering the structural elements from a producer. Therefore, this study classified some structural elements as a product, and the others cannot be classified as a product, so some elements have no classification value for the Uniclass product number and description parameters as shown in Figure 21.

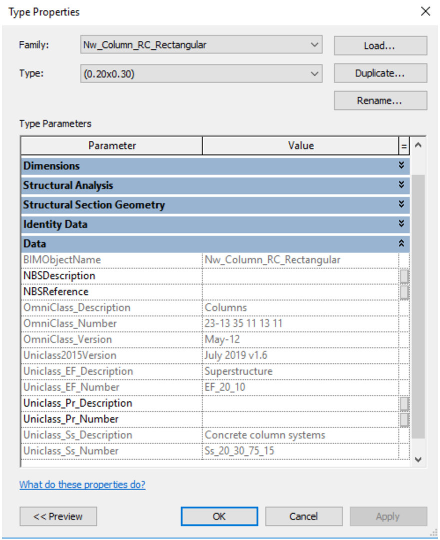


Figure 21– Cast in situ element classification

- **Exposure class parameter**

The European standard EN 206-1 categorized the concrete exposure classes according to various degradation mechanisms (Kulkarni, 2009). Consequently, the European exposure classes are divided into six major categories:

No risk of corrosion or attack.	**X0**
Corrosion caused by carbonation.	**XC1-XC2-XC3-XC4**
Corrosion caused by chlorides other than from sea water.	**XD1-XD2-XD3**
Corrosion caused by chlorides from sea water.	**XS1-XS2-XS3**
Freeze/thaw attack with or without de-icing salts.	**XF1-XF2-XF3-XF4**
Chemical attack	**XA1-XA2-XA3**

Table 5– The major categories of exposure classes

This study has developed to apply the exposure classes to all Newton reinforced concrete structural families by adding a new shared parameter as an "Instance" parameter, not "Type" under the "Materials and Finishes" group.

The main difference between "Instance" and "Type" parameters is that the "Instance" parameter enables the user to modify the value of the parameter separately for every instance. In contrast, the

"Type" parameter enables the user to modify the parameter value to all elements of the family type. Furthermore, from a structural view, the "Instance" parameter is more accurate because the exposure class depends on the element's location in the building, not on its type. For instance, the building has two columns with the same family type, one of them located inside the building with no risk of corrosion and the other one located at the facade of the building with any reason of corrosion which affects the exposure class of the element.

The study is designed to allow the user to insert the exposure class parameter's value manually according to the division and sub-division of the European exposure classes as shown in Figure 22

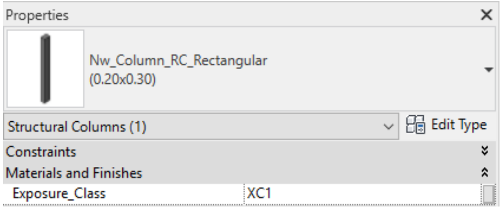


Figure 22– The exposure class parameter

- **IFC mapping using parameters**

This study is applied new shared parameters for IFC classification for all Newton used families as shown in Figure 23. Those shared parameters are stored in (.txt) external file, and the user can browse the file's location to insert it in the Revit project.

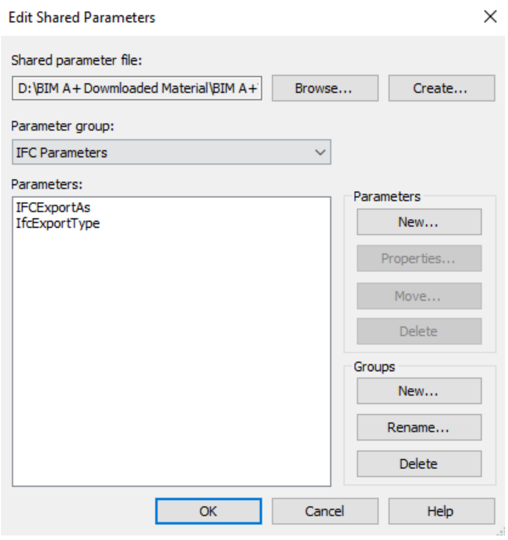


Figure 23– Newton IFC shared parameters

The IFC shared parameters for each Newton family were added as an “Instance” parameter, not a “Type”, to allow the user to choose the desired functionality of subcategory for each instance separately should be assigned. However, each shared parameter has a default value for the standard classification, and the user could change it. Also, all parameters were added under the “IFC parameters” group to be exported correctly to the IFC format.

In addition, the used default values of each IFC shared parameter are stored in the excel spreadsheet of the Newton database with a dropdown list for the possible options for each family to be exported with the correct value expression of the IFC classes and types according to IFC 4.0 as shown in Figure 24. The BIM manager must copy the desired value manually and paste it into the Revit IFC shared parameters value.

BIMObjectName	Families Old Naming	Uniclass_Ss_Description	niclass_Ss_Numb	IFCExportAs	IfcExportType
Structural Framing	Structural Framing				
NW_Beam_RC_Rectangular	M_Concrete-Rectangular Beam	Concrete beam systems	Ss_20_20_75_15	IfcBeamType.BEAM	BEAM
NW_Beam_RC_Rectangular	M_Concrete-Rectangular Beam	Concrete beam systems	Ss_20_20_75_15	IfcBeamType.BEAM	BEAM
NW_Beam_St_Angle_L	L-Angles	Steel beam systems	Ss_20_20_75_80	IfcMemberType.USERDEFINED	USERDEFINED
NW_Beam_St_CircularHollowSection	Circular Hollow Sections	Steel beam systems	Ss_20_20_75_80		BEAM
NW_Beam_St_HEB	H-Wide Flange Beams	Steel beam systems	Ss_20_20_75_80		BEAM
NW_Beam_St_IPE	IPE-Beams	Steel beam systems	Ss_20_20_75_80		BEAM
NW_Beam_St_IPN	IPN-Beams	Steel beam systems	Ss_20_20_75_80		BEAM
NW_Beam_St_RectangularHollowSection	RHS-Rectangular Hollow Section	Steel beam systems	Ss_20_20_75_80		BEAM
NW_Beam_St_SquareHollowSection	SHS-Square Hollow Section	Steel beam systems	Ss_20_20_75_80	IfcBeamType.BEAM	BEAM
NW_Beam_St_UPN	U-Channels	Steel beam systems	Ss_20_20_75_80	IfcMemberType.USERDEFINED	USERDEFINED
NW_Frame_St_Trapezoidal	TELHA trapezoidal	Solid steel slab systems	Ss_30_16_10_80	IfcSlabType.USERDEFINED	USERDEFINED

IfcMemberType.POST
IfcMemberType.PURLIN
IfcMemberType.RAFTER
IfcMemberType.STRINGER
IfcMemberType.STRUT
IfcMemberType.STUD
IfcMemberType.USERDEFINED
IfcMemberType.NOTDEFINED

Figure 24– Newton IFC classification database

3.2.8. Materials library development

The library of materials would serve as an input to the objects library as all Newton objects would be created out of materials according to the structural usage. This section aims to clarify the content data of materials by reviewing the properties that make up a Revit material and the different possible uses beyond defining the appearance of elements.

The way materials are used may vary significantly from project to project, and therefore the level of information need might vary. Thus, the user must be aware of the intended use of materials when working on a model. Carefully filling in all the properties of materials might be a waste of time if these will never be used. On the other hand, not paying attention to material properties that will be needed down the road might pose a more significant problem when it needs to go through all the materials and revise and complete the missing fields.

Most Newton projects follow the Eurocode for design of concrete structures (EN 1992) and Eurocode for design of steel structures (EN 1993). Thus, the material properties must serve the requirements of the Newton office to achieve its BIM uses. The Revit material library has materials that follow the Eurocode with their naming convention and structural properties; thus, the Revit material library has been used with applying some modification to serve Newton uses.

- **Information aspect**

In most cases, the material's name is an important property, which will be used to identify the composition of the model elements, such as the different layers that make up a wall or a slab. The naming convention for the used materials in Newton office were developed to follow the same naming convention of the Eurocode as shown in Figure 25.

- **Visualization aspect**

This aspect relates to the way materials will be represented in drawings or other views. Thus, this is a crucial element in almost every project. This study used the default values of Revit library materials in visualization of materials, which will not affect the BIM uses of Newton 3D models.

- **Analysis aspect**

This aspect relates to the properties of materials required for analysis, such as structural calculations or energy performance simulations. This study kept the Thermal properties of the materials with the default values as it will not affect the desired BIM uses.

The physical properties shown in Figure 25 are the essential properties for the Revit material library. It directly affects the structural analysis stage when the model is exported to another structural analysis software (Robot software). The values of the physical properties were developed to follow the Eurocodes to achieve Newton BIM uses in the structural design.

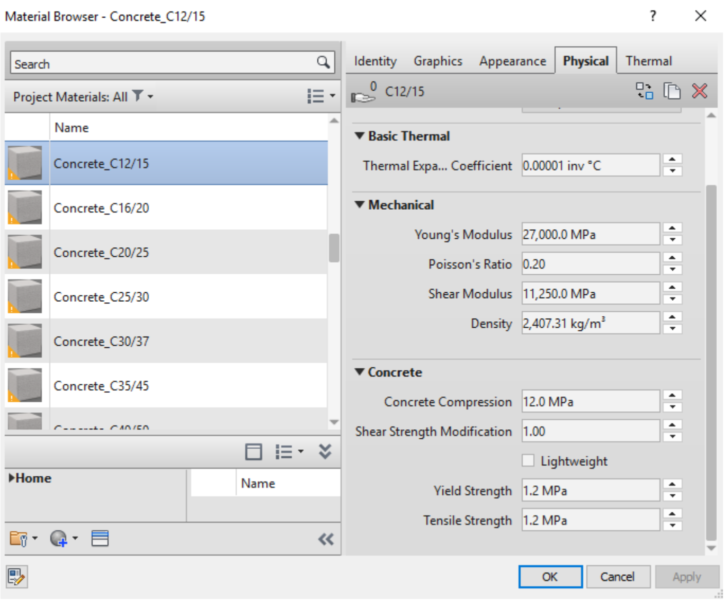


Figure 25– The structural properties of the Revit materials

3.3. Database system

Any fact should have an important aspect which is called information. People can use this information to communicate and change data. The data that users use should be managed efficiently and stored in a manageable database. Better stored data in a database system can result in accurate information. The database is a crucial structure system to store information in an organised, logical way, leading to efficient data management that can be stored, shared, and integrated.

This study developed a new database for all Newton used Revit families after applying the classification systems and naming convention. This database has been saved in two different ways, the first one in an Excel spreadsheet and the other in Newton Revit Template ".rte" file. The BIM manager is the only one who has the responsibility to add or modify the information in the database. Also, the synchronization between the (.rte) file and the excel spreadsheet must be done manually by the BIM manager.

The Excel spreadsheet is composed of several columns and rows. The rows contain the used Newton Revit families under main categories (Structural Columns, Structural Foundations, Structural Framing, Floors, and Walls). Each category contains all the types of this specific family; picking on it opens new rows with all the family types, illustrates in Figure 26.

Figure 26– Families and types of Revit objects

The columns of the database excel sheet in figure 27 contains several aspects of information for each family type which is matching with the created Revit shared parameters: starting from the new naming convention for each Revit family and the old naming with Portuguese language, without applying any BIM object standards. In addition, classification information which has NBS specification, Uniclass 2015, and Omniclass with the number, description, and version for each element. Also, IFC classification with two different parameters (IFCExportAs & IFCExportType).

BIMObjectName	Families Old Naming	NBSDescription	NBSReference	OmniClass_Description	OmniClass_Number	OmniClass_Version
Structural Columns	Structural Columns					
NW_Column_RC_Circular	NW-Pilares Circulares			Columns	23-13 35 11 13 11	May-12
NW_Column_RC_Circular	NW-Pilares Circulares	Precast concrete columns	45-15-68/310	Columns	23-13 35 11 13 11	May-12
NW_Column_RC_Rectangular	NW-Pilares em Betão Armado			Columns	23-13 35 11 13 11	May-12
NW_Column_RC_Rectangular	NW-Pilares em Betão Armado	Precast concrete columns	45-15-68/310	Columns	23-13 35 11 13 11	May-12
NW_Column_ST_Circular	CHS-Circular Hollow Section-Column	Carbon steel beams, columns, channels and tee sections	45-60-50/382	Columns	23-13 35 11 13 11	May-12
NW_Column_ST_HEB	NW-Pilares Metálicos	Carbon steel beams, columns, channels and tee sections	45-60-50/382	Columns	23-13 35 11 13 11	May-12
NW_Column_ST_RectangularHollowSection	RHS-Rectangular Hollow Section-Column	Carbon steel beams, columns, channels and tee sections	45-60-50/382	Columns	23-13 35 11 13 11	May-12
NW_Column_ST_SquareHollowSection	SHS-Square Hollow Section-Column	Carbon steel beams, columns, channels and tee sections	45-60-50/382	Columns	23-13 35 11 13 11	May-12
NW_Column_ST_VariableSection_667x250x12	WTC-S-VARIAVEL	Carbon steel beams, columns, channels and tee sections	45-60-50/382	Columns	23-13 35 11 13 11	May-12

Figure 27– Naming and classification in Newton database

3.4. Modelling Technical Manual

3.4.1. Introduction

This section covers structural BIM modelling and the required information content of the BIM models produced by the structural designer in the Newton design office. BIM models aim to achieve controlled decision-making and support the information flow within the design group, the owner, and the contractor. This guideline covers the BIM model produced by the structural designer and will hereafter be referred to as the structural model. The structural model develops and becomes more specific as the design process progresses.

This document establishes a standard modelling approach to serve Newton BIM uses incorporating the structural design concept. The BIM model can facilitate coordination and collaboration at design, drawings production (including plans, sections, and elevations) and QTO stages. In addition, it is considered as a guide for creating a BIM model suitable to be exported to other structural analysis software when the data interlinking process becomes mature and practical.

This version of modelling involves reinforced concrete elements of superstructure only, and Autodesk Revit has been the modelling tool throughout this document. Therefore, it is assumed that users shall possess structural engineering knowledge and Revit modelling skill when using this guide.

The Annexes attached in this dissertation contain the full structural modelling guidelines to provide users with a standard step-by-step guide for their modelling tasks.

3.4.2. Modelling of Structural Elements

The “Modelling of structural elements” section describes the standard modelling approach for major structural elements of the BIM structural model in the right way to achieve Newton BIM Uses. This section is divided according to the structural elements as follows:

1- Foundations

This section aims to model all the structural elements related to foundations step by step, such as Foundation walls, Wall footing, Piers and Pilasters, Isolated footings and Piles, Foundation slab, and Step footing.

2- Columns

The columns section contains the appropriate way to model columns, posts, and hangers by picking the structural column family elements according to the sectional shape. All columns should be defined between the levels “floor by floor,” as shown in Figure 28, where they support other elements. And top of their supporting elements (like the top of the column/wall/beam and foundation below), with required level offsets, even if the cross-section does not change across different floors. In this way, it is possible to obtain automatic measurements of columns per floor and obtain nodes “points” in the analytical model at the different floor levels. However, there may be exceptional situations in which this rule cannot be applied. The modeller must explain the situation to the BIM Coordinator and the structural engineer responsible for the project.

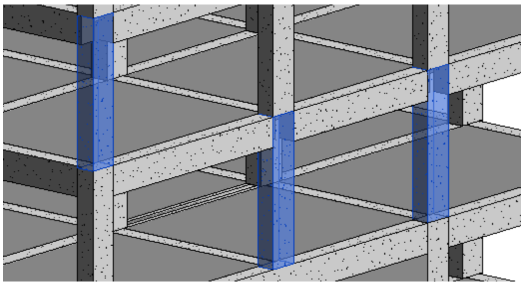


Figure 28– Columns modelling

3- Walls

All walls "Shear, Core, Bearing, Hanger, Stub, and Parapets" should be modelled with appropriate types from the Basic Wall category family with its Structural Usage property. All walls should be defined with Top and Base Constraints between the levels "floor by floor" as columns that serve as support for other elements and top of their supporting elements as shown in Figure 29. In addition, the top-level walls should be extended to the top of slabs being supported instead of the bottom of slab elements only.

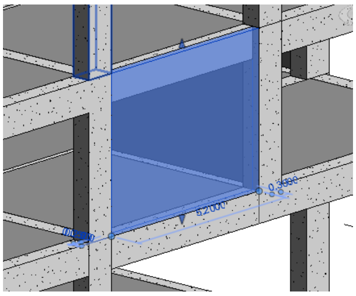


Figure 29– Wall modelling

As shown in Figure 30, parapet walls and parapet walls with piers have a different way of conceptual modelling from ordinary walls. The base level and the top level of the parapet wall should be assigned with similar levels, and the top offset made equal to the required parapet height. Also, it should be modelled as individual walls spanned between pier edges, and the pier should be modelled with a structural column family element.

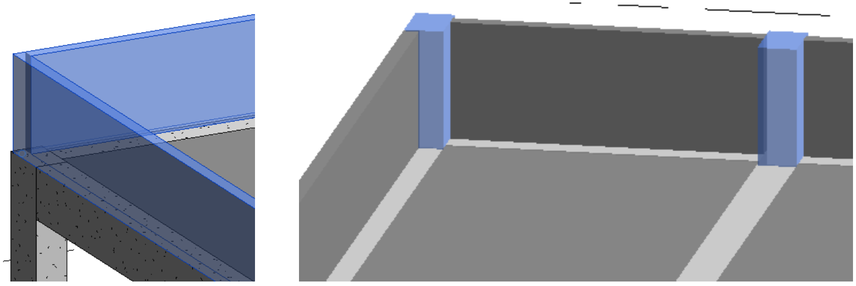


Figure 30– parapet wall modelling with piers

For irregularly shaped wall modelling, the main issue is that the irregular part will be neglected from the structural analysis due to modelling it as (Model in-place), which be neglected in the exported analytical model to the structural analysis software.

4- Beams

All beams should be modelled with appropriate family types from “Structural Framing” or “Structural Beam System” category families. Also, all continuous beams should be modelled “span by span”, and all beams should be connected to their supports by one of the following methods (Secondary beam rested on main beam, Beam rested on a column, and Beam rested on a structural wall).

5- Slabs

The modeller should choose appropriate types from the “Floor” family according to the structural usage. All slab elements should be modelled “panel by panel”. Also, for all suspended slabs, “One-way slabs & Two-way slabs” boundaries should be defined, while flat slabs floor system boundaries should be located at the centres of the supporting columns.

6- Staircases

Structural staircases have difficulties in modelling as the elements modelled by the Stair family is belonged to architectural model elements, not the structural ones. Thus, the modelling approach of staircases is to model architecturally, then create an in-place model above the architectural one.

7- Precast elements

In this section, the study used the new tool in Revit 2021 for the “Precast” tab, which is used only for the structural system elements “Walls & Floors”. This tool has many features, such as a split tool that split elements into different segments with different dimensions according to design. Also, the reinforcement tool allows the modeller to create the reinforcement in the precast elements by controlling the rebars direction, distribution, and type. In addition, the shop drawing tool creates all necessary shop drawings documentation for the elements “Rebar List Template & Details Sheet for side, plan, elevation and section view”.

3.4.3. Model Quality Assurance

A Quality Assurance workflow should be part of the project to keep the model performance. This section provides a checklist for the project team to check the compliance of the BIM structural models to this guide. Modeller must carry out a self-audit according to this guide to ensure that the developed models can comply with this guide before issuing the models for project collaboration. On the other hand, the project team is advised to return the auditing result to the modellers for rectifying the models when non-compliance and modelling errors are discovered.

The Annexes attached in this dissertation contain the full Quality check list for the Revit template and for the structural model. *Global parameters* can be created for multiple objects from different categories, not just a specific category.

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4. AUTOMATING NEWTON TASKS

4.1. Introduction

Visual programming enables users to create a script by changing graphical elements rather than text programming, typical for developing a code. This research has developed some scripts by Dynamo, open-source software that enables visual programming for Autodesk Revit. Dynamo is used to automate some steps and can be widely adopted by users without textual programming skills. In addition, Dynamo has proven to be a suitable tool to approach BIM design workflow, reduce labour time, increase quality assurance, and support software interoperability. The use of Dynamo exhibits its effectiveness to automate repetitive tasks. Companies are always looking for possibilities to simplify, optimise and improve their processes. They want to reduce, especially labour-intensive tasks.

4.2. Formwork

The main issue of the formwork modelling is that it is a temporary mould used as a concrete form that is usually not present in the Structural concrete BIM model because formwork is a temporary structure used only in the construction phase (Olsen & Taylor, 2017). In addition, there is no specific tool to model concrete formwork in the BIM software products (Monteiro & Martins, 2013). Users have to calculate the formwork quantity take-off manually or to develop a formwork model by alternative BIM elements to get the formwork quantity for the BIM model, which waste too much time and decrease the accuracy level, especially in large complex projects.

4.2.1. Concept and Methodology

One of this thesis's objectives is to develop a new method that automatically calculates the quantity take-off from any concrete structural BIM model with creating 3D model for the formwork at the same time. As shown in Figure 31 The relevant information needed to create the formwork model and extract the quantity take-off is extracted from the BIM model via Revit software. Dynamo is used to create the parametric modelling for the formwork depending on the Revit model for the concrete structure in a separate Revit template and add the formwork quantity values in a specific parameter in a specific formwork Revit template. Also, for the irregular concrete elements, the script can be run from Dynamo (Dynamo player) and directly write and visualise the results in the BIM model (Revit platform).

So, the parametric script which was created in Dynamo reads the information from the concrete structural model and uses the information to make calculations and produce the result of the formwork quantity take-off directly to the Revit list of shared parameters, simultaneously create a 3D model for the formwork elements in an independent Revit template.

The surface area of the formwork represents its quantity (Royal Institution of Chartered Surveyors (RISC), 2012). The surfaces of the reinforced concrete elements represent the surface area of the concrete formwork applied. The proposed method imports concrete elements from the Revit model:

columns, beams, slabs, walls, and foundations. Then, Dynamo will combine and deduct the overlapping parts before extracting the desired surfaces, representing the concrete formworks, and calculating their areas.

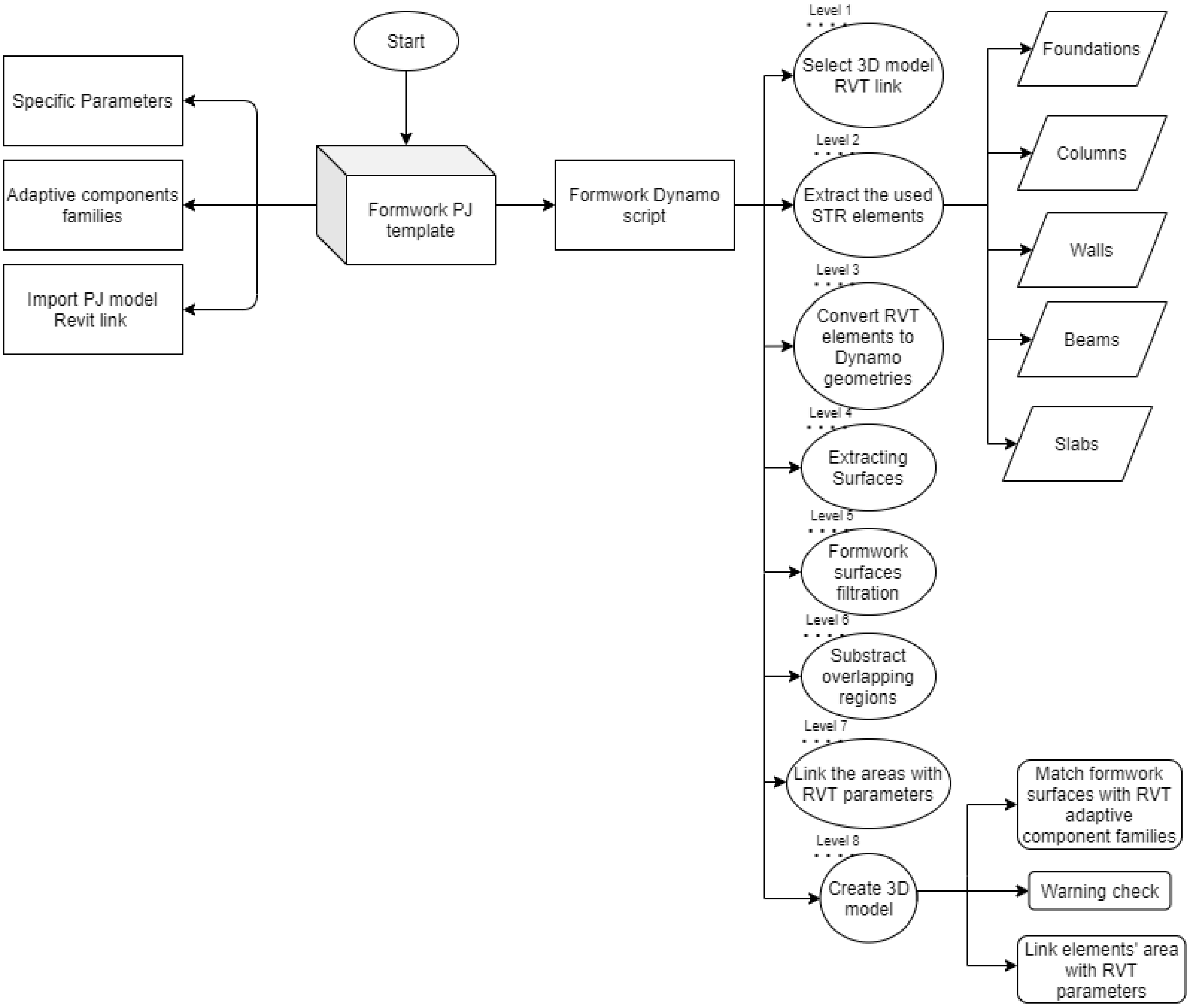

Figure 31– Dynamo script concept

4.2.2. Specific formwork template in Revit

Before running the Dynamo script, the user must open the Revit formwork template, which has the features that the Dynamo script can link with it. The main goal of this template is to create a separate Revit project file for the formwork model from the structural concrete Revit model. So, after running the Dynamo script, the user will have a new model for formwork only with all required data.

Formwork Parameters

In this template, Custom parameters for formwork areas were created to read the surface area for the structural concrete elements from Dynamo. Those parameters are stored in the system family “Project Information” because they do not belong to specific elements as shown in Figure 32. The formwork areas parameters were created as “Project parameters” under the “Construction” parameter group. Also, the formwork parameters are divided into one parameter for all HZ elements “Formwork area for Beams & Slabs", one parameter for VL elements "Formwork area for Columns & Walls", the last parameter for footing elements "Formwork area for Footings" and a parameter for the whole formwork project area "Total Formwork area for the structure".

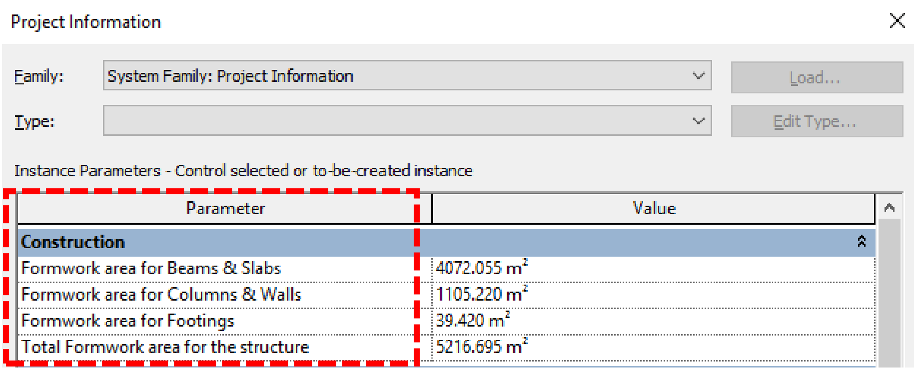

Figure 32– Creation of project parameters in Revit

Creation of formwork adaptive components

As shown in Figure 33, to make a visualization of the 3D formwork model in the Revit template, it needs to create a specific family to link with Dynamo data. So, new "Metric Generic Model Adaptive" families were created with a different number of nodes to adopt with different formwork shapes. After selection nodes numbers, the solid form was created with defining the thickness and the material of the formwork elements to create the formwork 3D model in Revit by loading all those adaptive families to the template. In this way, every formwork shape extracted from Dynamo is linked to the respective adaptive formwork family from the template. Once this connection is identified, the Dynamo script can be used to create the formwork 3D model in Revit.

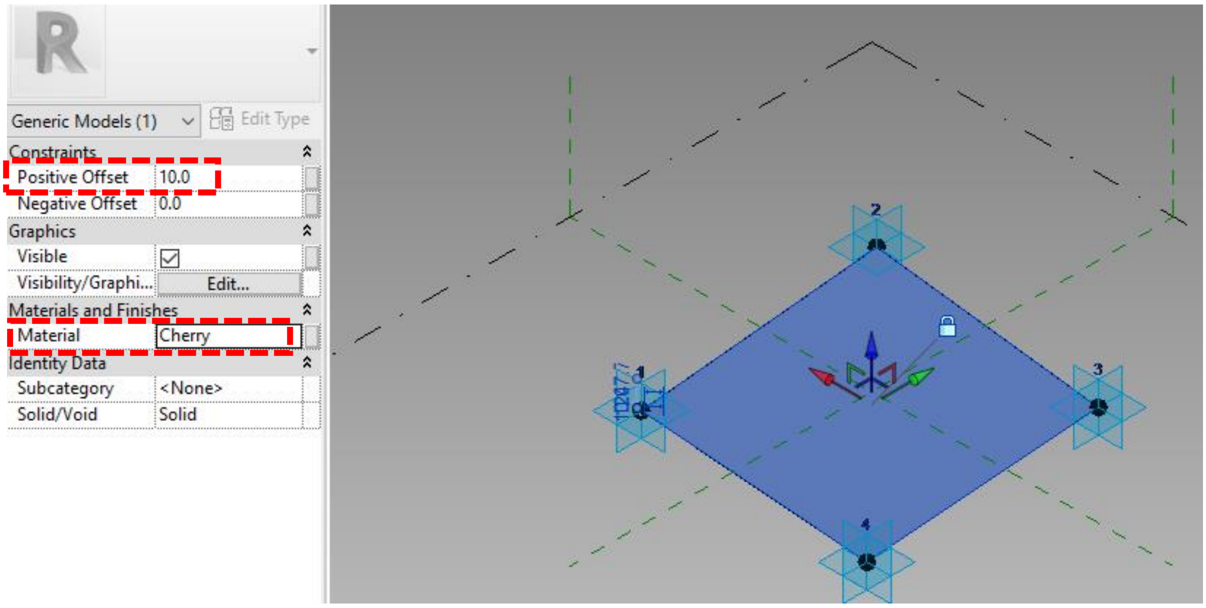

Figure 33– Creation of generic adaptive family for 4 nodes formwork

4.2.3. Dynamo script

Extracting information from the structural model

Before opening the Dynamo script, the user must import the Revit link for the concrete structural model in the formwork project file to create the formwork 3D model in a separate file from the structural model file to not mess with the structural project file itself. Also, if the 3D formwork model is created in the same file of the structural project model, the two models will be created above each other, and it will be difficult and time consuming to use. In addition, in this way, the user can control the formwork model creation because the information in the formwork template is defined before.

From the formwork project file, the user can open the Dynamo and choose the Revit project link from the dropdown list to start extracting the structural Revit model information.

The Dynamo script was used to extract the necessary geometrical information from the BIM model to perform its calculations.

The main issue in the selection phase is that selecting the desired elements categories (Structural Framing, Floors, Structural Columns, Walls, and Structural Foundations) from the Structural model Revit link is picking the family types and the family elements together. So, the Dynamo script needs to be filtered to select only the used family elements by removing the Revit element family types.

After extracting the Revit element, the Dynamo script converts the Revit elements into Dynamo geometry to apply the algorithms on it by combining the HZ elements "Beams & slabs", VL elements "Columns & Walls" and the foundation elements and convert the Dynamo solid geometries into surfaces as shown in figure 34.

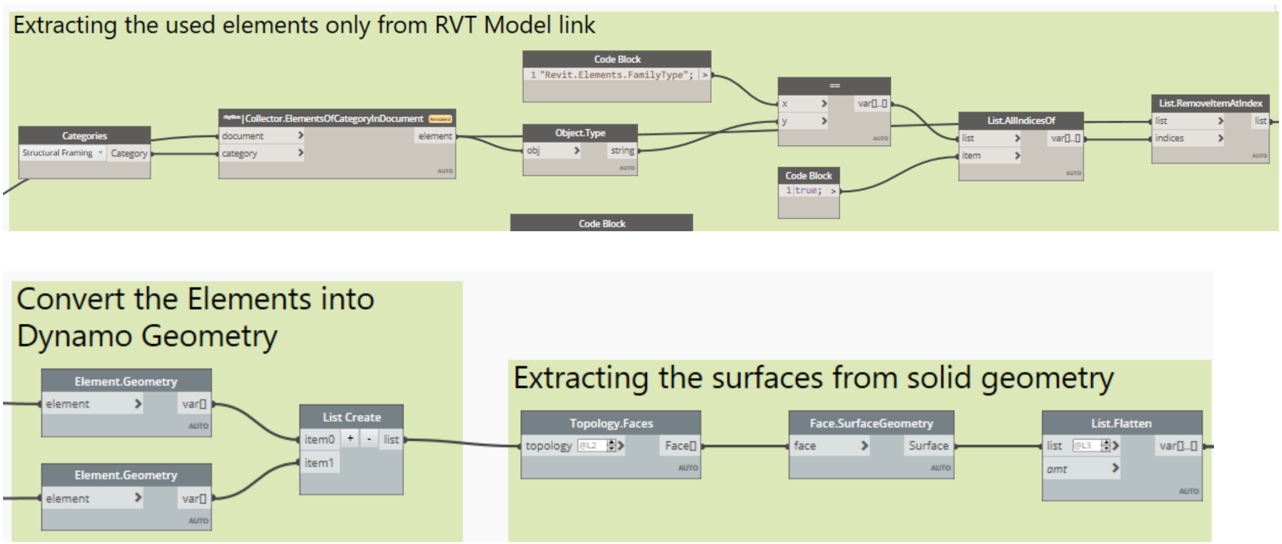

Figure 34– Extracting the used elements and converting them to Dynamo geometries.

After converting the Dynamo solid geometry into geometries surfaces, the Dynamo script makes a filtration for the formwork surface areas by removing the unused surfaces as shown in figure 35. For HZ elements "Beams & Slabs", the formwork elements consist of only side faces and bottom faces without the upper faces. For VL elements "Columns & Walls", the formwork elements consist of only the side faces without upper and bottom faces. For the foundation elements, the formwork elements consist of the side surfaces without the upper and bottom surfaces. In addition, the Dynamo script creates different colour coding for each type of element to facilitate the geometry visualization in Dynamo.

Some previous references recommended making a solid union from the beginning to make the whole structure as one solid, then explode the solid and extract the formwork surfaces. I did not follow this strategy in the Dynamo script for many reasons:

- This Dynamo script strategy would allow the user to get only the total formwork area for the whole structure at the end without getting the area of different elements separately.
- The script would not allow the user to make colour coding for the different geometries in Dynamo.
- It will be very complicated to remove the upper or bottom surfaces of the VL elements "Columns & Walls" if the user models the VL elements "Floor by Floor". This Dynamo strategy could work in a good way if the user models the VL elements as one element from level 0 to the top level without dividing it by floor, which is not the correct way to model the VL elements.

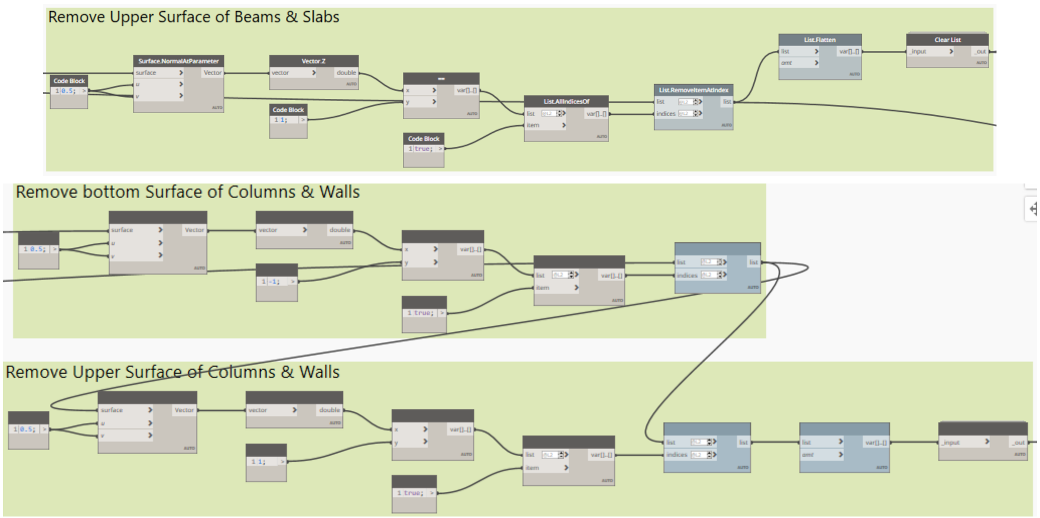

Figure 35– Selection of the formwork surfaces

After extracting the desired formwork surfaces for each element, there are duplicated surface areas between the HZ elements and VL elements that need to be removed before calculating the surface area of the elements and creating the formwork 3D model.

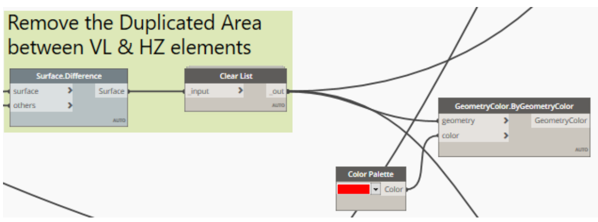

Figure 36– Removing the duplicated surface area.

Linking the formwork areas with the created parameters

The Dynamo script in this phase extract the surface area for the VL elements “Columns & walls”, HZ elements “Beams & Slabs”, footing elements and the total formwork area for the whole structure after removing the overlapped areas between the elements, then link those areas with Revit parameters which stored in the system family “Project Information” as mentioned before.

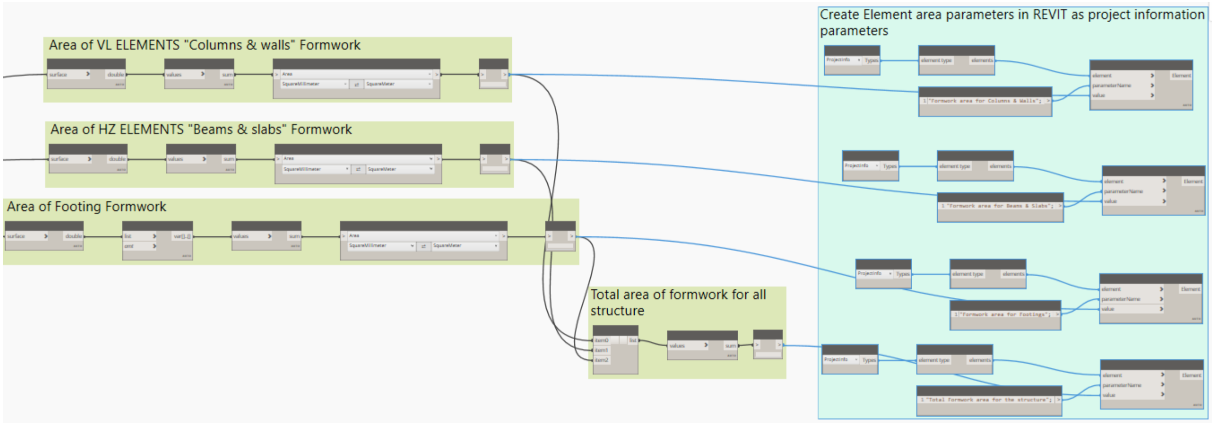

Figure 37– Extracting the formwork areas and linking it with Revit parameters.

Creating the Revit formwork 3D model

After creating metric generic model families with the points of Dynamo surfaces, defining material of wood and the plates’ thickness, in this phase, the Dynamo script matches the geometry surfaces with the adaptive component families in Revit by points. Dynamo should match the same formwork surface points with the same points of the generic model families.

Several generic model families have been created that could be mainly used for all formwork faces, from formwork plate contains 4 points to 24 points. If the number of points exceeded 24 points, the user should define a new generic model family for it.

In addition, the Dynamo script has a warning check as shown in figure 38 for the number of points for each surface to give the user a warning if the number of points exceeded 24 points.

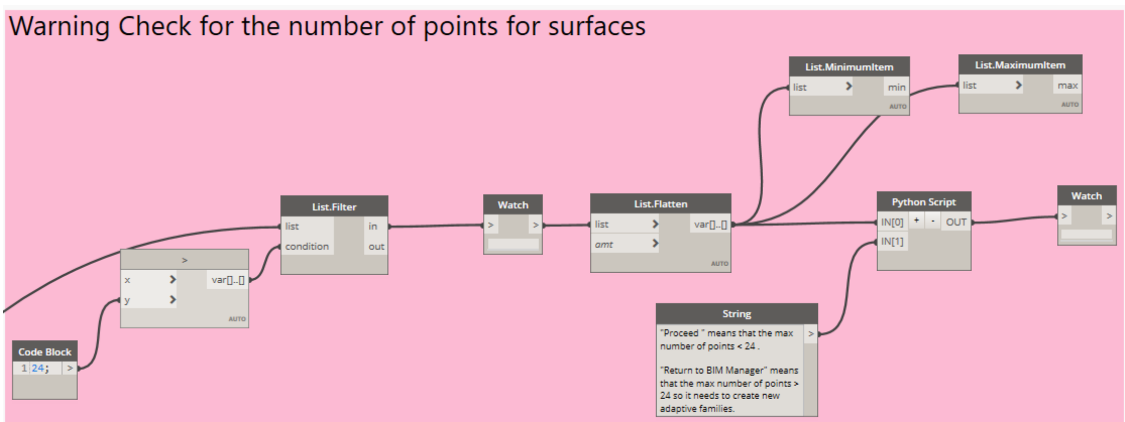

Figure 38-Dynamo script for number of points warning check.

After creating the 3D formwork model in Revit, the Dynamo script links each formwork surface to a new area parameter as shown in figure 40 so that the user could get the surface area for each element separately directly from Revit as shown in figure 39.

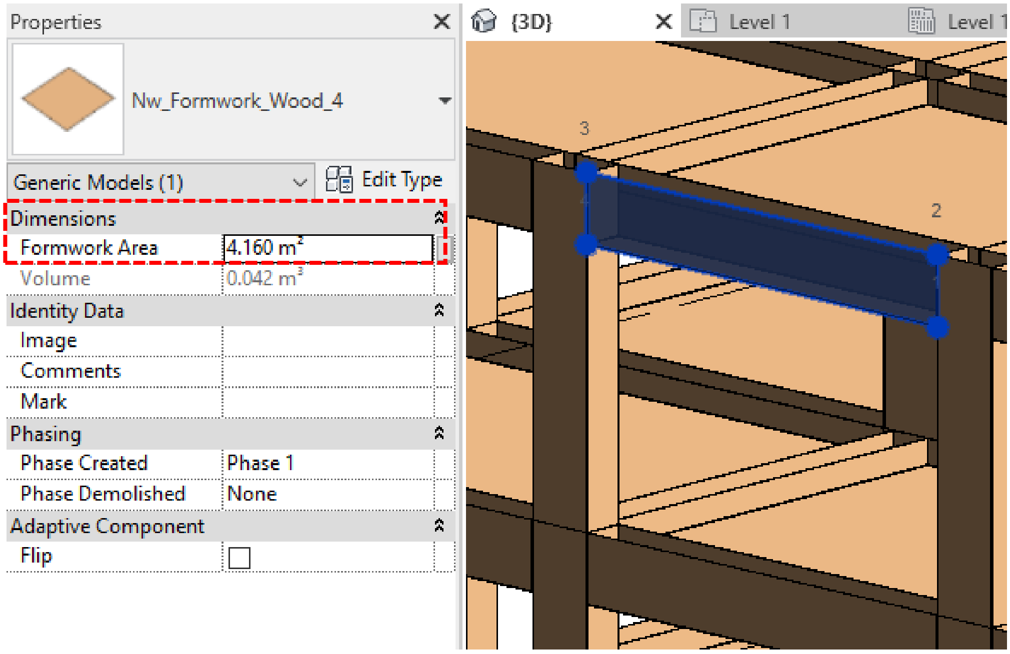

Figure 39 – Adding area parameters to formwork elements.

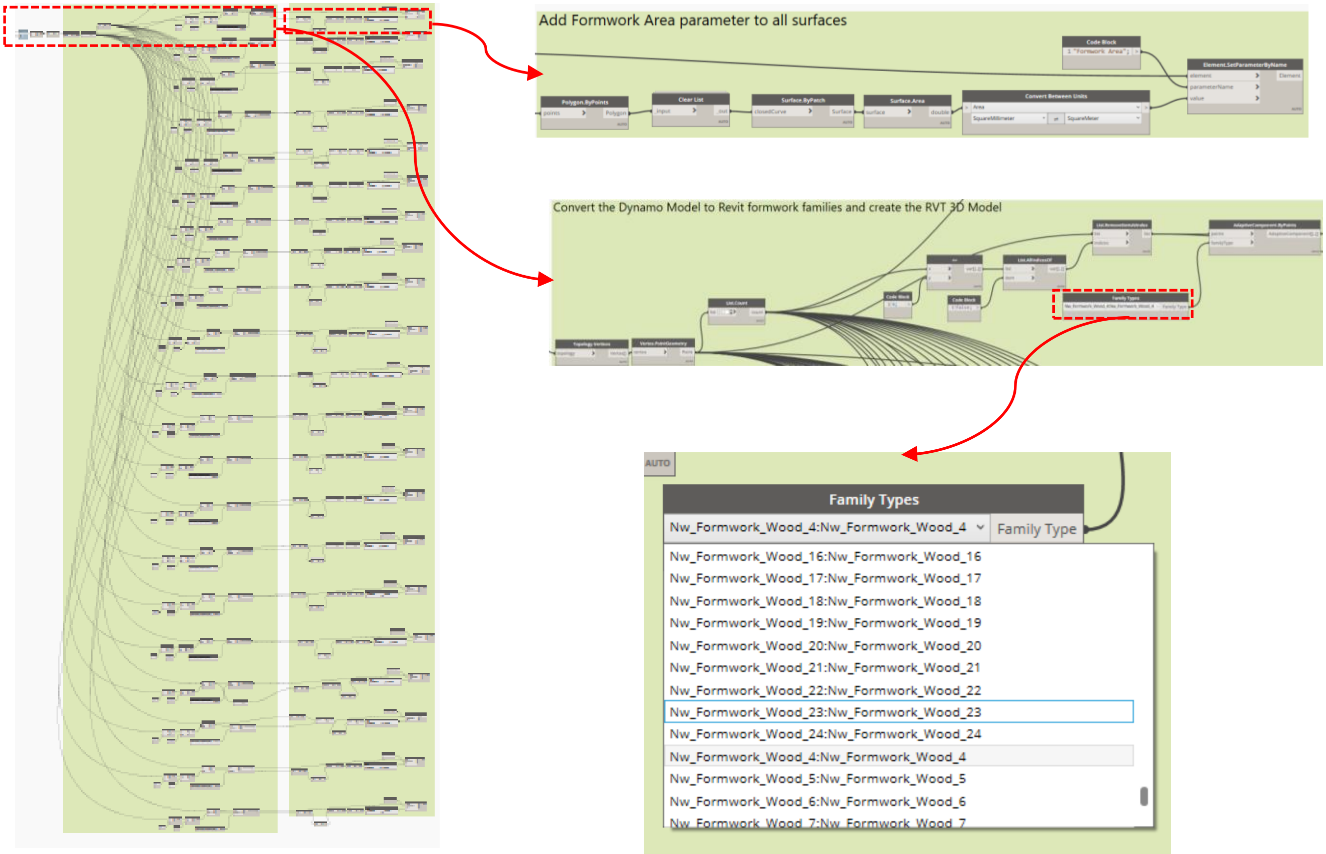

Figure 40 – Creating the 3D Revit model and add areas parameter to each element.

Formwork Dynamo script application

This part of this thesis aimed to create a fully automated process for extracting the formwork data and creating a 3D visualization model in order to eliminate the use of third-party tools and expertise, to speed the process and include it in the cost estimation phase of the project, particularly since the early decision-making phase.

This formwork Dynamo script shows good performance and results by creating the formwork 3D model in a separate Revit project as shown in figure 41, extracting the surface area for each formwork face and the accumulative surface area for VL elements HZ elements, footings, and the whole building.

Another benefit of the automated formwork procedure integrated with the BIM environment would be reducing human mistakes, which usually happen during the static and traditional method of calculation, making the data more reliable and accurate.

The main issue of this Dynamo script is that it works only for the regular shapes and for the structural elements only from Revit because of the linking between the Dynamo geometry surfaces and the Revit generic adaptive families. So for the irregular elements, another Dynamo script has been developed to solve this Dynamo script issue.

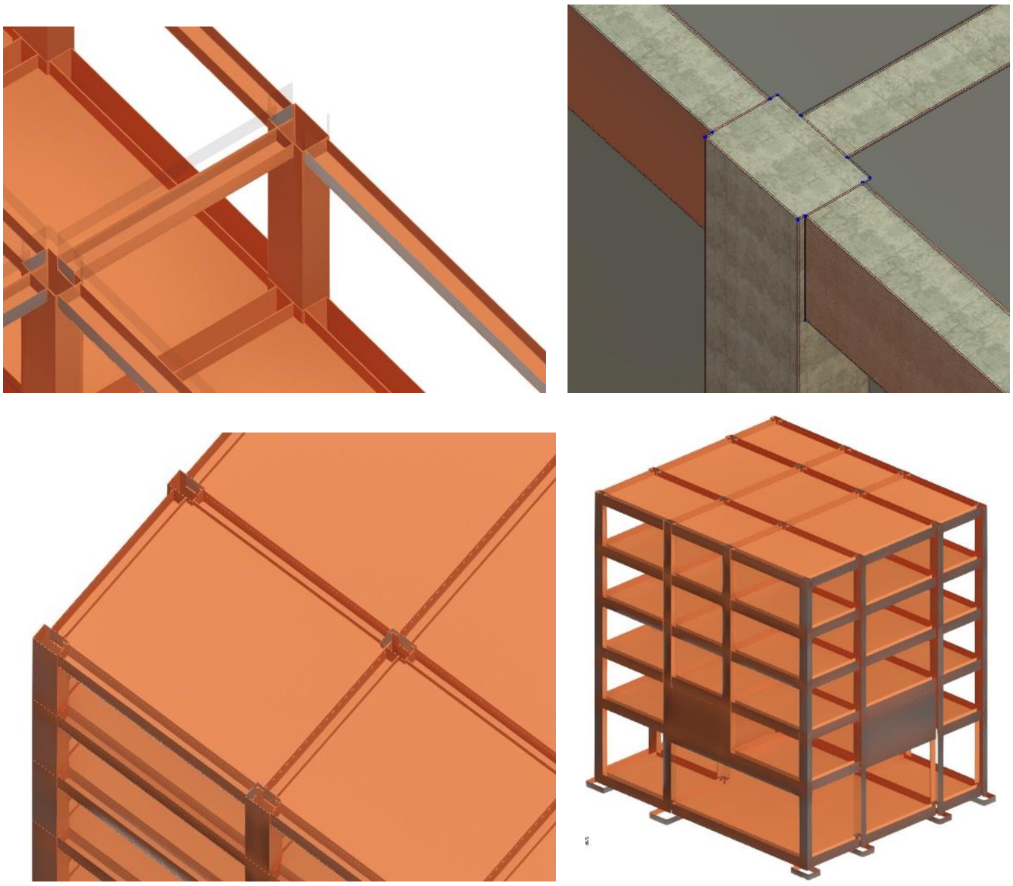

Figure 41 – Formwork 3D model Details

4.2.4. The irregular elements 3D modelling

Dynamo script for the Irregular elements

The previous Dynamo script does not show promising results for the distinctive elements and non-structural elements such as slanted columns, circular columns, curved walls, stairs, and ramps. So that, a new Dynamo script has been developed specifically for this type of element.

The strategy in this script is to allow the user to pick the element surface directly from the Revit structural project file, which needs to create formwork for it. Once picking the surface, the formwork will be created with a custom parameter for the surface area.

The category used in Revit to make the formwork is “Casework”. After defining the Revit category, the user must create a new shared parameter for the “Formwork Area” to link it to the Dynamo script to the surface area of the formwork.

The Dynamo script has been developed to define the formwork thickness, material, and category to model the formwork by selecting the desired surface. Also, it linked to the Revit to add the surface area value to the “Formwork Area” created shared parameter in Revit.

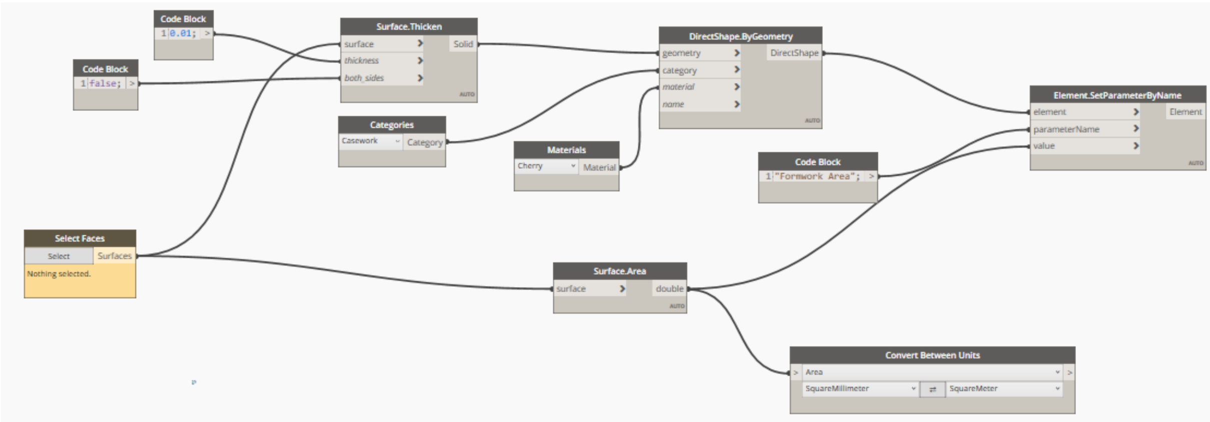

Figure 42 – Formwork Dynamo script for irregular shapes

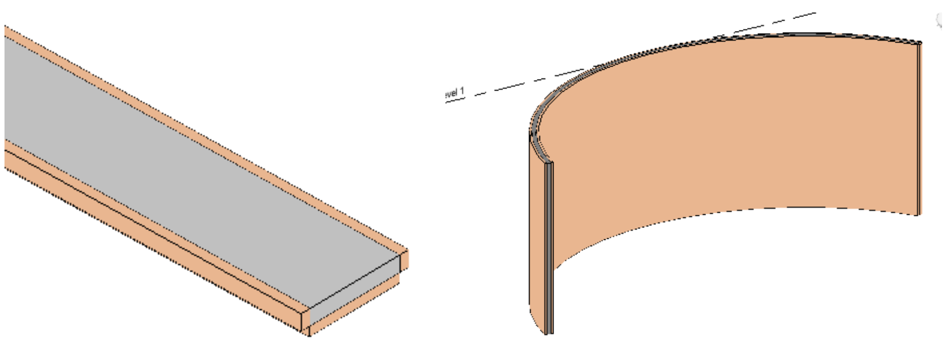

Figure 43 – Formwork 3D model for irregular shapes & non-structural elements

4.3. Footing Insulation

4.3.1. Concept and Methodology

In this section, Dynamo script has been developed to automate the process of calculating the quantity take-off of the footing insulation from the structural BIM model with creating a 3D model for it at the same time after defining the insulation material and specific Revit parameters for footing insulation area.

The strategy as shown in figure 44 is to allow the user to select all the elements that need to be insulated directly from the Revit structural project file. Once make the elements selection, then run the Dynamo player, the Dynamo player shows the total insulation area, also the insulation 3D model will be created with a custom parameter for the insulation surface area.

The category used in Revit to make the insulation modelling is “Generic Models”. After defining the Revit category, the user must create a new shared parameter for the “Insulation Area” and a new Insulation material to link it to the Dynamo.

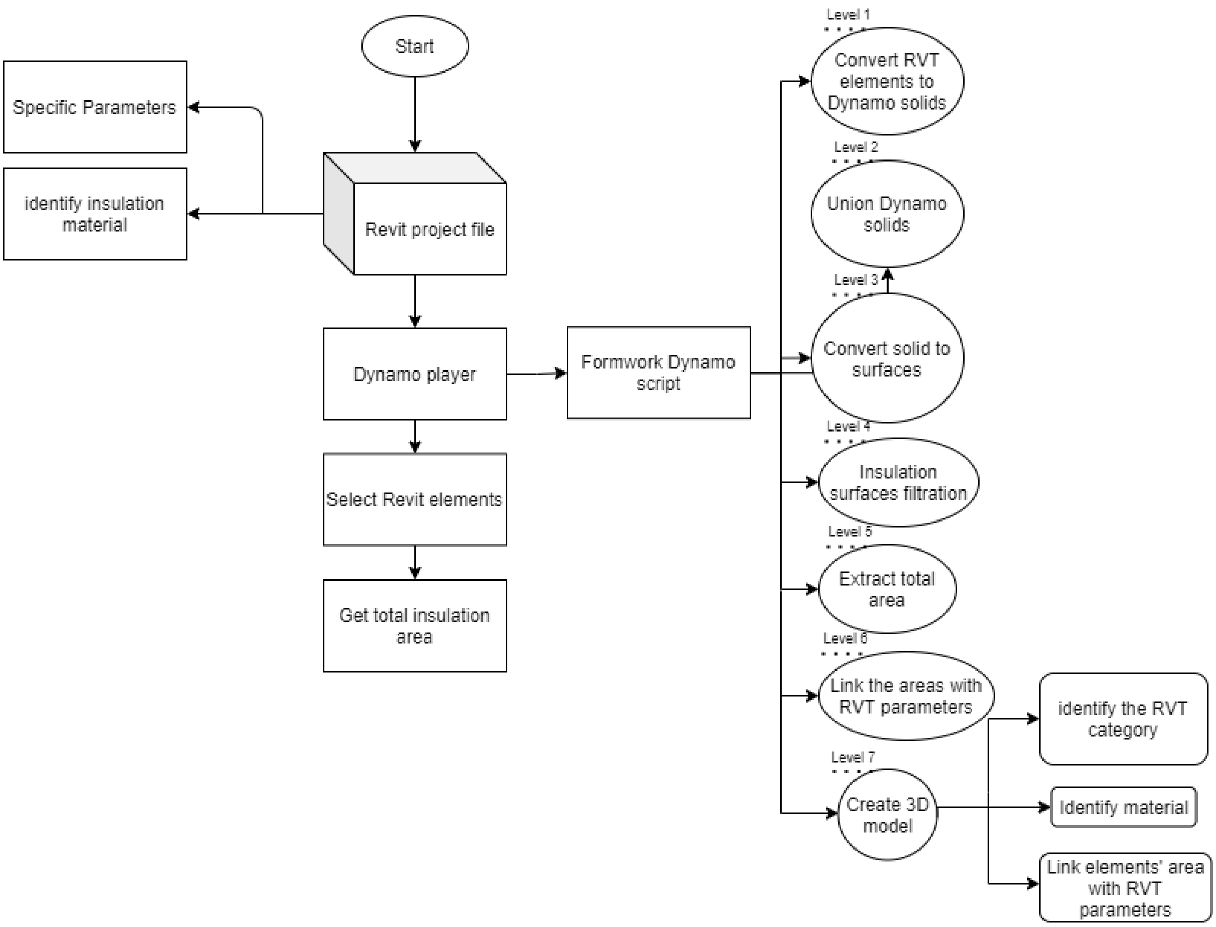

Figure 44 – Dynamo script concept

4.3.2. Identifying Revit information

Insulation parameters

Custom parameters for the insulation area were created to read the surface area for all the sub-ground elements which need to be insulated from Dynamo. This "Insulation Area" parameter is a shared parameter created for instance element and specially for "Generic Models" category which is the Revit family category would match with insulation elements. Once the user picks on any insulation face, the Insulation Area parameter gets a value automatically.

Insulation material

Before running the Dynamo script, the user must define a new material specially for the insulation in Revit from the material library, the new material for the insulation is "Damp-proofing" to link it to Dynamo script and create the 3D model.

4.3.3. Dynamo script

Extracting information from the structural model

The essential process is selecting the desired elements that need to be insulated. In this study, the chosen way to do the elements' selection is the manual way. The user must filtrate for all the desired elements. In this way, the desired element in Revit is linked to the Dynamo script. Once the connection is identified, the Dynamo script can be used to calculate the insulation surface area and create the 3D model.

The main issue of this strategy is that the Dynamo will not differentiate the foundation elements from the superstructure elements. So, the selection needs to be done very responsibly and accurately to obtain a realistic result.

After selecting the Revit elements, the Dynamo script is designed to convert the Revit elements into Dynamo geometries, then union all the solid geometries to become one geometry and extract the surfaces from the union solid. This strategy is followed to subtract the overlapping areas between the Revit elements.

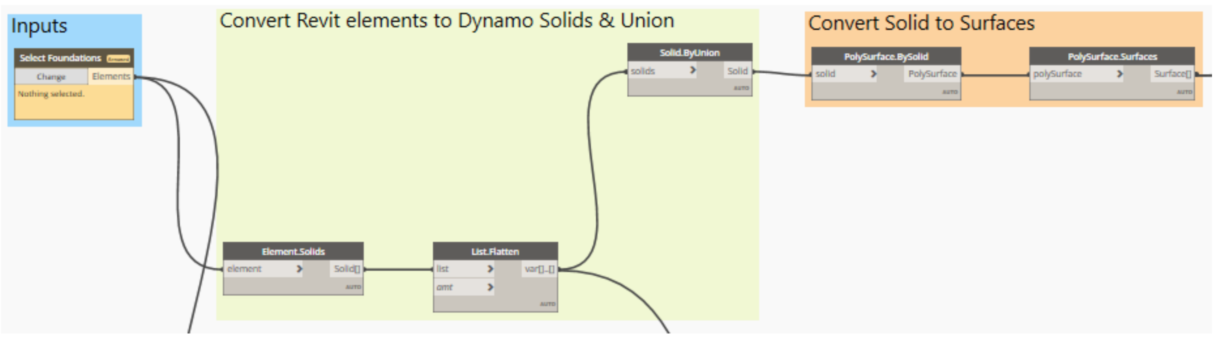

Figure 45 – Dynamo script for selecting elements from Revit

Creating insulation surfaces

In this phase, the Dynamo script is designed to extract only the insulation surface as shown in figure 46 by removing the upper and the lower surfaces for all elements. This strategy is applied by identifying a point at the middle of each surface and filter the surfaces according to vector z, then removing the maximum and the minimum value of vector z.

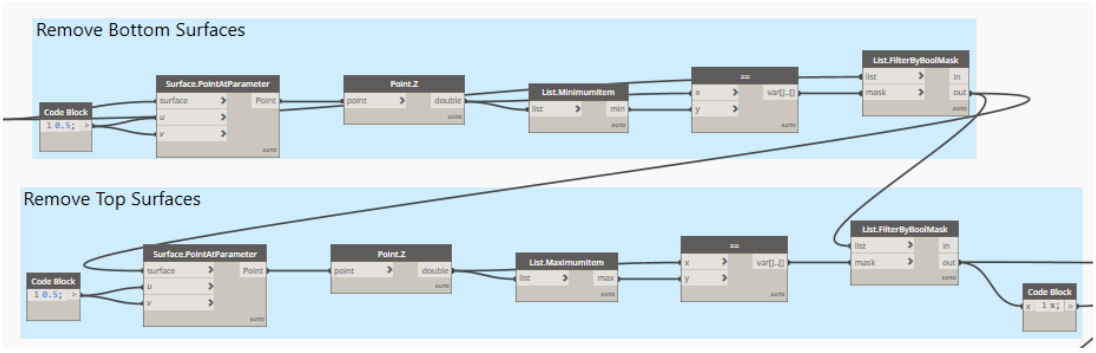

Figure 46 – Dynamo script creating insulation surfaces

The main issue in this strategy is that the bottom surfaces of tie beams need to be removed which is not considered as maximum or minimum surface according to the direction of vector Z after making a union for all solid geometries. So, another strategy is applied in this study by filtering all tie beams solids geometry according to family category "Structural Framing", then making a line from all solids centroids and identify the length and the direction of those lines to intersect the bottom surfaces of the tie beams, then removing all the surfaces that intersect with any line as shown in figure 47.

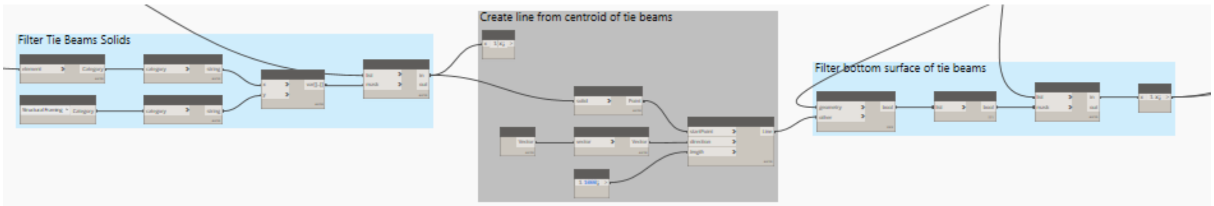

Figure 47 – Dynamo script for removing bottom surfaces of tie beams

After extracting the insulation surfaces for all Revit elements, the Dynamo script is designed to get the surface area for the insulation elements, accumulate the surfaces areas and get the total area as shown in figure 48.

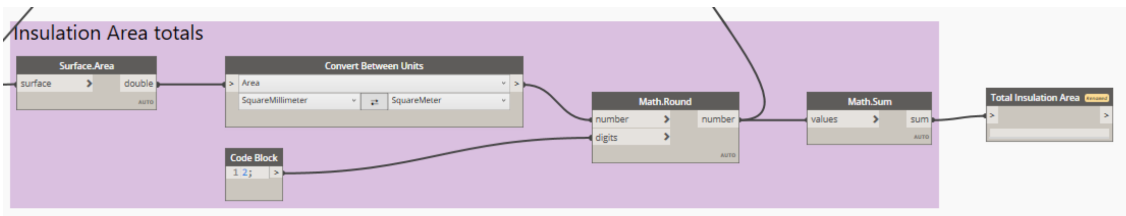

Figure 48 – Dynamo script for getting the insulation area

Creating the 3D model

In this study, the Dynamo script is developed to create the 3D model in Revit by transforming Dynamo solid geometry into Revit elements by defining some aspects to link Dynamo to Revit. The Dynamo script used “Generic Models” category to create the insulation elements in Revit, and for the insulation material, the Dynamo script defined the used material to be “Damp-proofing” which is defined in the Revit project file. In addition, the Dynamo script is developed to extract the insulation area for the surfaces and link it to Revit through a specific parameter “Insulation Area” which is created before in Revit project file.

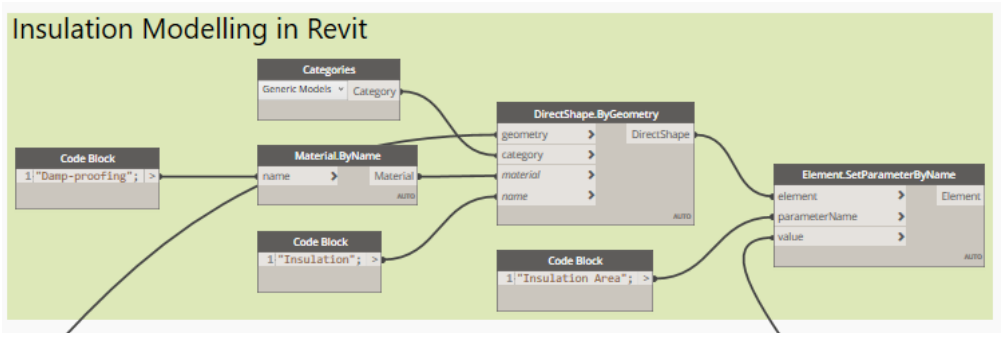

Figure 49 – Dynamo script for Creating the 3D model in Revit

Dynamo player

The Dynamo script is designed to allow the user to use the Dynamo player plugin to select the elements need for insulation. Once the user run the Dynamo player, the total insulation area appears in the Dynamo player tab as shown in figure 50. In addition, the 3D model of insulation is created above the Structural model and by hiding the structural model, the user could receive only the 3D model of insulation with area parameter for each element.

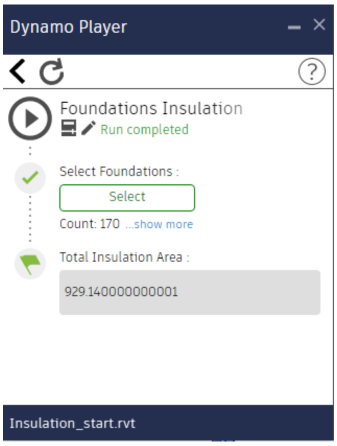

Figure 50 – Dynamo Player interface for Insulation

Insulation Dynamo script application

This part of this thesis aimed to create a fully automated process for extracting the footing insulation data and creating a 3D visualization model as shown in figure 51 in order to eliminate the use of third-party tools and expertise, to speed the process and include it in the cost estimation phase of the project, particularly since the early decision-making phase.

This Insulation Dynamo script shows good performance and results by creating the insulation 3D model, extracting the surface area for each insulation face and the total insulation area for all the elements from the Dynamo player tab.

Another benefit of the automated insulation procedure integrated with the BIM environment would be reducing human mistakes, which usually happen during the static and traditional method of calculation, making the data more reliable and accurate.

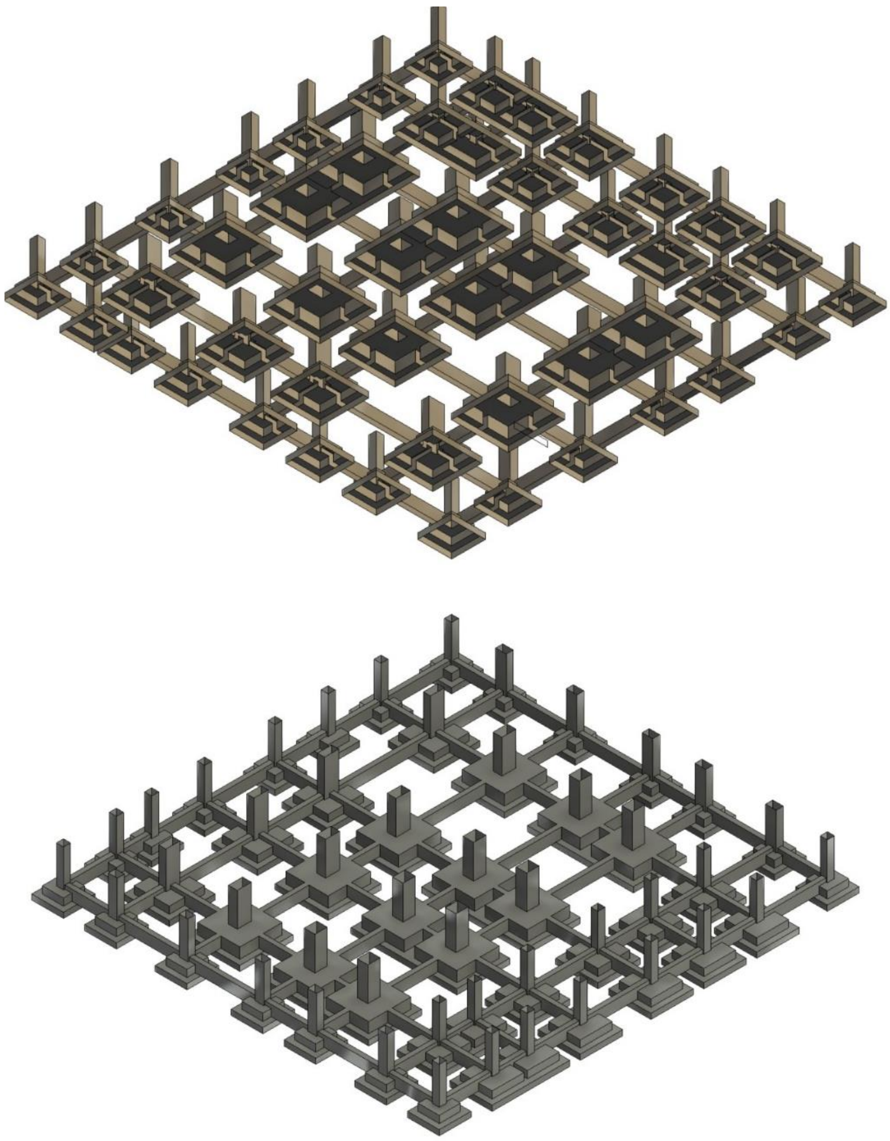

Figure 51 –Insulation 3D model details

4.4. Splitting VL elements at levels

One of this thesis's objectives is to develop new methods that automatically calculates the quantity take-off from any concrete structural BIM model in the right way without affecting the other BIM uses of the model in an accurate, efficient, and time-saving way.

For modelling VL elements "Columns & Walls" in Revit, some users used to model columns from bottom to top level as one element. Others used to model VL elements level by level for other purposes. For example, at the coordination phase in the project between the structural department and the architectural department, the architect may ask the structural engineer for changes in the location, orientation, type, and material of columns or walls for any architectural purposes. So, it will be more efficient, time-saving, and accurate to model all columns or walls in different levels as one element from the bottom level to the top level and make the changes one time for one element more than applying changes by selecting all columns level by level. However, splitting VL elements level by level is very important at the following phases after the coordination phase. At the quantity take-off phase, it is essential to split columns or walls by level to get accurate quantity and cost estimating for each level individually. In addition, the columns and walls must be modelled level by level for the structural analysis phase, especially to link the Revit BIM model to Robot software to create the correct analytical model for the structural analysis purpose.

4.4.1. Concept and Methodology

Users must split VL elements at levels manually or create different BIM models for the same project with different modelling elements according to BIM uses, which waste too much time and decrease the accuracy level, especially in large complex projects. Or using alternative BIM plugins to split VL elements at levels and get the quantity of the VL elements for the BIM model, which could be money-consuming or affect clashes in the BIM model.

In this study, the Dynamo script is used to split all the VL elements for the 3D Revit model using the Dynamo player plugin. Once selection the VL elements and the levels, all selected VL elements will split in the Revit model as shown in figure 52.

The main issue of the Dynamo is that it does not accept to split the elements at points; there is no specific order to make it directly from the Dynamo. Therefore, the solution which has developed in this study is to change the VL elements' levels to start from bottom level to level 1 instead of top-level. Then duplicate the VL elements each level to reach the top level with the same type, properties, location, and orientation of the original VL elements.

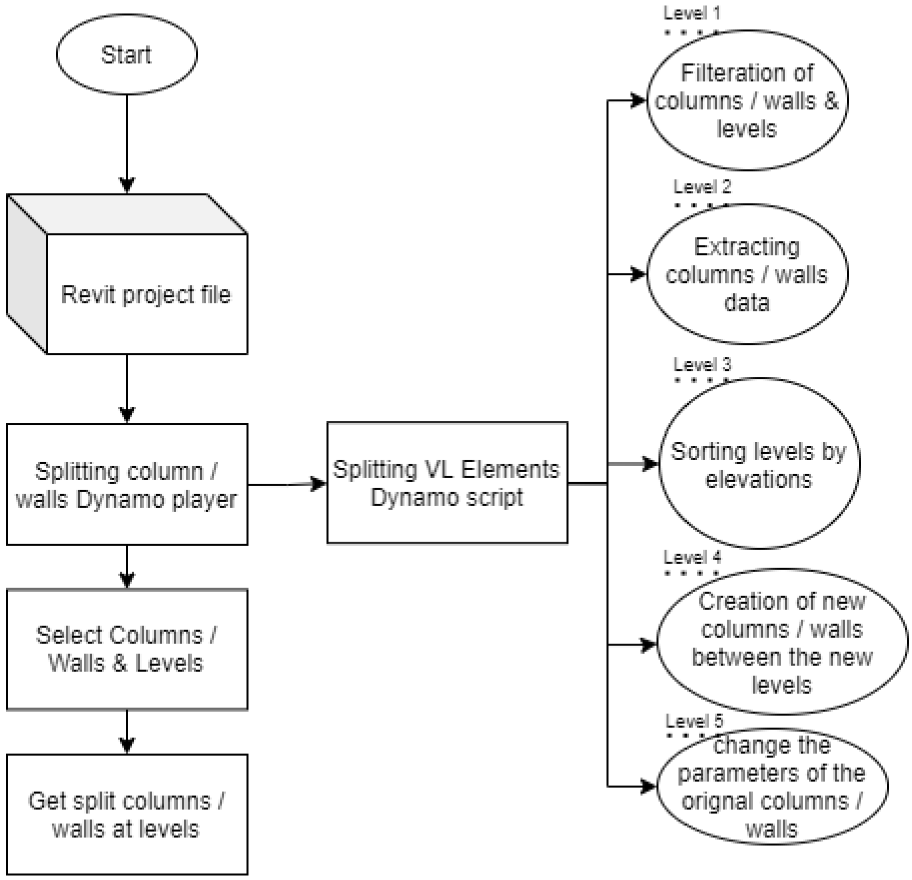

Figure 52 –Concept and methodology of Splitting VL elements Dynamo script

4.4.2. Dynamo script for splitting columns at levels

Extracting information from the structural model

The Dynamo script is developed to allow the user to select the elements and the levels as shown in figure 53. Then, it automatically applies filtration to extract only the structural columns and levels from the Revit model. The selected levels are the levels that the user wants to split the column on it, so in the selection phase, the user must not choose the bottom and top levels.

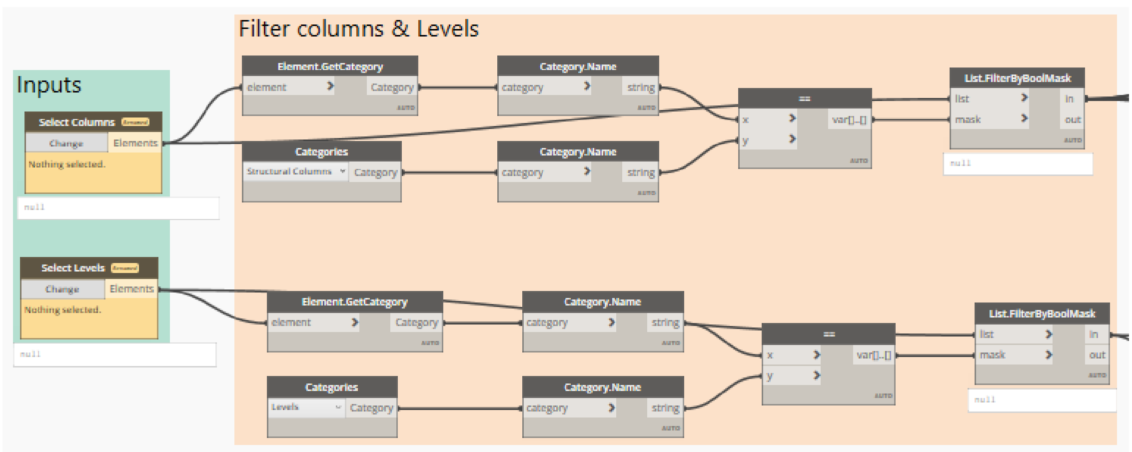

Figure 53 –Dynamo script for selection of elements and levels

In addition, the Dynamo script is designed to extract all the information for the selected columns as shown in figure 54 “The top-level, the location, the orientation and the top offset” by extracting the values of the Revit parameters to use it in the following Dynamo script. The insertion point determines the location of the columns, and the X vector determines the orientation.

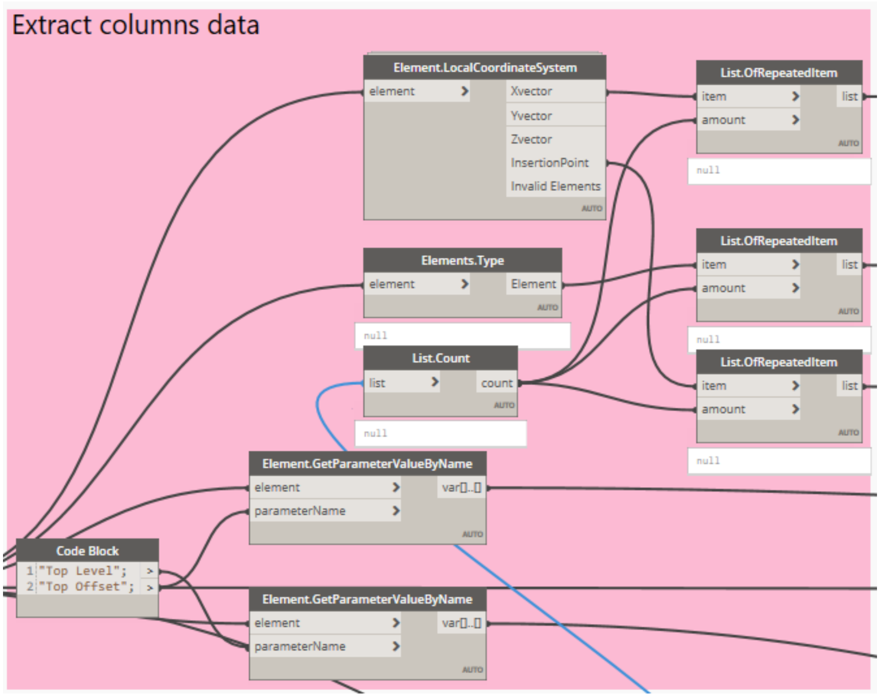

Figure 54 –Extracting column data

After extracting the required level to split columns, the Dynamo script is designed to reorder the levels to be in order according to their elevations.

Creation of split column elements

The Dynamo script is developed to use the extracted information from the original column element, modelled from the bottom to top-level. This information is used to create another column element between levels with the same properties, location, and orientation by using the original columns family type, location point, and the selected new levels. The main issue of this strategy is that the new level list may not read the data from the column element due to problems in levels list management that it does not match the level list with the number of original column elements. Therefore, to solve this problem, the Dynamo script is designed to count the original column number and repeat the new level list to be compatible with the same original columns number.

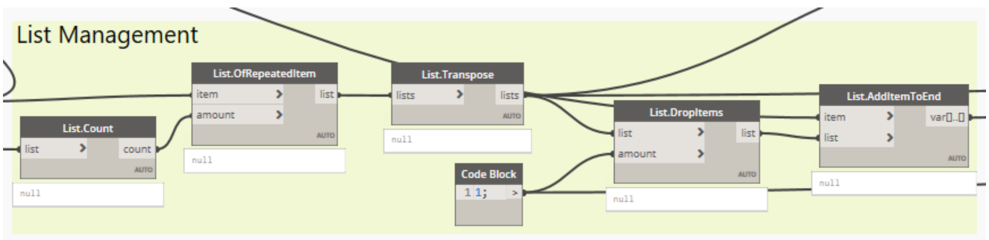

Figure 55–Dynamo script for new levels list management

After creating new column elements at the selected levels, the Dynamo script is developed to change the top offset parameter of the created columns at the last level to be compatible with the top offset of the original columns.

Moreover, one of these Dynamo script issues is that after creating the new columns at levels, the orientation of the columns follows the global direction of the X-axis, which could make conflicts with the orientation of the original columns. Therefore, the Dynamo script is designed to change the orientation of the newly created columns to be compatible with the orientation of the original column elements. By making rotation for all new columns with the same angle between the local X direction for original columns and the global X-axis.

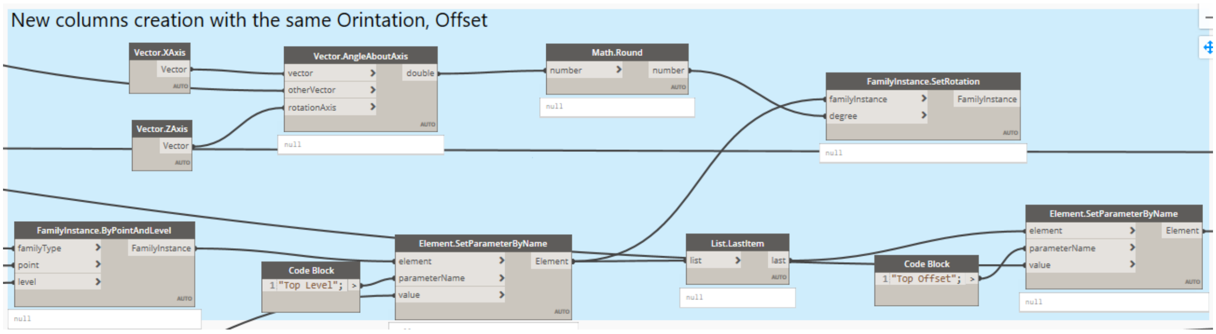

Figure 56 –Dynamo script for new columns creation

After that, the Dynamo script is developed to change the parameters of the original columns to be compatible with the other new columns. By changing the top-level parameter of the column to be the first selected level by elevation and removing the original column's top offset as the offset is already applied for the new columns at the last level. So, the original columns changed to be located between the bottom and the first selected level without offsets instead of the bottom level and the top level with top offsets.

The essential part of the Dynamo script is to make the changing parameters of the original columns after creating the new columns level by level. Thus, it ensures that the Dynamo script will not occur clashes between the top level of the original columns and the top level of the created new columns.

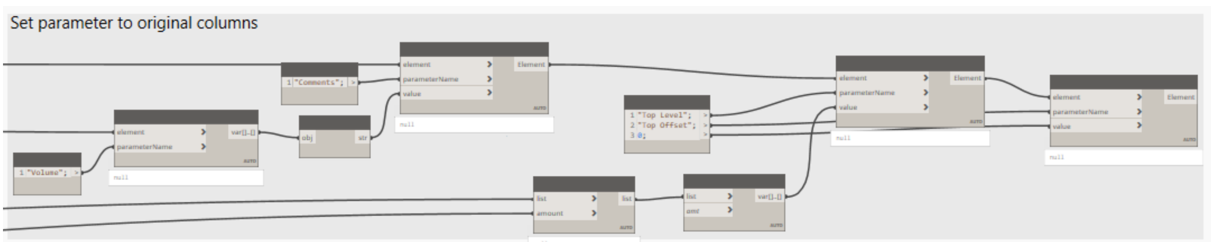

Figure 57 –Dynamo script for remodel the original columns

In summary, the Dynamo script strategy is to reorder the selected levels by elevations and create new columns between them with the same type, orientation, location, and properties of the original columns. For example, for the columns in the first level, the first level to be the bottom level, the second level to be the top-level, and for the columns in the second level, the second level is the bottom level, the third level is the top level, and so on. In addition, rearrange the original column levels between the bottom level and the first selected level by elevation.

Dynamo player

Dynamo player was used to run the scripts to simplify the procedure of splitting columns at levels. However, the dynamo scripts often become heavy and complicated to run and very difficult to understand by other users who are not the developer or do not have specific Dynamo knowledge.

The Dynamo script is designed to allow the user to select the desired Dynamo script in the Dynamo player plugin, select the desired columns that need to split and select the levels to split columns on it. Then, by clicking “Play”, The Dynamo player creates everything automatically without any need to open the Dynamo script.

4.4.3. Dynamo script for splitting walls at levels

Extracting information from the structural model

The Dynamo script for splitting walls at levels is developed to allow the user to select the walls and the levels like the splitting columns at levels Dynamo script. The main difference between column script and wall script is that the columns elements are defined by point. In contrast, the wall's elements are characterised by a curve which leads to some changes in the core but without changing the concept and the methodology of the Dynamo script.

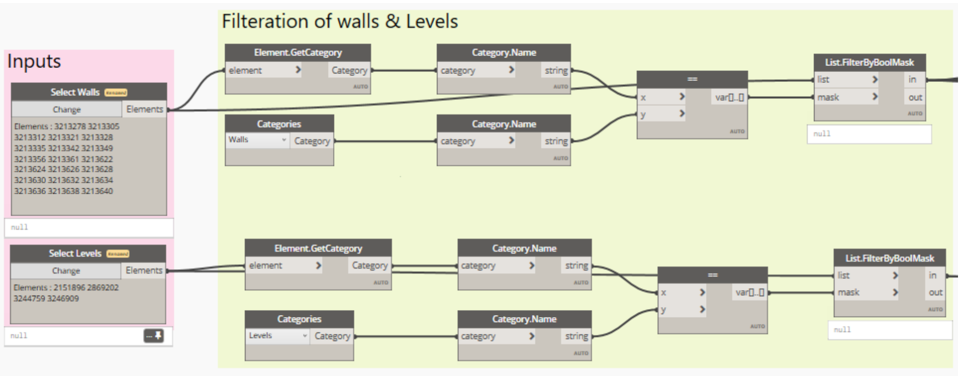

Figure 58–Dynamo script for selection walls and levels

In the selection phase, the walls Dynamo script is developed to allow the user to choose the elements as the column Dynamo script and filtrate the walls and the levels only. In addition, extract all the information for the selected walls with some differences from the column Dynamo script. For example, there is no need to extract the location point of the walls like columns as walls are not defined by points. Also, there is no need for all the Dynamo nodes to adapt the orientation of new columns to the original columns because walls are drawn by curves, not by points. Also, Revit defined the levels of wall elements by "Constraint" parameters, not "Levels", so the Dynamo script is designed to extract to the top constraint of walls to get the top level.

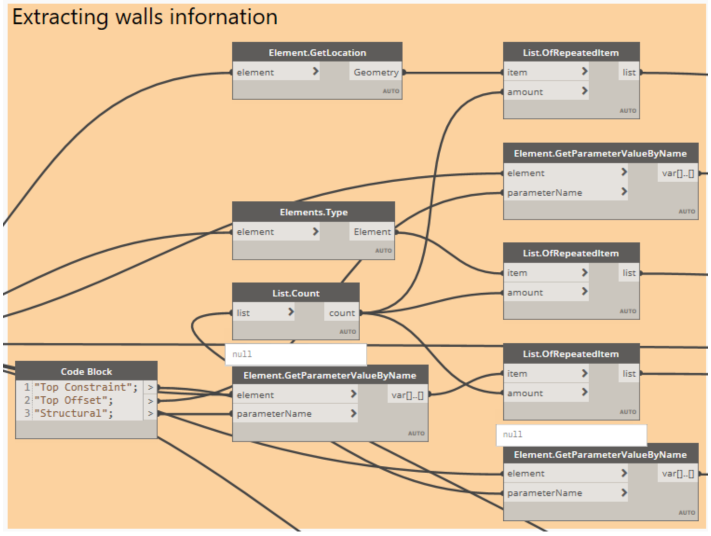

Figure 59 –Dynamo script for extracting walls information

After extracting the required level to split columns, the Dynamo script is designed to reorder the levels to be in order according to their elevations.

Creation of split wall elements

The Dynamo script is developed to use the extracted information from the original wall elements, modelled from the bottom to top-level. This information is used to create other wall elements between levels with the same properties and location by using the original wall family type, location line, and the selected new levels. The main difference in this phase between column Dynamo script and walls Dynamo script is drawing the new wall elements. The used way for drawing walls is to define location by curves, the start and the end level, and wall type instead of the way of drawing columns by defining the column type, levels, and point.

One of the main issues in this strategy is that after creating the new walls in Dynamo, they may not appear in the Revit views because they are not defined as structural walls in Revit. The main reason for this problem is that the structural wall discipline parameter in Revit must be “Structural” discipline. The “Structural” parameter is marked to allow Revit software to deal with the structural walls, not architectural ones. Therefore, to solve this problem in Revit, the Dynamo script is modified to extract the “Structural” parameter from the original wall elements and set it as a new parameter for all new wall elements.

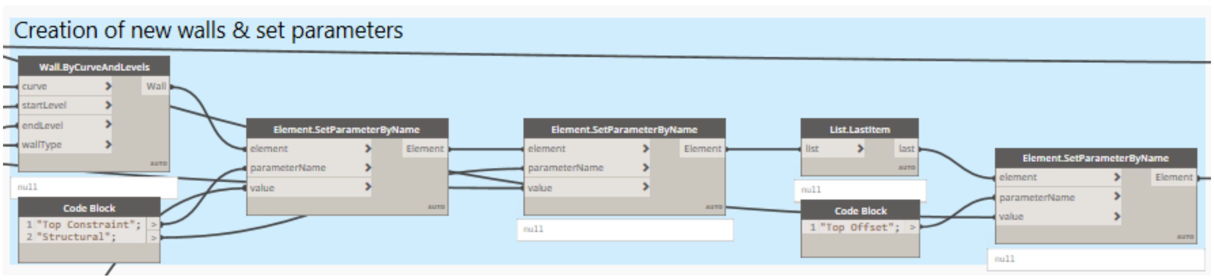

Figure 60–Dynamo script for sorting levels by elevations

As for the column Dynamo script, the main issue of this strategy is that the new level list may not read the data from the wall element due to problems in levels list management. As a result, it does not match the level list with the number of original wall elements. Therefore, to solve this problem, the Dynamo script is designed to count the original wall number and repeat the new level list to be compatible with the same original walls number.

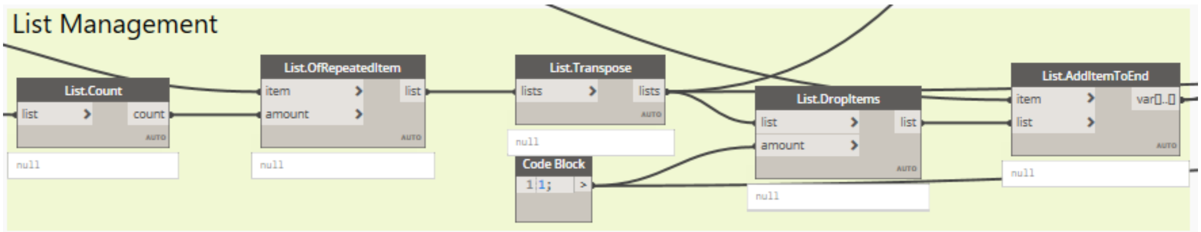

Figure 61 –Dynamo script for new levels list management

After creating new wall elements at the selected levels, the Dynamo script is developed to change the top offset parameter of the created walls at the last level to be compatible with the top offset of the original walls.

After that, the Dynamo script is developed to change the parameters of the original walls to be compatible with the other new walls. By changing the top-constraint parameter of the walls to be the first selected level by elevation and removing the original column's top offset as the offset is already applied for the new walls at the last level. So, the original walls changed to be located between the bottom and the first selected level without offsets instead of the bottom level and the top level with top offsets.

The essential part of the Dynamo script is to make the changing parameters of the original walls after creating the new columns level by level. Thus, it ensures that the Dynamo script will not occur clashes between the top level of the original walls and the top level of the created new walls.

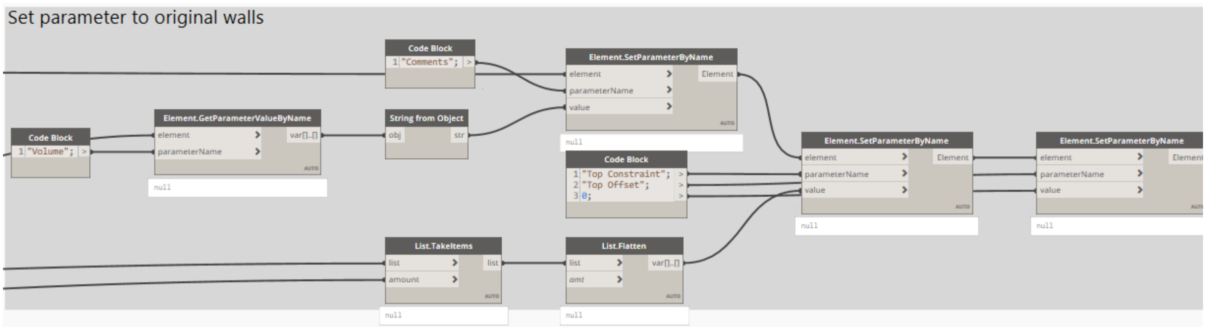

Figure 62 –Dynamo script for remodel the original walls

In summary, the Dynamo script strategy is to reorder the selected levels by elevations and create new walls between them with the same type, discipline, location, and properties as the original walls. In addition, rearrange the original wall levels between the bottom level and the first selected level by elevation. *Global parameters* can be created for multiple objects from different categories, not just a specific category.

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5. CONCLUSION

5.1. General conclusion

This study aimed to upgrade the Newton office work process to deal with the new BIM challenges. During this dissertation work, **four main outputs** were developed and provided for BIM implementation upgrading in Newton. The main output and corresponding conclusion of the creation and implementation tools and processes are followed below:

1. **The Newton Revit template** was updated which significantly affect the BIM productivity. Also, the template can increase BIM working efficiency, which leads to more consistency across different company projects. The main goal of templates is to be compatible with the desired BIM uses, save more time working with Revit, and follow the company standard, which serves the Portuguese and the European markets.

2. **The internal libraries of Newton objects** were developed by implementing Uniclass 2015 and Omniclass classification systems for efficient specification, scheduling, and cost estimation. The classification systems allow the used Revit families to be identified, described, and well organised within the BIM environment. In addition, the classification system facilitates the searching, sorting, extracting, and analysing of the data. Using a unified classification system ensures consistency and reduces ambiguity. Also, it allows the user to collect and compare data across several projects. In addition, a **new database** is developed for all Newton used families. This database has been saved in two different ways, the first one in an Excel spreadsheet and the other in Newton Revit Template ". rte." file. This database is a crucial structure system to store information of Revit families in an organised, logical way, leading to efficient data management that can be stored, shared, and integrated.

3. **New Dynamo scripts** were developed to increase the efficiency of Revit software and Newton work productivity. Also, automate some repetitive design tasks so designers can use their productive time more wisely. This study developed a parametric script which was created in Dynamo to read the information from the concrete structural Revit model and use the information to make calculations and produce the result of the formwork quantity take-off directly to the Revit list of shared parameters, simultaneously create a 3D model for the formwork elements in an independent Revit template. Also, for the irregular concrete elements, the script can be run from (Dynamo player) and directly write and visualise the results in the BIM model (Revit platform). In addition, another Dynamo script has been developed to automate the process of calculating the quantity take-off of the footing insulation from the structural BIM model with creating a 3D model for it at the same time after defining the insulation material and specific Revit parameters for footing insulation area. Moreover, this study developed a new Dynamo script to split all the VL elements for the 3D Revit model using the Dynamo player plugin. Once selection the VL elements and the levels, all selected VL elements will split in the Revit model.

4. **A technical modelling guide manual** was developed for Newton BIM uses. This manual aims to be a standard for modelling procedures for the Newton team to achieve controlled BIM structural model. In addition, it aims to facilitate coordination and collaboration at design and drawings production stages and create a BIM model suitable to be exported to other structural analysis software.

5.2. Future Development

Even though the dissertation, comprising its conceptual and practical work accomplished their goals, some issues are still not contemplated due to the time limitation and some improvements that would enhance the work were identified.

As a further development, Automation of extracting the QTO and linking it with elements specifications would bring a higher level of digitalization for Newton. Besides, linking the Newton's template with the external database would empower the proposed framework to deal with other BIM uses. In addition, automation of modelling quality by creating scripts or external digital tool to check the elements modelling procedure and give warnings if the way of modelling is not correct with extracting excel report for the modelling quality check.

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LIST OF ACRONYMS AND ABBREVIATIONS

BIM	Building Information Modelling
NBS	National Building Specification
API	Application Programming Interface
AEC	Architectural, Engineering and Construction
CSI	Construction Specifications Institute
CSC	Construction Specifications Canada
QTO	Quantity Take-off
ODBC	Open Database Connectivity
MVD	Model View Definition

APPENDICES

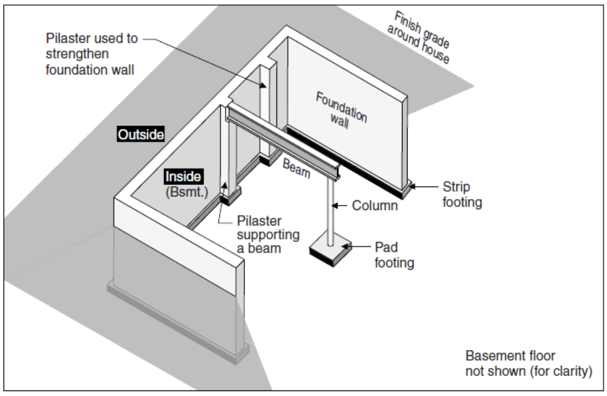
APPENDIX 1: UPDATED NEWTON OBJECTS

BIMObjectName	Families Old Naming	NBSDescription	NBSReference	OmniClass_Description	OmniClass_Number	OmniClass_Version	Uniclass2015Version	niclass_EF_Descripti	niclass_EF_Numb	iclass_Pr_Descripti	iclass_Pr_Numb	Uniclass_Ss_Description	niclass_Ss_Numb	IFCExportAs	IfcExportType
Structural Columns	**Structural Columns**														
Nw_Column_RC_Circular	NW-Pilares Circulares			Floor Structural Frame	21-02 10 10 10	May-12	July 2019 v1.6	Superstructure	EF_20_10	Concrete columns	Pr_20_85_16_15	Concrete column systems	Ss_20_30_75_15	IfcColumnType.COLUMN	COLUMN
Nw_Column_RC_Rectangular	NW-Pilares em Betão Armado			Floor Structural Frame	21-02 10 10 10	May-12	July 2019 v1.6	Superstructure	EF_20_10	Concrete columns	Pr_20_85_16_15	Concrete column systems	Ss_20_30_75_15	IfcColumnType.COLUMN	COLUMN
Nw_Column_Steel_Circular	CHS-Circular Hollow Section-Column			Floor Structural Frame	21-02 10 10 10	May-12	July 2019 v1.6	Superstructure	EF_20_10	Carbon steel columns	Pr_20_85_16_11	Steel column systems	Ss_20_30_75_80	IfcColumnType.COLUMN	COLUMN
Nw_Column_Steel_HEB	NW-Pilares Metálicos			Floor Structural Frame	21-02 10 10 10	May-12	July 2019 v1.6	Superstructure	EF_20_10	Carbon steel columns	Pr_20_85_16_11	Steel column systems	Ss_20_30_75_80	IfcColumnType.COLUMN	COLUMN
Nw_Column_Steel_RectangularHollowSection	RHS-Rectangular Hollow Section-Column			Floor Structural Frame	21-02 10 10 10	May-12	July 2019 v1.6	Superstructure	EF_20_10	Carbon steel columns	Pr_20_85_16_11	Steel column systems	Ss_20_30_75_80	IfcColumnType.COLUMN	COLUMN
Nw_Column_Steel_SquareHollowSection	SHS-Square Hollow Section-Column			Floor Structural Frame	21-02 10 10 10	May-12	July 2019 v1.6	Superstructure	EF_20_10	Carbon steel columns	Pr_20_85_16_11	Steel column systems	Ss_20_30_75_80	IfcColumnType.COLUMN	COLUMN
Nw_Column_Steel_VariableSection_667x250x12	WTC-S-VARIAVEL			Floor Structural Frame	21-02 10 10 10	May-12	July 2019 v1.6	Superstructure	EF_20_10	Carbon steel columns	Pr_20_85_16_11	Steel column systems	Ss_20_30_75_80	IfcColumnType.COLUMN	COLUMN
Structural Foundations	**Structural Foundations**														
Nw_Pile_RC_Boared	Estaca de Betão Armado	In situ concrete bored piling system	15-05-65/120	Bored Piles	21-01 10 20 15	May-12	July 2019 v1.6	Substructure	EF_20_05	Concrete piles	Pr_20_85_62_18	In situ concrete bored piling systems	Ss_20_05_65_41	IfcPileType.BORED	BORED_PILE
Nw_Pile_RC_Driven	Estaca de Betão Armado	Precast concrete piles	45-15-60/310	Driven Piles	21-01 10 20 10	May-12	July 2019 v1.6	Substructure	EF_20_05	Concrete piles	Pr_20_85_62_18	Driven precast or prestressed concrete piling systems	Ss_20_05_65_24	IfcPileType.DRIVEN	DRIVEN_PILE
Nw_FoundationSlab_RC_LT1_0.30	LT1	In situ reinforced concrete raft foundation system	15-05-15/130	Raft Foundations	21-01 10 20 60	May-12	July 2019 v1.6	Substructure	EF_20_05			Reinforced concrete raft foundation systems	Ss_20_05_15_72	IfcSlabType.BASESLAB	FOUNDATION_SLAB
Nw_FoundationSlab_RC_M1_0.90	M1	In situ reinforced concrete raft foundation system	15-05-15/130	Raft Foundations	21-01 10 20 60	May-12	July 2019 v1.6	Substructure	EF_20_05			Reinforced concrete raft foundation systems	Ss_20_05_15_72	IfcSlabType.BASESLAB	FOUNDATION_SLAB
Nw_FoundationSlab_RC_P1_2.00	P1	In situ reinforced concrete raft foundation system	15-05-15/130	Raft Foundations	21-01 10 20 60	May-12	July 2019 v1.6	Substructure	EF_20_05			Reinforced concrete raft foundation systems	Ss_20_05_15_72	IfcSlabType.BASESLAB	FOUNDATION_SLAB
Nw_FoundationSlab_RC_Plinto_0.50	Plinto	In situ reinforced concrete raft foundation system	15-05-15/130	Raft Foundations	21-01 10 20 60	May-12	July 2019 v1.6	Substructure	EF_20_05			Reinforced concrete raft foundation systems	Ss_20_05_15_72	IfcSlabType.BASESLAB	FOUNDATION_SLAB
Nw_FoundationSlab_RC_Plinto2_1.00	Plinto 2	In situ reinforced concrete raft foundation system	15-05-15/130	Raft Foundations	21-01 10 20 60	May-12	July 2019 v1.6	Substructure	EF_20_05			Reinforced concrete raft foundation systems	Ss_20_05_15_72	IfcSlabType.BASESLAB	FOUNDATION_SLAB
Nw_FoundationSlab_RC_S1_0.30	S1 (h=0.30)	In situ reinforced concrete raft foundation system	15-05-15/130	Raft Foundations	21-01 10 20 60	May-12	July 2019 v1.6	Substructure	EF_20_05			Reinforced concrete raft foundation systems	Ss_20_05_15_72	IfcSlabType.BASESLAB	FOUNDATION_SLAB
Nw_FoundationSlab_RC_S1_0.60	S1 (h=0.60)	In situ reinforced concrete raft foundation system	15-05-15/130	Raft Foundations	21-01 10 20 60	May-12	July 2019 v1.6	Substructure	EF_20_05			Reinforced concrete raft foundation systems	Ss_20_05_15_72	IfcSlabType.BASESLAB	FOUNDATION_SLAB
Nw_FoundationSlab_RC_S2_0.30	S2 (h=0.30)	In situ reinforced concrete raft foundation system	15-05-15/130	Raft Foundations	21-01 10 20 60	May-12	July 2019 v1.6	Substructure	EF_20_05			Reinforced concrete raft foundation systems	Ss_20_05_15_72	IfcSlabType.BASESLAB	FOUNDATION_SLAB
Nw_FoundationSlab_RC_S2_0.50	S2 (h=0.50)	In situ reinforced concrete raft foundation system	15-05-15/130	Raft Foundations	21-01 10 20 60	May-12	July 2019 v1.6	Substructure	EF_20_05			Reinforced concrete raft foundation systems	Ss_20_05_15_72	IfcSlabType.BASESLAB	FOUNDATION_SLAB
Nw_FoundationSlab_RC_S3_0.30	S3 (h=0.30)	In situ reinforced concrete raft foundation system	15-05-15/130	Raft Foundations	21-01 10 20 60	May-12	July 2019 v1.6	Substructure	EF_20_05			Reinforced concrete raft foundation systems	Ss_20_05_15_72	IfcSlabType.BASESLAB	FOUNDATION_SLAB
Nw_FoundationSlab_RC_S3_0.70	S3 (h=0.70)	In situ reinforced concrete raft foundation system	15-05-15/130	Raft Foundations	21-01 10 20 60	May-12	July 2019 v1.6	Substructure	EF_20_05			Reinforced concrete raft foundation systems	Ss_20_05_15_72	IfcSlabType.BASESLAB	FOUNDATION_SLAB
Nw_FoundationSlab_RC_S4_0.30	S4 (h=0.30)	In situ reinforced concrete raft foundation system	15-05-15/130	Raft Foundations	21-01 10 20 60	May-12	July 2019 v1.6	Substructure	EF_20_05			Reinforced concrete raft foundation systems	Ss_20_05_15_72	IfcSlabType.BASESLAB	FOUNDATION_SLAB
Nw_FoundationSlab_RC_S5_0.30	S5 (h=0.30)	In situ reinforced concrete raft foundation system	15-05-15/130	Raft Foundations	21-01 10 20 60	May-12	July 2019 v1.6	Substructure	EF_20_05			Reinforced concrete raft foundation systems	Ss_20_05_15_72	IfcSlabType.BASESLAB	FOUNDATION_SLAB
Nw_FoundationSlab_RC_S5_0.45	S5 (h=0.45)	In situ reinforced concrete raft foundation system	15-05-15/130	Raft Foundations	21-01 10 20 60	May-12	July 2019 v1.6	Substructure	EF_20_05			Reinforced concrete raft foundation systems	Ss_20_05_15_72	IfcSlabType.BASESLAB	FOUNDATION_SLAB
Nw_FoundationSlab_RC_S6_0.30	S6 (h=0.30)	In situ reinforced concrete raft foundation system	15-05-15/130	Raft Foundations	21-01 10 20 60	May-12	July 2019 v1.6	Substructure	EF_20_05			Reinforced concrete raft foundation systems	Ss_20_05_15_72	IfcSlabType.BASESLAB	FOUNDATION_SLAB
Nw_FoundationSlab_RC_S7_0.30	S7 (h=0.30)	In situ reinforced concrete raft foundation system	15-05-15/130	Raft Foundations	21-01 10 20 60	May-12	July 2019 v1.6	Substructure	EF_20_05			Reinforced concrete raft foundation systems	Ss_20_05_15_72	IfcSlabType.BASESLAB	FOUNDATION_SLAB
Nw_FoundationSlab_RC_S8_0.40	S8 (h=0.40)	In situ reinforced concrete raft foundation system	15-05-15/130	Raft Foundations	21-01 10 20 60	May-12	July 2019 v1.6	Substructure	EF_20_05			Reinforced concrete raft foundation systems	Ss_20_05_15_72	IfcSlabType.BASESLAB	FOUNDATION_SLAB
Nw_FoundationSlab_RC_SMS2_0.40	SMS2 (h=0.40)	In situ reinforced concrete raft foundation system	15-05-15/130	Raft Foundations	21-01 10 20 60	May-12	July 2019 v1.6	Substructure	EF_20_05			Reinforced concrete raft foundation systems	Ss_20_05_15_72	IfcSlabType.BASESLAB	FOUNDATION_SLAB
Nw_FoundationWall_RC_0.50	Spar1 (h=0.50m)	In situ reinforced concrete retaining wall system	10-35-40/140	Wall Foundations	21-01 10 10 10	May-12	July 2019 v1.6	Substructure	EF_20_05			Reinforced concrete retaining wall systems	Ss_20_60_35_70	IfcFootingType.USERDEFINED	USERDEFINED
Structural Framing	**Structural Framing**														
Nw_Beam_RC_Rectangular	M_Concrete-Rectangular Beam			Floor Structural Frame	21-02 10 10 10	May-12	July 2019 v1.6	Superstructure	EF_20_10	Concrete beams	Pr_20_85_08_15	Concrete beam systems	Ss_20_20_75_15	IfcBeamType.BEAM	BEAM
Nw_Beam_Steel_Angle_L	L-Angles			Floor Structural Frame	21-02 10 10 10	May-12	July 2019 v1.6	Superstructure	EF_20_10	Carbon steel beams	Pr_20_85_08_11	Steel beam systems	Ss_20_20_75_80	IfcMemberType.USERDEFINED	USERDEFINED
Nw_Beam_Steel_CircularHollowSection	Circular Hollow Sections			Floor Structural Frame	21-02 10 10 10	May-12	July 2019 v1.6	Superstructure	EF_20_10	Carbon steel beams	Pr_20_85_08_11	Steel beam systems	Ss_20_20_75_80	IfcBeamType.BEAM	BEAM
Nw_Beam_Steel_HEB	H-Wide Flange Beams			Floor Structural Frame	21-02 10 10 10	May-12	July 2019 v1.6	Superstructure	EF_20_10	Carbon steel beams	Pr_20_85_08_11	Steel beam systems	Ss_20_20_75_80	IfcBeamType.BEAM	BEAM
Nw_Beam_Steel_IPE	IPE-Beams			Floor Structural Frame	21-02 10 10 10	May-12	July 2019 v1.6	Superstructure	EF_20_10	Carbon steel beams	Pr_20_85_08_11	Steel beam systems	Ss_20_20_75_80	IfcBeamType.BEAM	BEAM
Nw_Beam_Steel_IPN	IPN-Beams			Floor Structural Frame	21-02 10 10 10	May-12	July 2019 v1.6	Superstructure	EF_20_10	Carbon steel beams	Pr_20_85_08_11	Steel beam systems	Ss_20_20_75_80	IfcBeamType.BEAM	BEAM
Nw_Beam_Steel_RectangularHollowSection	RHS-Rectangular Hollow Section			Floor Structural Frame	21-02 10 10 10	May-12	July 2019 v1.6	Superstructure	EF_20_10	Carbon steel beams	Pr_20_85_08_11	Steel beam systems	Ss_20_20_75_80	IfcBeamType.BEAM	BEAM
Nw_Beam_Steel_SquareHollowSection	SHS-Square Hollow Section			Floor Structural Frame	21-02 10 10 10	May-12	July 2019 v1.6	Superstructure	EF_20_10	Carbon steel beams	Pr_20_85_08_11	Steel beam systems	Ss_20_20_75_80	IfcBeamType.BEAM	BEAM
Nw_Beam_Steel_UPN	U-Channels			Floor Structural Frame	21-02 10 10 10	May-12	July 2019 v1.6	Superstructure	EF_20_10	Carbon steel beams	Pr_20_85_08_11	Steel beam systems	Ss_20_20_75_80	IfcMemberType.USERDEFINED	USERDEFINED
Nw_Frame_Steel_Trapezoidal	TELHA trapezoidal	Solid steel slab	20-20-10/105	Floor Decks, Slabs, and Toppings	21-02 10 10 20	May-12	July 2019 v1.6	Superstructure	EF_20_10			Solid steel slab systems	Ss_30_16_10_80	IfcSlabType.USERDEFINED	USERDEFINED
Floors	**Floors**														
Nw_Deck_STR_0.03	Deck-Estrutura 3mm	Decking systems	20-15-25/125	Floor Decks, Slabs, and Toppings	21-02 10 10 20	May-12	July 2019 v1.6	Floors	EF_30_20			Decking systems	Ss_30_20_30_25	IfcSlabType.FLOOR	FLOOR
Nw_Floor_BeamAndBlock_0.20	Viga e bloco de 200 mm			Floor Decks, Slabs, and Toppings	21-02 10 10 20	May-12	July 2019 v1.6	Floors	EF_30_20			Beam and block floor systems	Ss_30_12_05	IfcSlabType.FLOOR	FLOOR
Nw_Floor_LightWeightRC_0.22	Betão Leve	In situ reinforced concrete floor, roof deck or balcony system	20-05-80/145	Floor Decks, Slabs, and Toppings	21-02 10 10 20	May-12	July 2019 v1.6	Floors	EF_30_20	Concrete solid slabs	Pr_20_85_14_16	Concrete slab deck systems	Ss_30_16_10_16	IfcSlabType.FLOOR	FLOOR
Nw_Floor_RC_LA_0.12	LA (e=0.12)	In situ reinforced concrete floor, roof deck or balcony system	20-05-80/145	Floor Decks, Slabs, and Toppings	21-02 10 10 20	May-12	July 2019 v1.6	Floors	EF_30_20	Concrete solid slabs	Pr_20_85_14_16	Concrete slab deck systems	Ss_30_16_10_16	IfcSlabType.FLOOR	FLOOR
Nw_Floor_RC_LAP1_0.05	LAP1 35+5	In situ reinforced concrete floor, roof deck or balcony system	20-05-80/145	Floor Decks, Slabs, and Toppings	21-02 10 10 20	May-12	July 2019 v1.6	Floors	EF_30_20	Concrete solid slabs	Pr_20_85_14_16	Concrete slab deck systems	Ss_30_16_10_16	IfcSlabType.FLOOR	FLOOR
Nw_Floor_RC_LAT_0.45	LAT (e=0.15)	In situ reinforced concrete floor, roof deck or balcony system	20-05-80/145	Floor Decks, Slabs, and Toppings	21-02 10 10 20	May-12	July 2019 v1.6	Floors	EF_30_20	Concrete solid slabs	Pr_20_85_14_16	Concrete slab deck systems	Ss_30_16_10_16	IfcSlabType.FLOOR	FLOOR
Nw_Floor_RC_LAT_EX_0.35	LAT-Ex (e=0.15)	In situ reinforced concrete floor, roof deck or balcony system	20-05-80/145	Floor Decks, Slabs, and Toppings	21-02 10 10 20	May-12	July 2019 v1.6	Floors	EF_30_20	Concrete solid slabs	Pr_20_85_14_16	Concrete slab deck systems	Ss_30_16_10_16	IfcSlabType.FLOOR	FLOOR
Nw_Floor_RC_LAV_0.06	LAV (e=0.18)	In situ reinforced concrete floor, roof deck or balcony system	20-05-80/145	Floor Decks, Slabs, and Toppings	21-02 10 10 20	May-12	July 2019 v1.6	Floors	EF_30_20	Concrete solid slabs	Pr_20_85_14_16	Concrete slab deck systems	Ss_30_16_10_16	IfcSlabType.FLOOR	FLOOR
Nw_Floor_RC_LCC1_0.12	LCC 1 (e=0.12m)	In situ reinforced concrete floor, roof deck or balcony system	20-05-80/145	Floor Decks, Slabs, and Toppings	21-02 10 10 20	May-12	July 2019 v1.6	Floors	EF_30_20	Concrete solid slabs	Pr_20_85_14_16	Concrete slab deck systems	Ss_30_16_10_16	IfcSlabType.FLOOR	FLOOR
Nw_Floor_RC_LCC2_0.18	LCC 2 (e=0.18m)	In situ reinforced concrete floor, roof deck or balcony system	20-05-80/145	Floor Decks, Slabs, and Toppings	21-02 10 10 20	May-12	July 2019 v1.6	Floors	EF_30_20	Concrete solid slabs	Pr_20_85_14_16	Concrete slab deck systems	Ss_30_16_10_16	IfcSlabType.FLOOR	FLOOR
Nw_Floor_RC_LE2_0.18	LE2 (e=0.18m)	In situ reinforced concrete floor, roof deck or balcony system	20-05-80/145	Floor Decks, Slabs, and Toppings	21-02 10 10 20	May-12	July 2019 v1.6	Floors	EF_30_20	Concrete solid slabs	Pr_20_85_14_16	Concrete slab deck systems	Ss_30_16_10_16	IfcSlabType.FLOOR	FLOOR
Nw_Floor_RC_LFA1_0.38	LFA1 (e=0.38)	In situ reinforced concrete floor, roof deck or balcony system	20-05-80/145	Floor Decks, Slabs, and Toppings	21-02 10 10 20	May-12	July 2019 v1.6	Floors	EF_30_20	Concrete solid slabs	Pr_20_85_14_16	Concrete slab deck systems	Ss_30_16_10_16	IfcSlabType.FLOOR	FLOOR
Nw_Floor_RC_LFA2_0.50	LFA2 (e=0.50)	In situ reinforced concrete floor, roof deck or balcony system	20-05-80/145	Floor Decks, Slabs, and Toppings	21-02 10 10 20	May-12	July 2019 v1.6	Floors	EF_30_20	Concrete solid slabs	Pr_20_85_14_16	Concrete slab deck systems	Ss_30_16_10_16	IfcSlabType.FLOOR	FLOOR
Nw_Floor_RC_LM1_0.20	LM1 (e=0.20)	In situ reinforced concrete floor, roof deck or balcony system	20-05-80/145	Floor Decks, Slabs, and Toppings	21-02 10 10 20	May-12	July 2019 v1.6	Floors	EF_30_20	Concrete solid slabs	Pr_20_85_14_16	Concrete slab deck systems	Ss_30_16_10_16	IfcSlabType.FLOOR	FLOOR
Nw_Floor_RC_LM1_0.23	LM1 (e=0.23)	In situ reinforced concrete floor, roof deck or balcony system	20-05-80/145	Floor Decks, Slabs, and Toppings	21-02 10 10 20	May-12	July 2019 v1.6	Floors	EF_30_20	Concrete solid slabs	Pr_20_85_14_16	Concrete slab deck systems	Ss_30_16_10_16	IfcSlabType.FLOOR	FLOOR
Nw_Floor_RC_LM2_0.20	LM2 (e=0.20)	In situ reinforced concrete floor, roof deck or balcony system	20-05-80/145	Floor Decks, Slabs, and Toppings	21-02 10 10 20	May-12	July 2019 v1.6	Floors	EF_30_20	Concrete solid slabs	Pr_20_85_14_16	Concrete slab deck systems	Ss_30_16_10_16	IfcSlabType.FLOOR	FLOOR
Nw_Floor_RC_LM2_0.23	LM2 (e=0.23)	In situ reinforced concrete floor, roof deck or balcony system	20-05-80/145	Floor Decks, Slabs, and Toppings	21-02 10 10 20	May-12	July 2019 v1.6	Floors	EF_30_20	Concrete solid slabs	Pr_20_85_14_16	Concrete slab deck systems	Ss_30_16_10_16	IfcSlabType.FLOOR	FLOOR
Nw_Floor_RC_LM3_0.25	LM3 (e=0.25)	In situ reinforced concrete floor, roof deck or balcony system	20-05-80/145	Floor Decks, Slabs, and Toppings	21-02 10 10 20	May-12	July 2019 v1.6	Floors	EF_30_20	Concrete solid slabs	Pr_20_85_14_16	Concrete slab deck systems	Ss_30_16_10_16	IfcSlabType.FLOOR	FLOOR
Nw_Floor_RC_LM4_0.20	LM4 (e=0.20)	In situ reinforced concrete floor, roof deck or balcony system	20-05-80/145	Floor Decks, Slabs, and Toppings	21-02 10 10 20	May-12	July 2019 v1.6	Floors	EF_30_20	Concrete solid slabs	Pr_20_85_14_16	Concrete slab deck systems	Ss_30_16_10_16	IfcSlabType.FLOOR	FLOOR
Nw_Floor_RC_LM4_0.50	LM4 (e=0.50)	In situ reinforced concrete floor, roof deck or balcony system	20-05-80/145	Floor Decks, Slabs, and Toppings	21-02 10 10 20	May-12	July 2019 v1.6	Floors	EF_30_20	Concrete solid slabs	Pr_20_85_14_16	Concrete slab deck systems	Ss_30_16_10_16	IfcSlabType.FLOOR	FLOOR
Nw_Floor_RC_LMPool_0.30	LMPiscina	Swimming pool floor tiling system	30-70-75/175	Pools	21-06 10 50 10	May-12	July 2019 v1.6	Floors	EF_30_20			Swimming pool floor tiling systems	Ss_37_40_85_83	IfcSlabType.FLOOR	FLOOR
Nw_Ramp_RC_0.25	Rampa	Internal ramp system	30-05-40/140	Ramps	21-02 10 10 50	May-12	July 2019 v1.6	Ramps	EF_35_20			Concrete stair or ramp systems	Ss_35_10_85_15	IfcSlabType.FLOOR	FLOOR
Nw_Ramp_RC_0.35	Rampa Térrea	Internal ramp system	30-05-40/140	Ramps	21-02 10 10 50	May-12	July 2019 v1.6	Ramps	EF_35_20			Concrete stair or ramp systems	Ss_35_10_85_15	IfcSlabType.FLOOR	FLOOR
Nw_Ramp_RC_LM_0.25	LM_Rampa (e=0.25)	Internal ramp system	30-05-40/140	Ramps	21-02 10 10 50	May-12	July 2019 v1.6	Ramps	EF_35_20			Concrete stair or ramp systems	Ss_35_10_85_15	IfcSlabType.FLOOR	FLOOR
Nw_Slab_RC_ExistingToMaintain_0.35	Laje Existente a Manter	In situ reinforced concrete floor, roof deck or balcony system	20-05-80/145	Floor Decks, Slabs, and Toppings	21-02 10 10 20	May-12	July 2019 v1.6	Floors	EF_30_20	Concrete solid slabs	Pr_20_85_14_16	Concrete slab deck systems	Ss_30_16_10_16	IfcSlabType.FLOOR	FLOOR
Walls	**Walls**														
Nw_Wall_Glass_Int_0.05	Cristalera	In situ glass block wall system	25-10-40/140	Interior Glazed Partitions	21-03 10 10 20	May-12	July 2019 v1.6	Walls	EF_25_10			Glass block wall systems	Ss_25_13_33_33	IfcWallType.PARTITIONING	
Nw_Wall_Glass_Int_0.10	Cristalera 2	In situ glass block wall system	25-10-40/140	Interior Glazed Partitions	21-03 10 10 20	May-12	July 2019 v1.6	Walls	EF_25_10			Glass block wall systems	Ss_25_13_33_33	IfcWallType.PARTITIONING	
Nw_Wall_ConcreteMasonry_Ext_50_100p_0.264	CW 102-50-100p	In situ reinforced concrete wall structure system	25-15-35/140	Exterior Wall Construction	21-02 20 10 20	May-12	July 2019 v1.6	Walls	EF_25_10			Reinforced concrete wall structure systems	Ss_25_11_16_70	IfcWallType.SOLIDWALL	
Nw_Wall_ConcreteMasonry_Ext_50_140p_0.304	CW 102-50-140p	In situ reinforced concrete wall structure system	25-15-35/140	Exterior Wall Construction	21-02 20 10 20	May-12	July 2019 v1.6	Walls	EF_25_10			Reinforced concrete wall structure systems	Ss_25_11_16_70	IfcWallType.SOLIDWALL	
Nw_Wall_ConcreteMasonry_Ext_50_215p_0.379	CW 102-50-215p	In situ reinforced concrete wall structure system	25-15-35/140	Exterior Wall Construction	21-02 20 10 20	May-12	July 2019 v1.6	Walls	EF_25_10			Reinforced concrete wall structure systems	Ss_25_11_16_70	IfcWallType.SOLIDWALL	
Nw_Wall_ConcreteMasonry_Ext_85_100p_0.299	CW 102-85-100p	In situ reinforced concrete wall structure system	25-15-35/140	Exterior Wall Construction	21-02 20 10 20	May-12	July 2019 v1.6	Walls	EF_25_10			Reinforced concrete wall structure systems	Ss_25_11_16_70	IfcWallType.SOLIDWALL	
Nw_Wall_ConcreteMasonry_Ext_85_140p_0.339	CW 102-85-140p	In situ reinforced concrete wall structure system	25-15-35/140	Exterior Wall Construction	21-02 20 10 20	May-12	July 2019 v1.6	Walls	EF_25_10			Reinforced concrete wall structure systems	Ss_25_11_16_70	IfcWallType.SOLIDWALL	
Nw_Wall_ConcreteMasonry_Ext_85_215p_0.414	CW 102-85-215p	In situ reinforced concrete wall structure system	25-15-35/140	Exterior Wall Construction	21-02 20 10 20	May-12	July 2019 v1.6	Walls	EF_25_10			Reinforced concrete wall structure systems	Ss_25_11_16_70	IfcWallType.SOLIDWALL	
Nw_Wall_RC_Ext_0.20	CxE1	In situ reinforced concrete wall structure system	25-15-35/140	Exterior Wall Construction	21-02 20 10 20	May-12	July 2019 v1.6	Walls	EF_25_10			Reinforced concrete wall structure systems	Ss_25_11_16_70	IfcWallType.SOLIDWALL	
Nw_Wall_RC_Ext_0.225	Exterior - 225mm Concrete	In situ reinforced concrete wall structure system	25-15-35/140	Exterior Wall Construction	21-02 20 10 20	May-12	July 2019 v1.6	Walls	EF_25_10			Reinforced concrete wall structure systems	Ss_25_11_16_70	IfcWallType.SOLIDWALL	
Nw_Wall_RC_Ext_0.30	Exterior - 300mm Concrete	In situ reinforced concrete wall structure system	25-15-35/140	Exterior Wall Construction	21-02 20 10 20	May-12	July 2019 v1.6	Walls	EF_25_10			Reinforced concrete wall structure systems	Ss_25_11_16_70	IfcWallType.SOLIDWALL	
Nw_Wall_MetalStudLayer_Ext_0.46	Exterior - Block on Mtl. Stud			Exterior Wall Construction	21-02 20 10 20	May-12	July 2019 v1.6	Walls	EF_25_10			Prefabricated metal wall systems	Ss_25_12_85_60	IfcWallType.SOLIDWALL	
Nw_Wall_MetalStudLayer_Ext_0.35	Exterior - Brick on Mtl. Stud			Exterior Wall Construction	21-02 20 10 20	May-12	July 2019 v1.6	Walls	EF_25_10			Prefabricated metal wall systems	Ss_25_12_85_60	IfcWallType.SOLIDWALL	
Nw_Wall_Concreteblocks_Ext_0.429	Exterior - Enlucido en ladrillo en bloque	In situ reinforced concrete wall structure system	25-15-35/140	Exterior Wall Construction	21-02 20 10 20	May-12	July 2019 v1.6	Walls	EF_25_10			Reinforced concrete wall structure systems	Ss_25_11_16_70	IfcWallType.SOLIDWALL	
Nw_Wall_MetalLayer_Ext_0.35	Exterior - Ladrillo en entramado metálico			Exterior Wall Construction	21-02 20 10 20	May-12	July 2019 v1.6	Walls	EF_25_10			Prefabricated metal wall systems	Ss_25_12_85_60	IfcWallType.SOLIDWALL	
Nw_Wall_BrickPlaster_Ext_0.429	Exterior - Reboco em tijolo no bloco	In situ reinforced concrete wall structure system	25-15-35/140	Exterior Wall Construction	21-02 20 10 20	May-12	July 2019 v1.6	Walls	EF_25_10			Reinforced concrete wall structure systems	Ss_25_11_16_70	IfcWallType.SOLIDWALL	
Nw_Wall_ConcreteMasonry_Ext_0.429	Exterior - Render on Brick on Block	In situ reinforced concrete wall structure system	25-15-35/140	Exterior Wall Construction	21-02 20 10 20	May-12	July 2019 v1.6	Walls	EF_25_10			Reinforced concrete wall structure systems	Ss_25_11_16_70	IfcWallType.SOLIDWALL	
Nw_Wall_MetalBrick_Ext_0.35	Exterior - Tijolo em montante metálico			Exterior Wall Construction	21-02 20 10 20	May-12	July 2019 v1.6	Walls	EF_25_10			Prefabricated metal wall systems	Ss_25_12_85_60	IfcWallType.SOLIDWALL	
Nw_Wall_RC_Foundation_0.30	Foundation - 300mm Concrete	In situ reinforced concrete retaining wall system	10-35-40/140	Wall Foundations	21-01 10 10 10	May-12	July 2019 v1.6	Substructure	EF_20_05			Reinforced concrete retaining wall systems	Ss_20_60_35_70	IfcFootingType.USERDEFINED	USERDEFINED
Nw_Wall_RC_Foundation_0.90	Foundation - 900mm Footing	In situ reinforced concrete retaining wall system	10-35-40/140	Wall Foundations	21-01 10 10 10	May-12	July 2019 v1.6	Substructure	EF_20_05			Reinforced concrete retaining wall systems	Ss_20_60_35_70	IfcFootingType.USERDEFINED	USERDEFINED
Nw_Wall_ConcreteMasonry_Ext_0.140	Generic - 140mm Masonry	In situ reinforced concrete wall structure system	25-15-35/140	Exterior Wall Construction	21-02 20 10 20	May-12	July 2019 v1.6	Walls	EF_25_10			Reinforced concrete wall structure systems	Ss_25_11_16_70	IfcWallType.SOLIDWALL	
Nw_Wall_Brick_Ext_0.20	Generic - 200mm			Exterior Wall Construction	21-02 20 10 20	May-12	July 2019 v1.6	Walls	EF_25_10			Lead brick wall systems	Ss_25_13_45	IfcWallType.SOLIDWALL	
Nw_Wall_ConcreteMasonry_Ext_0.225	Generic - 225mm Masonry	In situ reinforced concrete wall structure system	25-15-35/140	Exterior Wall Construction	21-02 20 10 20	May-12	July 2019 v1.6	Walls	EF_25_10			Reinforced concrete wall structure systems	Ss_25_11_16_70	IfcWallType.SOLIDWALL	
Nw_Wall_MetalStudLayer_InteriorPartition_0.079	Interior - 79mm Partition (1-hr)			Interior Fixed Partitions	21-03 10 10 10	May-12	July 2019 v1.6	Walls	EF_25_10			Prefabricated metal wall systems	Ss_25_12_85_60	IfcWallType.PARTITIONING	
Nw_Wall_MetalStudLayer_InteriorPartition_0.1355	Interior - 135mm Partition (2-hr)			Interior Fixed Partitions	21-03 10 10 10	May-12	July 2019 v1.6	Walls	EF_25_10			Prefabricated metal wall systems	Ss_25_12_85_60	IfcWallType.PARTITIONING	
Nw_Wall_MetalStudLayer_InteriorPartition_0.1385	Interior - 138mm Partition (1-hr)			Interior Fixed Partitions	21-03 10 10 10	May-12	July 2019 v1.6	Walls	EF_25_10			Prefabricated metal wall systems	Ss_25_12_85_60	IfcWallType.PARTITIONING	
Nw_Wall_ConcreteMasonry_Int_100_0.124	Interior - Blockwork 100	Masonry internal partition system	25-10-55/165	Interior Fixed Partitions	21-03 10 10 10	May-12	July 2019 v1.6	Walls	EF_25_10			Masonry internal partition systems	Ss_25_13_50_56	IfcWallType.PARTITIONING	
Nw_Wall_ConcreteMasonry_Int_140_0.164	Interior - Blockwork 140	Masonry internal partition system	25-10-55/165	Interior Fixed Partitions	21-03 10 10 10	May-12	July 2019 v1.6	Walls	EF_25_10			Masonry internal partition systems	Ss_25_13_50_56	IfcWallType.PARTITIONING	
Nw_Wall_ConcreteMasonry_Int_190_0.214	Interior - Blockwork 190	Masonry internal partition system	25-10-55/165	Interior Fixed Partitions	21-03 10 10 10	May-12	July 2019 v1.6	Walls	EF_25_10			Masonry internal partition systems	Ss_25_13_50_56	IfcWallType.PARTITIONING	
Nw_Wall_RC_Ext_MS_0.25	MS1 (e=0.25)	In situ reinforced concrete wall structure system	25-15-35/140	Exterior Wall Construction	21-02 20 10 20	May-12	July 2019 v1.6	Walls	EF_25_10			Reinforced concrete wall structure systems	Ss_25_11_16_70	IfcWallType.SOLIDWALL	
Nw_Wall_RC_Ext_MS_0.30	MS1 (e=0.30)	In situ reinforced concrete wall structure system	25-15-35/140	Exterior Wall Construction	21-02 20 10 20	May-12	July 2019 v1.6	Walls	EF_25_10			Reinforced concrete wall structure systems	Ss_25_11_16_70	IfcWallType.SOLIDWALL	
Nw_Wall_RC_Ext_MS_0.35	MS1 (e=0.35)	In situ reinforced concrete wall structure system	25-15-35/140	Exterior Wall Construction	21-02 20 10 20	May-12	July 2019 v1.6	Walls	EF_25_10			Reinforced concrete wall structure systems	Ss_25_11_16_70	IfcWallType.SOLIDWALL	
Nw_Wall_RC_Ext_MS_0.20	MS2 (e=0.20)	In situ reinforced concrete wall structure system	25-15-35/140	Exterior Wall Construction	21-02 20 10 20	May-12	July 2019 v1.6	Walls	EF_25_10			Reinforced concrete wall structure systems	Ss_25_11_16_70	IfcWallType.SOLIDWALL	

APPENDIX 2: MODELLING OF STRUCTURAL ELEMENTS

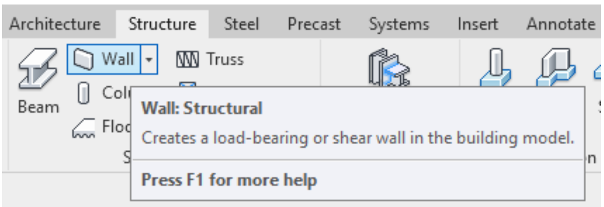
The “Modelling of structural elements” section describes the standard modelling approach for major structural elements of the BIM structural model.

1.1 Foundations:

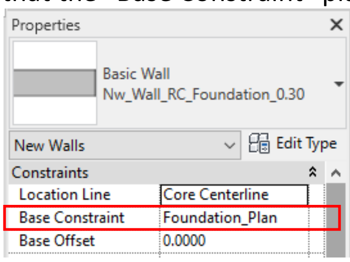


1) Foundation walls

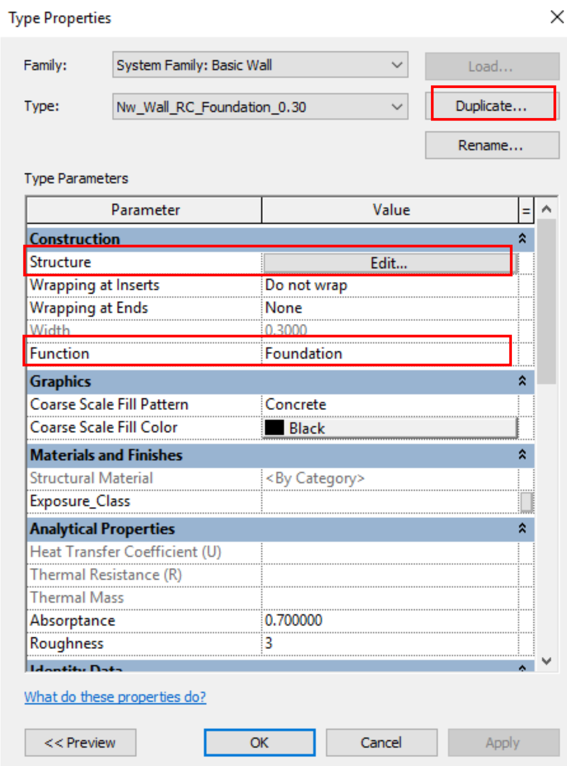
1- The setting up of the foundation wall starts from thickness, then adding it to the base of the model underneath the exterior architectural walls.
2- From the “Structure” tab → choose “Wall” type → select the required Foundation wall family.



3- The modeler should ensure that the “Base Constraint” plan is the foundation plan.

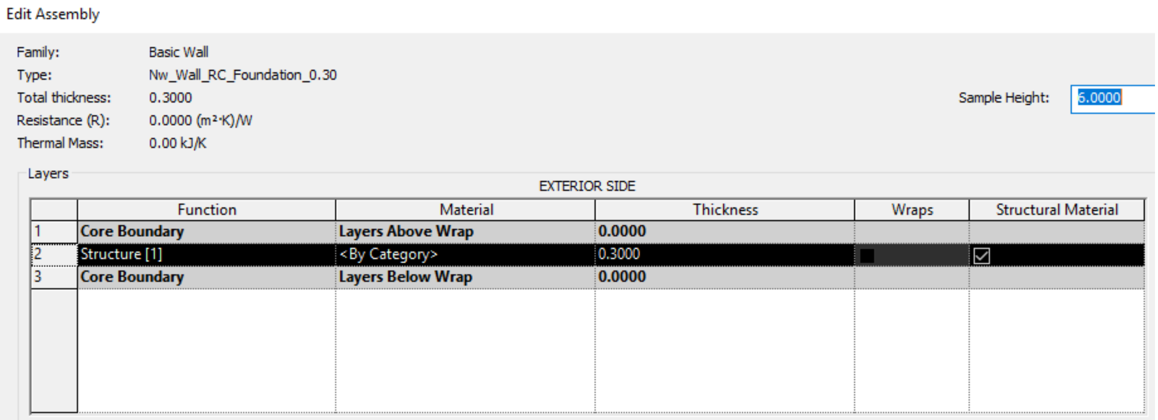


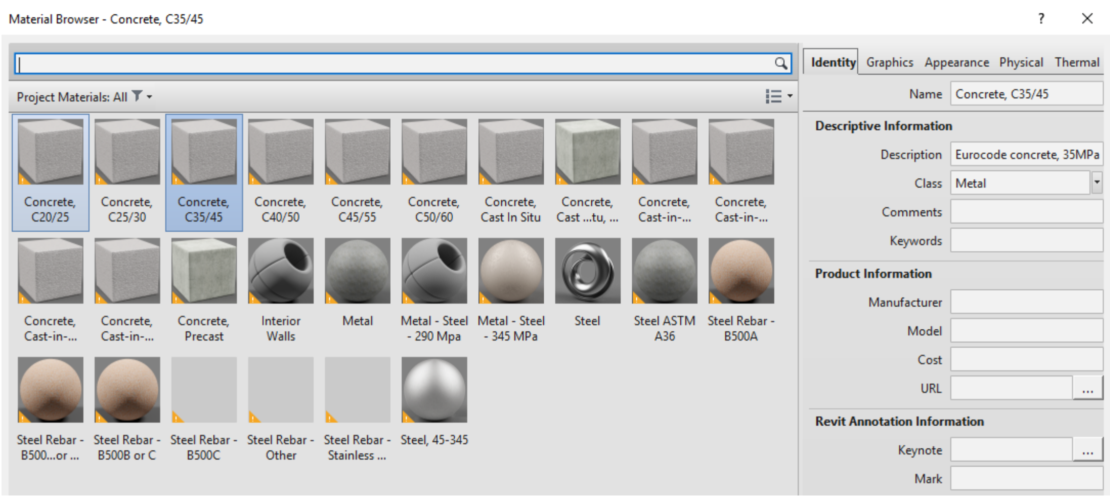
4- To create a new type of foundation wall, from “Properties” box → pick “Edit Type” → pick “Duplicate” → pick “Edit” to change the “Structure” parameter.
5- The modeler should ensure that the function of the wall is “Foundation”.



6- To create a new thickness ➔ change the “Thickness” of the “Structure” function.

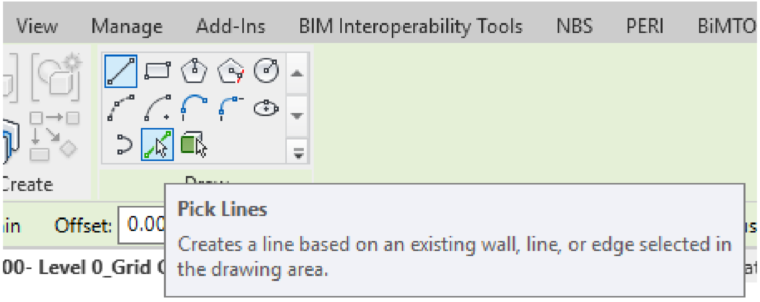
7- To change the material ➔ pick “By Category” and choose the required material from “Material Browser.”





8- From “Modify I Place Structural Wall” → modify the “Level” and the “Location line”. And from “Draw” panel, choose “Pick Lines” and select center lines of the perimeter of the architectural model.

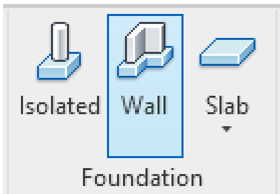
9- And from “Draw” panel, choose “Pick Lines” and select center lines of the perimeter of the architectural model.



2) *Wall footings “Strip footing”*

1- Wall footing is a strip footing that is hosted to foundation wall.

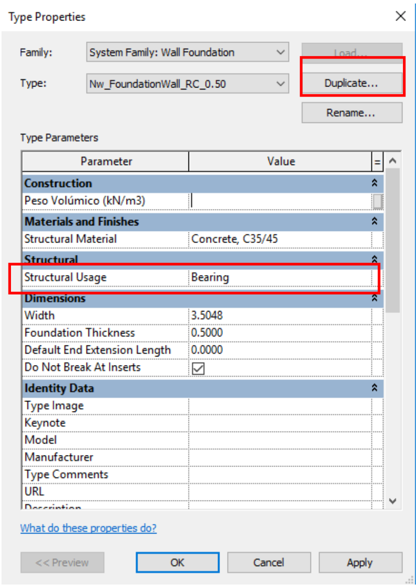
2- To add a wall footing, from “Project Browser” box → select the foundation level plan → from “Structure” tab → choose “Wall”  command from “Foundation” panel or type “F+T”.

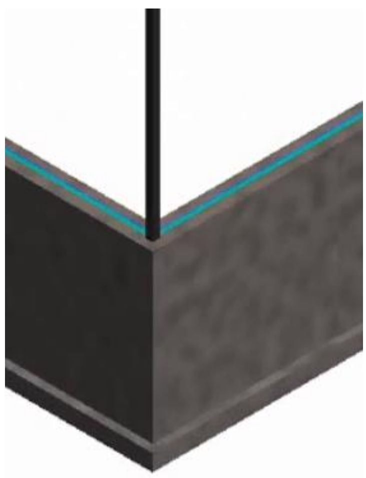


3- Choose the required foundation wall family → pick “Edit Type” → “Duplicate” to add new type with new dimensions and a new structural material.

4- The modeler should ensure that the structural usage is “Bearing”.

5- Select the foundation wall and it is going to place a footing underneath all the walls that are joined.

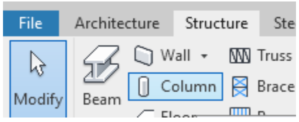


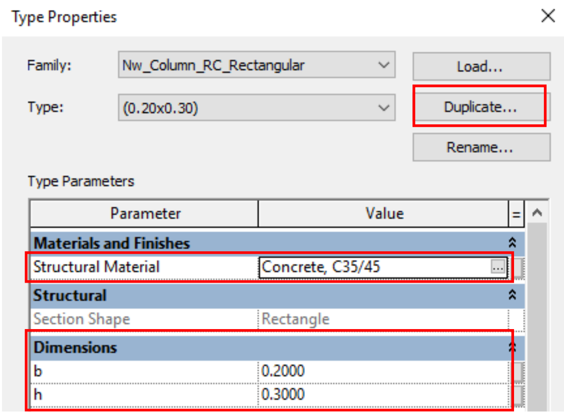


3) *Piers and Pilasters*

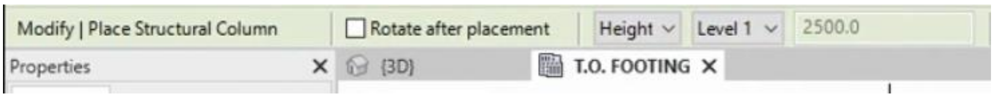
1- Piers and pilasters are considered columns in Revit, so we will use existing concrete column and modify it to become a pier.

2- Starting from “Project Browser” select the foundation level plan ➔ from “Structure” tab, ➔ choose “Column” ➔ choose the required concrete column family ➔ pick “Edit Type” ➔ pick “Duplicate” to add new type with new dimensions and a new structural material.

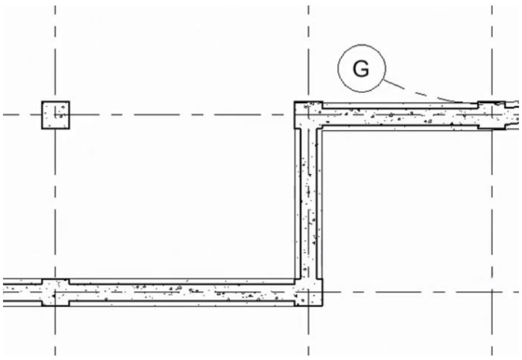


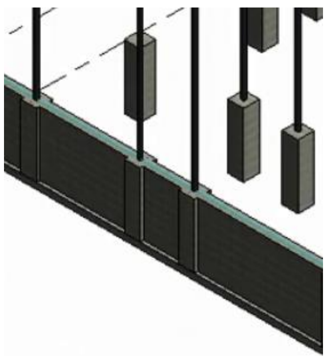


3- Then from “Modify I Place Structural Column” ➔ choose “Height” and the column to reach “Level 1”.



4- Pick the location of the piers and pilasters as the setting of the ordinary columns and the modeler should ensure that the material of the foundation wall, strip footings, piers and pilasters are the same.



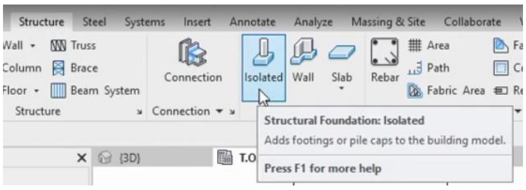


4) *Isolated footing & Piles*

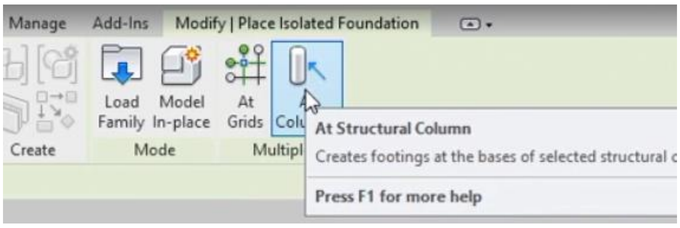
1- Piers and pilasters need something to bear on as well, this is way Revit has isolated footings. Like the strip footing, isolated footing is a bearing element for other foundation systems.

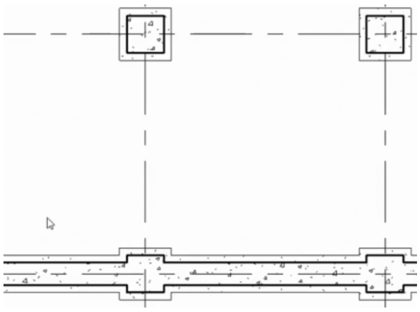
2- Starting from “Project Browser”, under structural plans ➔ select the foundation level plan ➔ from “Structure” tab ➔ choose “Isolated” command in “Foundation” panel ➔ choose the required footing family ➔ pick “Edit Type” ➔ pick “Duplicate” to add new type with new dimensions and a new structural material.

3- The modeler should ensure that it has the same other foundation elements material.



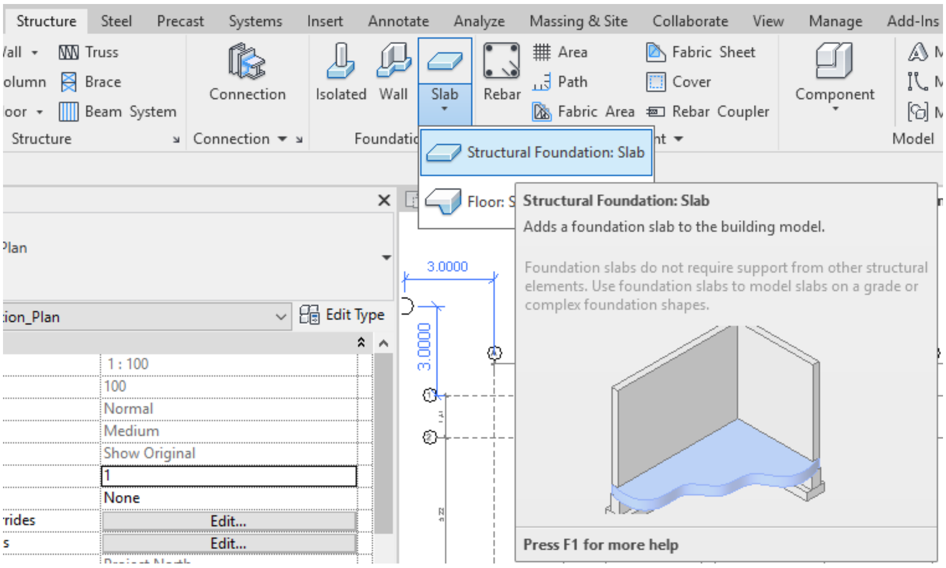
4- After editing the type, choose from “Modify” tab “At Column” command and select the desired columns to have the isolated footing or piles.



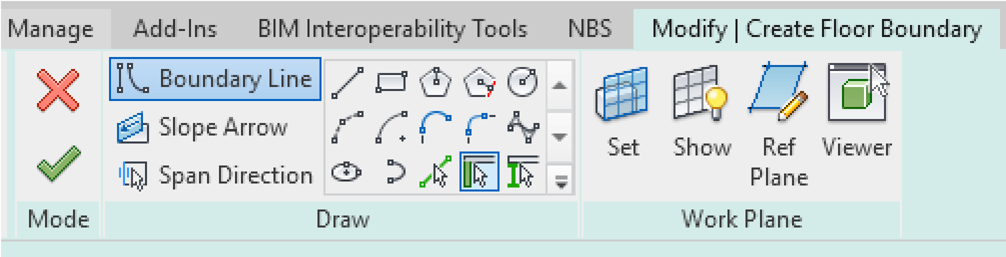


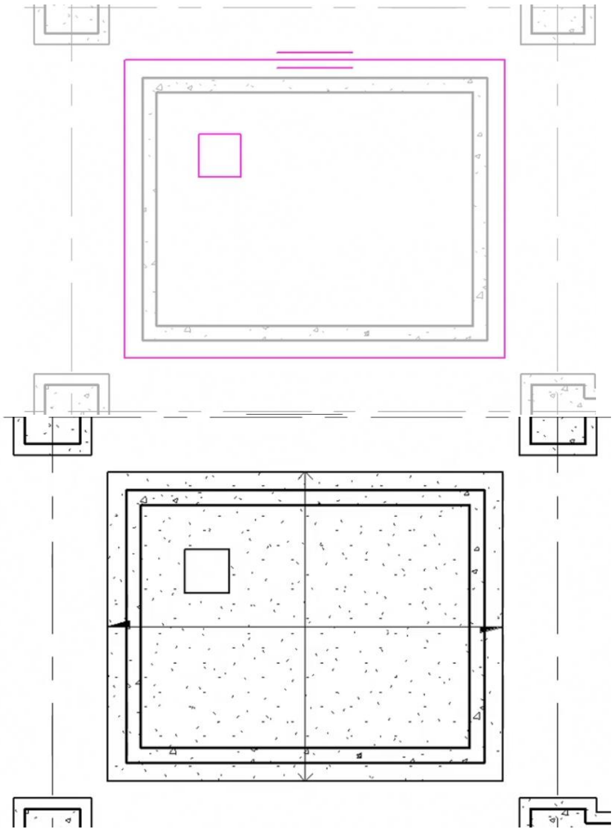
5) *Foundation Slab*

1- Starting from “Project Browser”, under structural plans → select the foundation level plan → from “Structure” tab → choose “Slab” command in “Foundation” panel → choose the required footing family → pick “Edit Type” → pick “Duplicate” to add new type with new dimensions and a new structural material.



2- Then set the boundary lines through picking walls or picking lines.

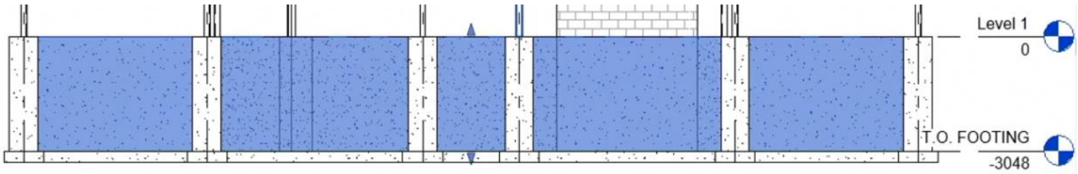




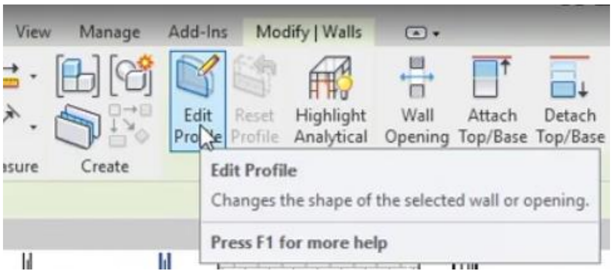
6) *Step footings*

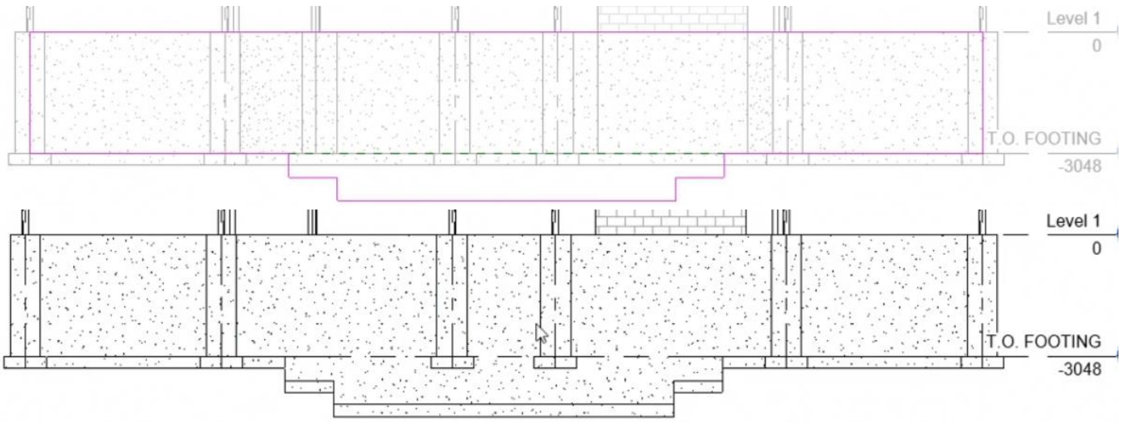
1- After modelling the foundation wall, we can create step footing foundation through editing the profile of foundation wall.

2- Starting from "Project Browser" → select the elevation view contains the foundation wall need to be stepped. To add the foundation wall → select it.

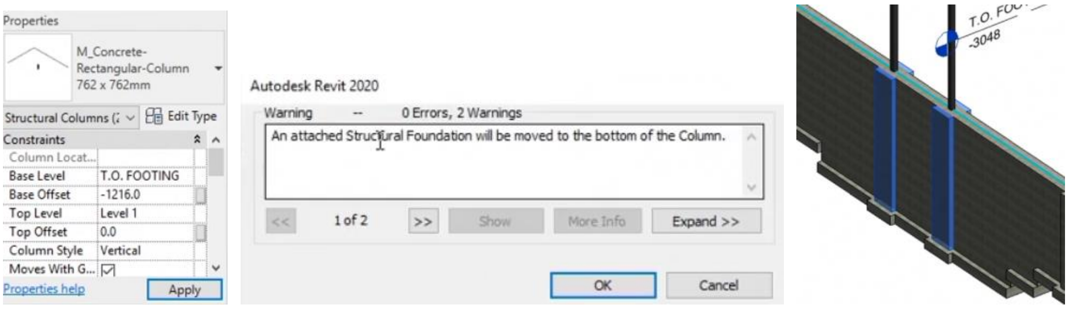


3- From "Mode" tab → choose "Edit Profile" → edit it by the required step footing profile.

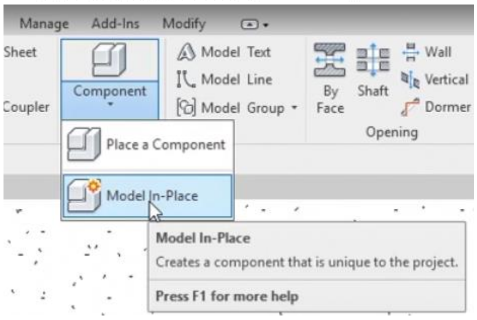




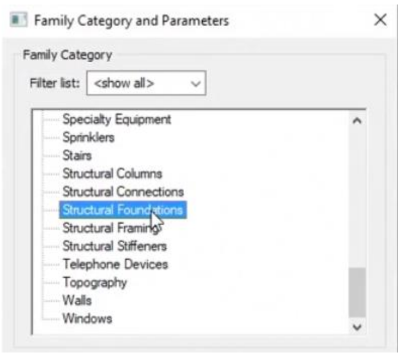
4- Then modify the base offset of piers to get the bottom of the piers attach with the bottom of foundation.



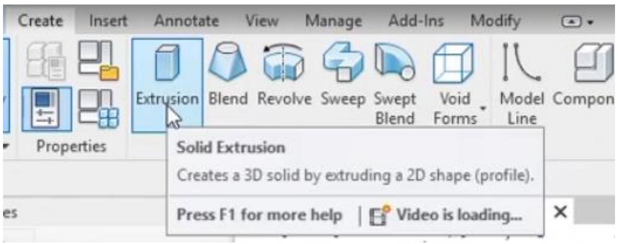
5- Fill the chunk of concrete that is needed in the corners. From the "Structure" tab → choose "Model In-Place" from "Component" command.

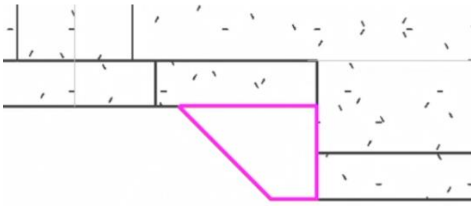


6- Choose "Structural Foundation" → edit the step footing.

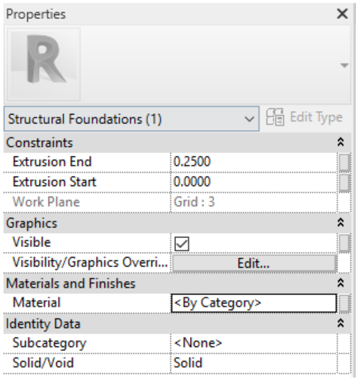


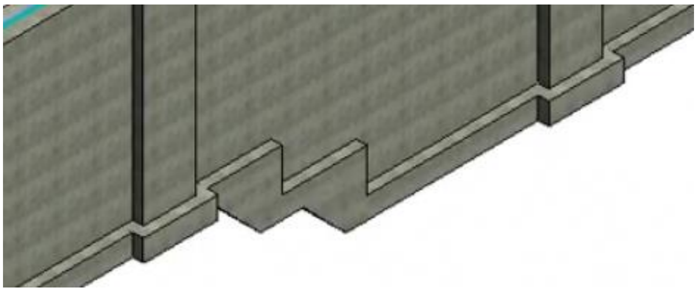
7- Click "Extrusion" command → choose "Pick a plane" in "Work plan" box → pick the plan → draw the element.





8- Change the properties of the extrusion, by modifying the “Extrusion End” to be the same width of footing → define its Material to be the same as the step footing → After finishing the model, select “Join” from “Modify” tab to join the extrusion with the existing step footing.





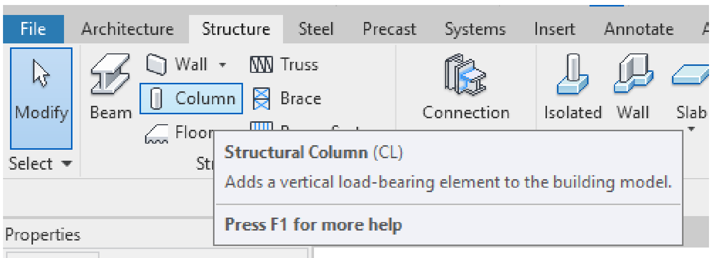
1.2 Columns

1) Modelling approach

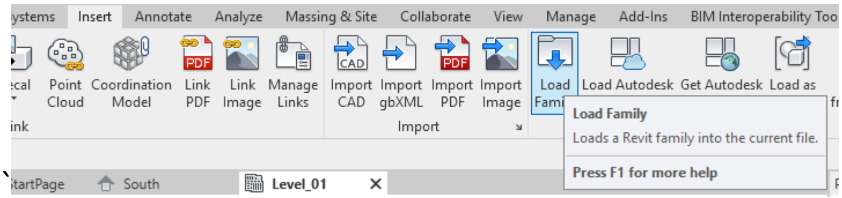
1- With a structural grid in place, adding columns is a snap. Also, when we add a column, we must specify the height of the columns as we are adding them.

2- All columns / post / hanger should be modeled with appropriate Structural Column category family elements selected according to their sectional shape.

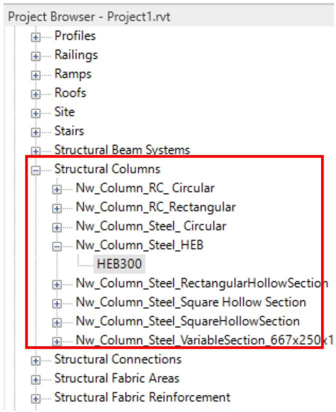
3- From “Structure” tab → choose “Column” command or type “C+L” to insert a structural column to the model.



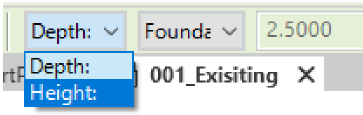
4- To load a specific structural column family, choose “Load Family” command from “Insert” tab → choose the required structural column from Newton Library.

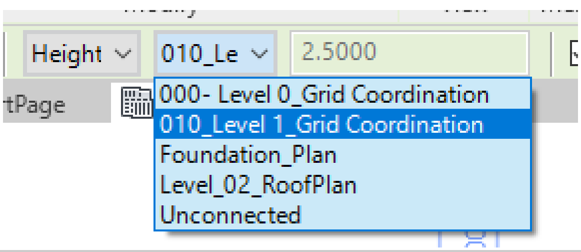


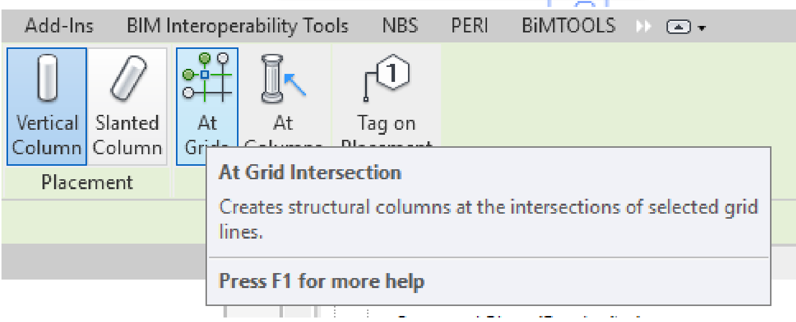
5- Or you can just drag and drop the required structural column type from the “Families” list in the “Project Browser”.



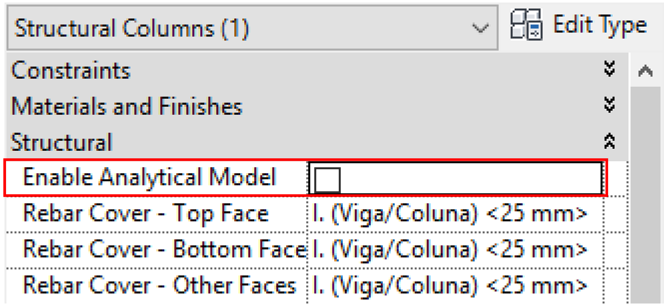
6- To insert columns, change the command “Depth” to be “Height” and this height goes up to the desired level ➔ pick on the required location of column “the intersection of HZ & VL grids” or use the command “At Grids” and select all the grids you want to insert columns on their intersections.



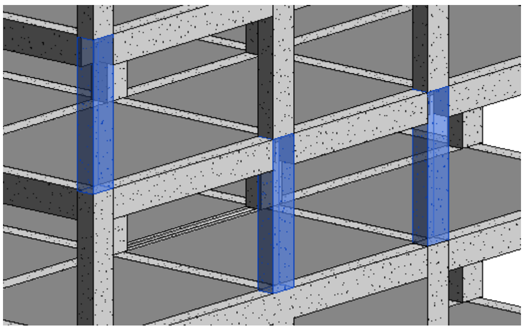


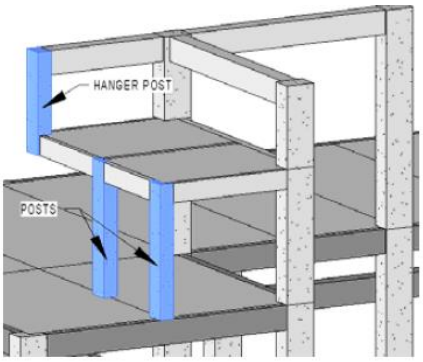


7- For those elements not to be included into the building structure analytical model ➔ modeler should uncheck the element instance property “Enable Analytical Model” check box.

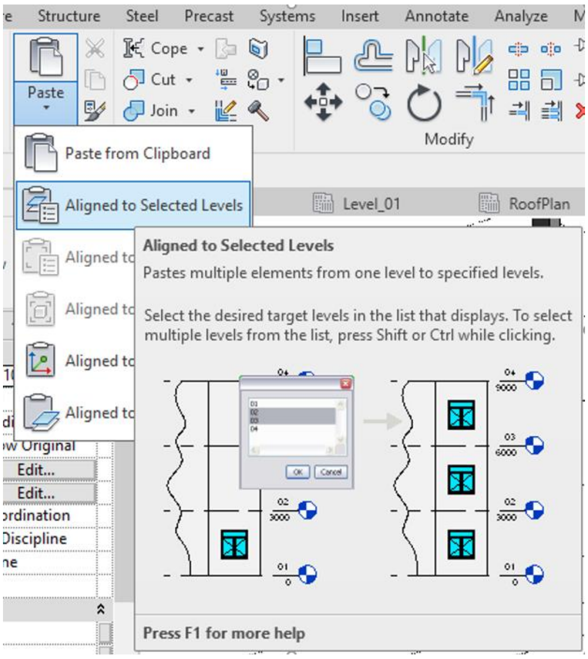


8- All columns should be defined between the levels ***"floor by floor"*** where they serve as support for other elements and top of their supporting elements (like top of the column / wall / beam and foundation below), with required level offsets, even if the cross section does not change across different floors. by this way, it is possible to obtain an automatic measurements of columns per floor, as well as to obtain nodes "points" in the analytical model at the different floor levels. However, there may be exceptional situations in which this rule cannot be applied. In this case, the modeler must explain the situation with the BIM Coordinator and the structural engineer responsible for the project.

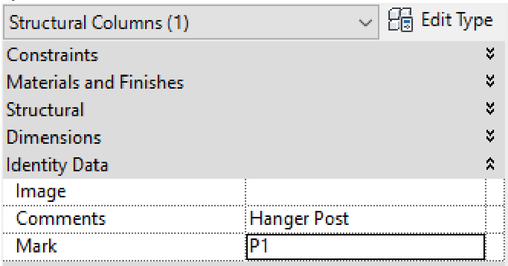




9- To model the concrete column across different levels, use the command "Copy to Clipboard" in "Modify" tab, which allows you to copy the element → use "Paste" command on the same tab with "Aligned to Selected Levels" → choose the floors you want to repeat the columns.

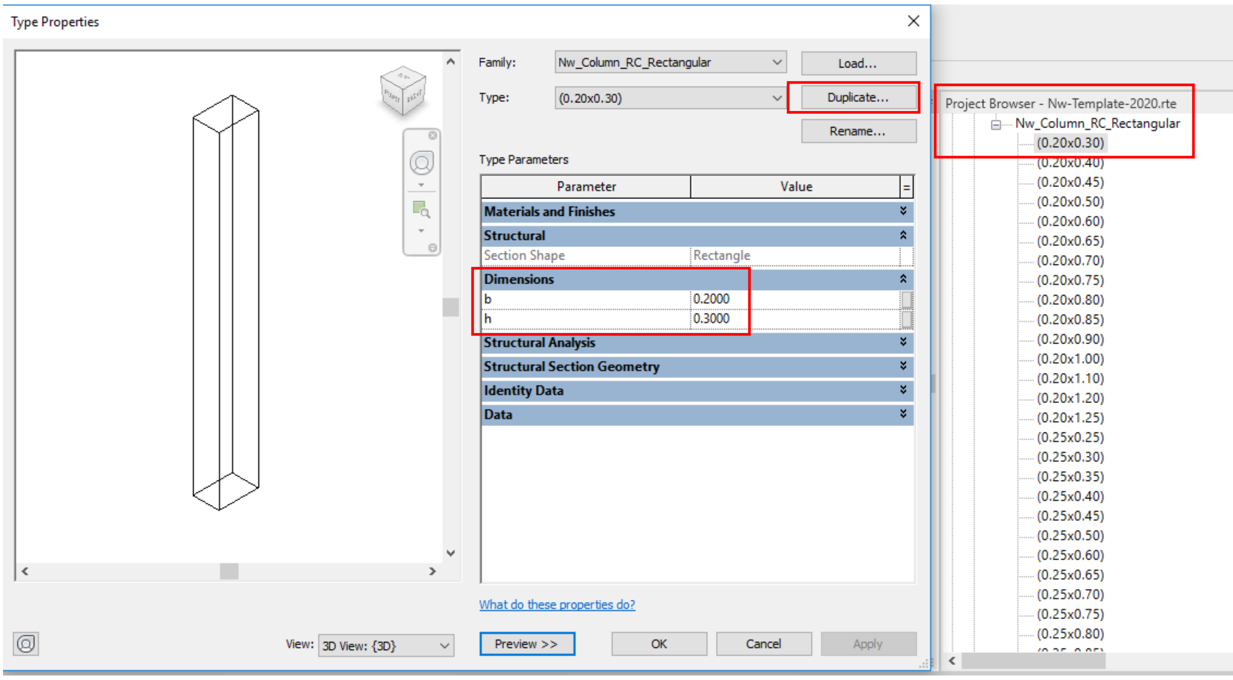


10- A descriptive Comments like “Hanger post” and “Post” is advised to be added to the Comment properties for those elements which are not used as normal columns.

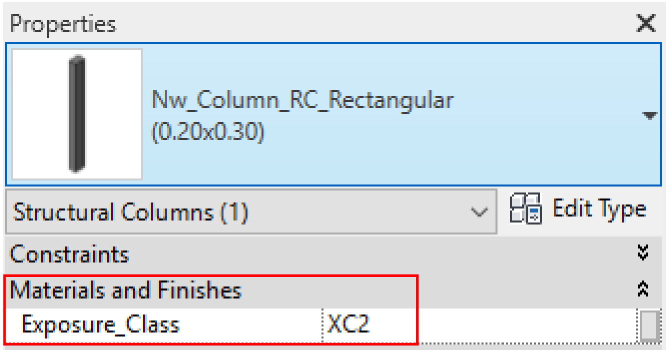


2) Structural Column Family Customization

1- For those element types not to be included in the column family types, the modeler should create a new column family type according to required design dimensions by “double clicking” on the column type to open the “Type properties” ➔ pick on “Duplicate” to add the new type ➔ change the naming of the new type to follow the naming convention of the column types ➔ change the column dimensions values to the new column dimensions “b & h”.



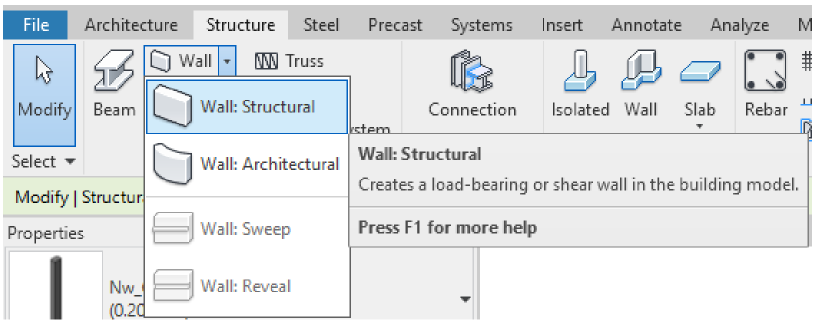
2- For each column instance, it is the modeler responsibility to change the Exposure Class of the column according to design.

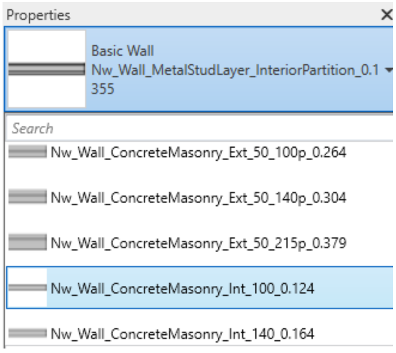


1.3 Walls

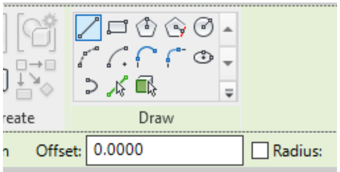
1) Modelling approach:

1- From "Structure" tab, choose "Wall" command to create a structural wall to the model ➔ Wall dropdown list ➔ Structural Wall ➔ Choose from "Properties" the wall type that you need.

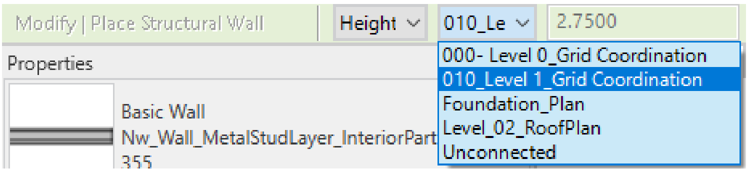




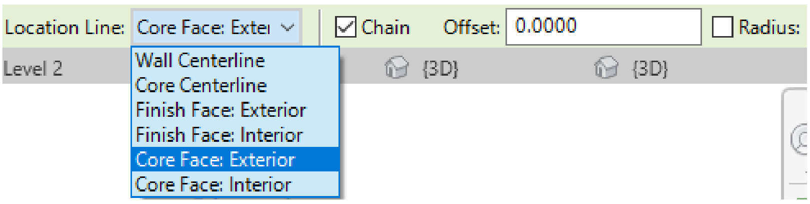
2- From "Modify I Place Structural Wall" → Choose line or any draw tools from the "Draw" panel.



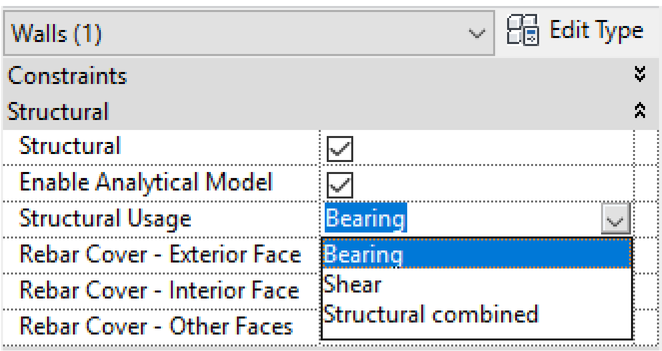
3- To insert wall, change the command "Depth" to be "Height" and this height goes up to the desired level. Or select "Depth" and the base level of the wall.



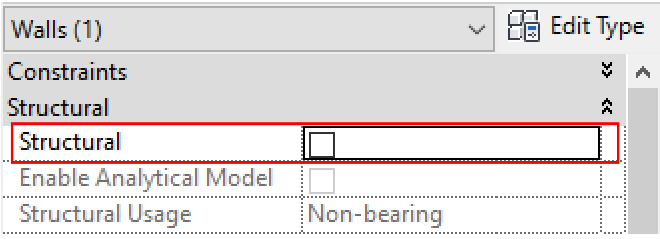
4- From the Option bar define the appropriate "Location Line" of the wall "Core Face: Exterior" or "Core Face: Interior. Also, check "Chain" to create a series of walls → set "Offset" to 0.0 and leave "Radius" unchecked as appropriate.



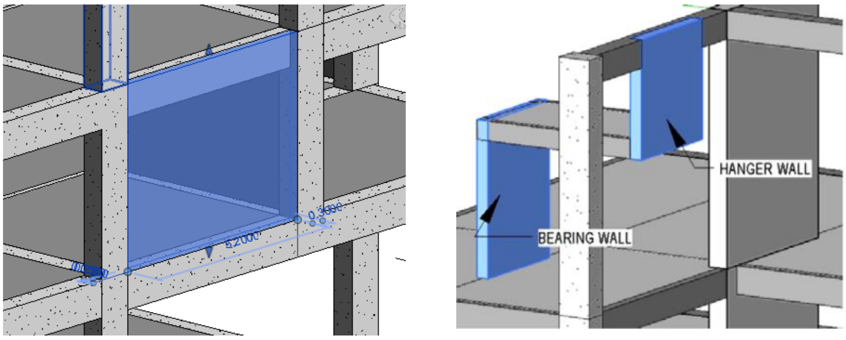
5- All walls **"Shear / Core / Bearing / Hanger / Stub and Parapets"** should be modeled with appropriate types from Basic Wall category family with its Structural Usage property.



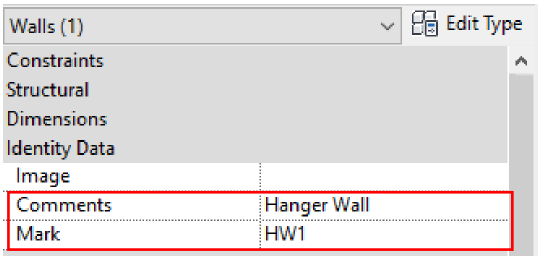
6- For those elements not to be included in analytical model, modeler should uncheck the element property “Structural” check box and the Structural Usage will be “Non-bearing” by default.



7- All walls should be defined with Top and Base Constraints between the levels ***“floor by floor”*** where they serve as support for other elements and top of their supporting elements. The top-level of walls should be extended to the top of slabs being supported instead of to the bottom of slab elements only.



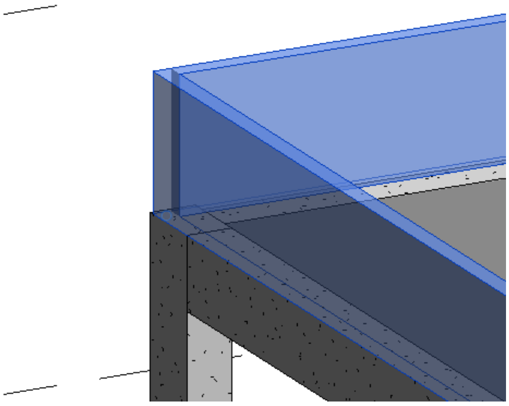
8- Description comments like “Hanger wall” and “Bearing wall” are required to be added to the Comment properties of wall such that their structural usage can be identified.

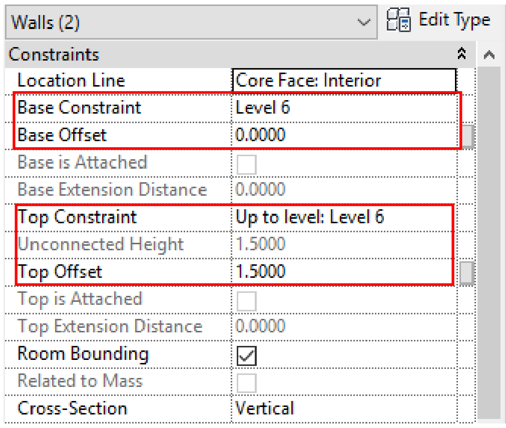


2) Parapet Walls:

1- the base Level and the top Level should be assigned with identical level together with the Top Offset made equal to the required parapet height.

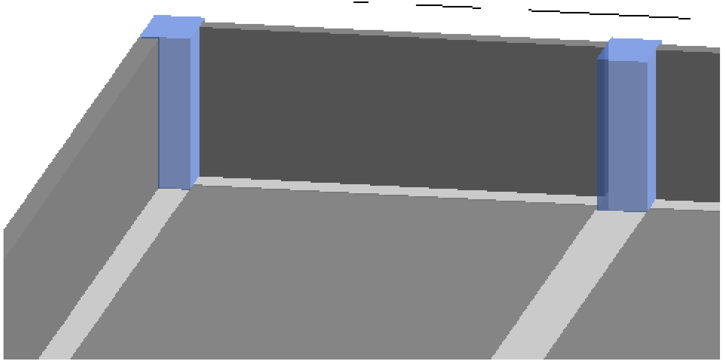
2- Parapet wall should be included into the story model in which the parapet wall is attached.

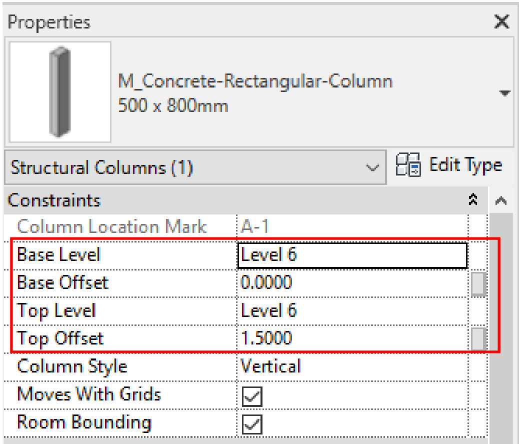


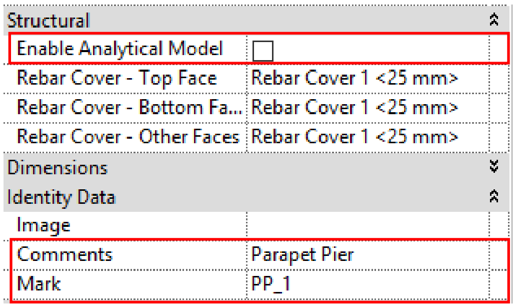


3) *Parapet walls with piers:*

1- the parapet walls should be modeled as individual walls spanned between pier edges and the pier should be modeled with structural column family element.
2- Like the parapet wall, both top level and base level of piers should be assigned with identical level with the Top which equals to the required parapet height.
3- The “Enable Analytical Model” property box should be unchecked.
4- The description “Parapet Pier” to be written the comments property.

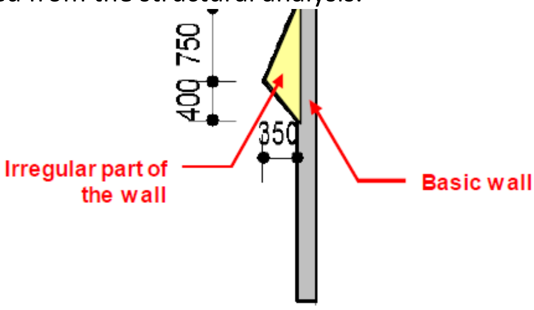






4) *Irregular Shaped wall Modelling Approach:*

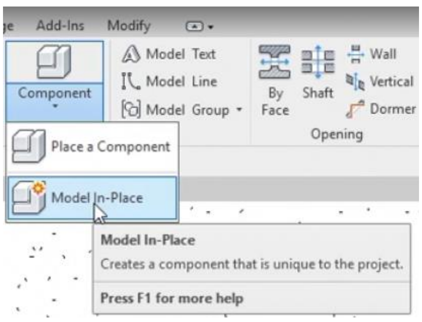
1- The main issue of modelling an irregular-shaped structural wall is that the irregular part will be neglected from the structural analysis.



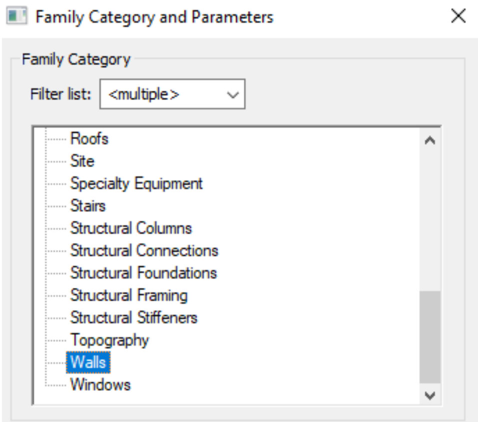
2- The basic wall element, without the irregular part, will be modeled by the ordinary way as mentioned before in sub-section 1.

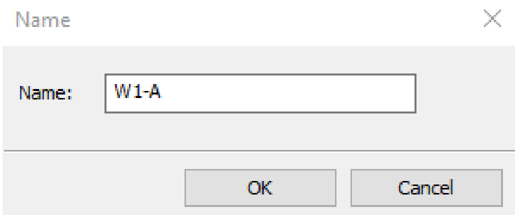
3- To model the irregular part, the modeler should create In-Place Model.

4- From the “Structure” tab → choose “Component” dropdown list → “Model In-Place” .

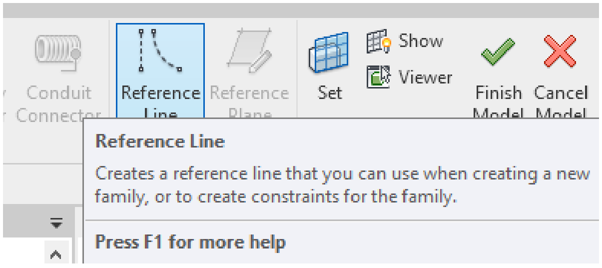


5- From Family Category and Parameters dialog → select Walls for Family Category → Click OK → From Name dialog, type the name for “in-place mode”, preferably same as the basic wall → Click OK.

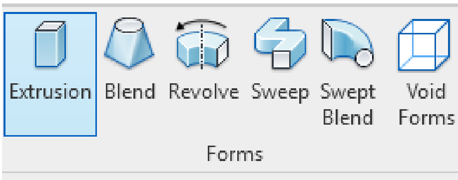


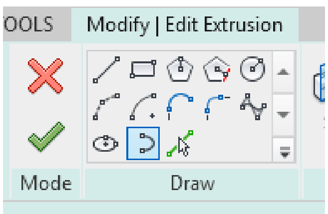


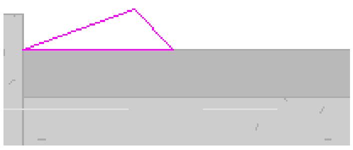
6- The modeler could use reference lines and dimensions to help in the sketching of the shape of the irregular part of the wall. From “Datum” panel → choose “Reference Line” → choose the suite tool under “Modify I Place Reference Lines” tag → Draw panel to sketch the reference line.



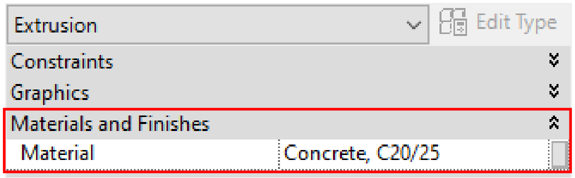
7- To Create the outline of the irregular part of the wall, from “Forms panel” → choose “Extrusion” → Choose appropriate draw tool to sketch the profile for the irregular part of the wall from “Modify I Create Extrusion” tag → “Draw” panel.



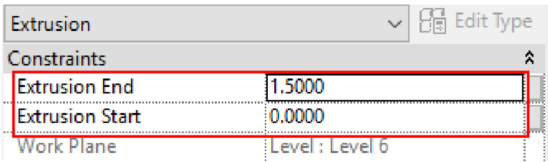




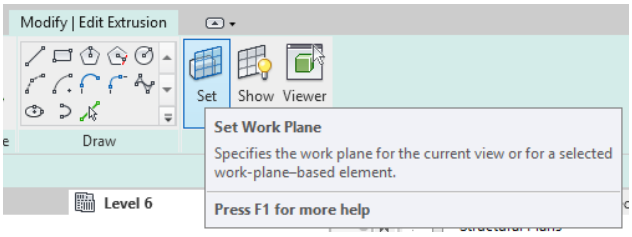
8- In the Properties box, select the required "Material" to be the same of the material of the basic wall.

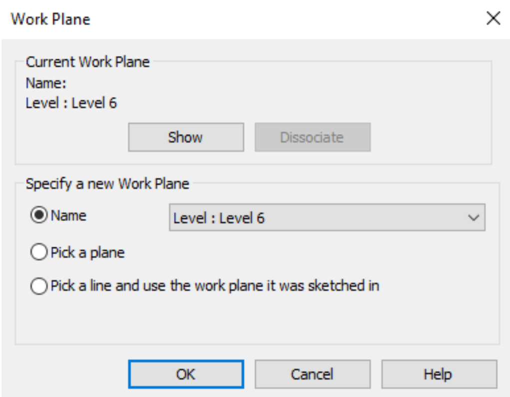


9- Ensure that the Work Plane "the bottom level of the wall" shown in the Properties box is at the level decided and the "Extrusion End" to be the same height of the wall.



10- Otherwise reset it using the tool in "Modify I create Extrusion tag" → "Work Plane panel" → choose "Set" → pick on the desired bottom level of the irregular wall.

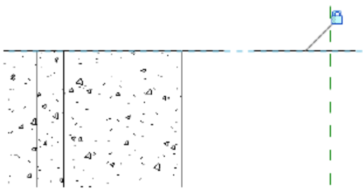




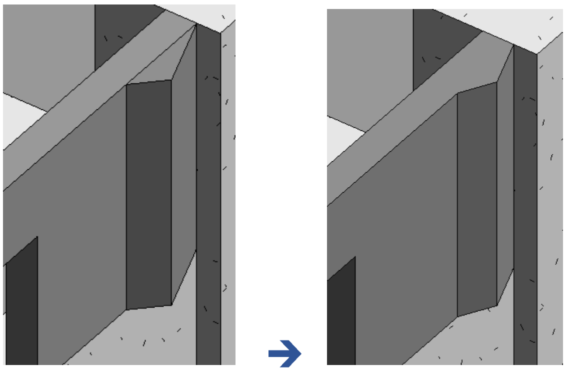
11- Click "Modify I Create Extrusion" tag → Mode panel → "Finish Edit Mode" ✓ to finish.

12- To align the top edge of the extrusion to the upper floor level, click "Modify I Walls" tag → "Modify panel" → "Align".

13- To create a constraint between the top edge and the aligned level, click the lock shown above the floor level line.



14- To join the Extrusion with the Basic wall, click “Modify” tag → “Geometry panel” → “Join ” dropdown list → “Join Geometry ”.

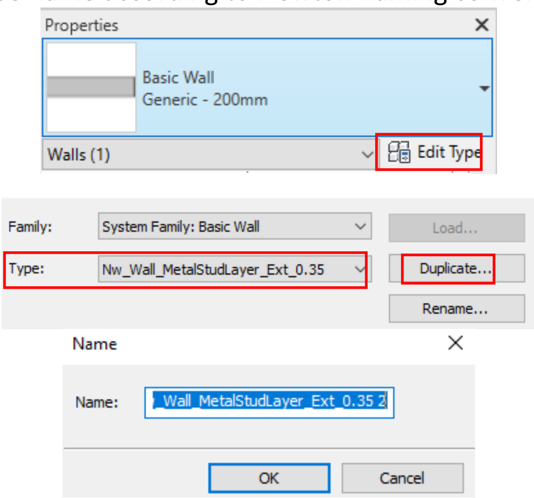


5) *Structural Wall Family Customization:*

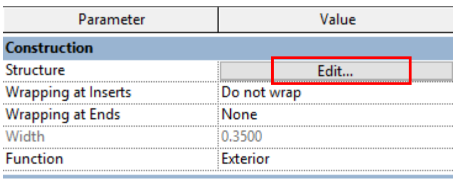
1- The Structural Wall is a system family which means that the family file cannot be created for wall, but it could be defined as a new wall type for individual models.

2- Some commonly used wall types have already defined in the Newton model template. For those wall types are not included in the walls system family, the modeler should create a new wall type according to required design aspects.

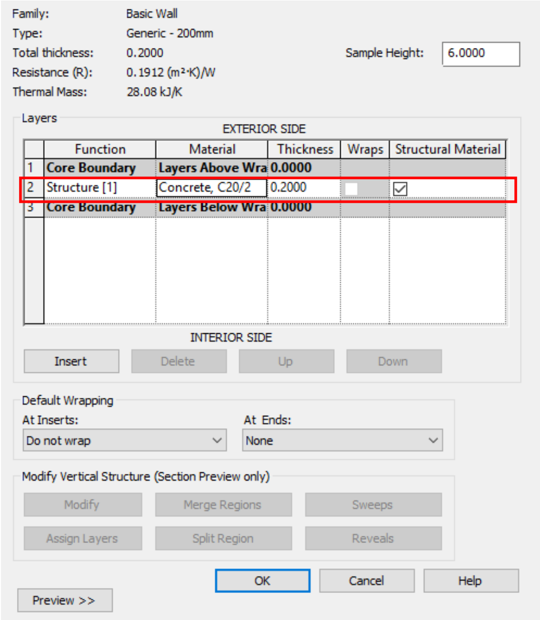
3- To create a new wall type, pick on “Edit Type” from “Properties” box → choose the Type that you want to edit → pick “Duplicate” to create a new wall type → Change the new wall type name according to Newton naming convention.



4- Click “Edit” for “Structure “property.



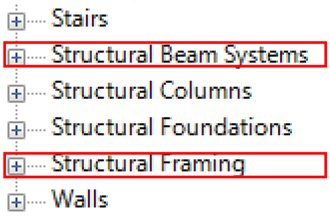
5- Change the “Material” of “Structure” and the “Thickness” to required value in the Edit Assembly dialog → click “OK”.



1.4 Beams

1) Modelling approach:

1- All beams should be modeled with appropriate family type from “Structural Framing” or “Structural Beam System” category families.

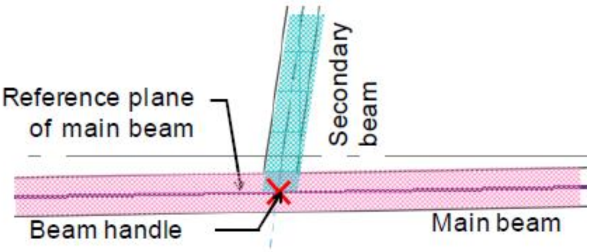


2- All continuous beams should be modeled “***span by span***”.

3- All beams should be connected to their supports by one of the following methods:

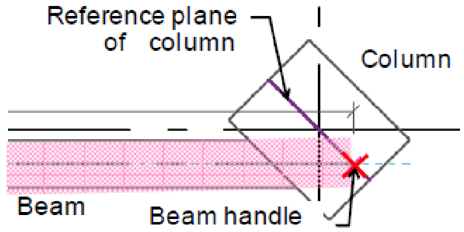
a. <u>Secondary beam rested on Main beam:</u>

The handle of the beam should be connected to the reference plane of its supporting beams. Normally, it is defined along the center of a Structural Framing family.



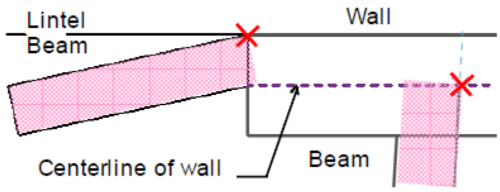
b. <u>Beam rested on Column:</u>

Beam supported on column should model with its end handle attached to any one of the reference planes of the column. Normally, they are along the major and minor axes of the column section.

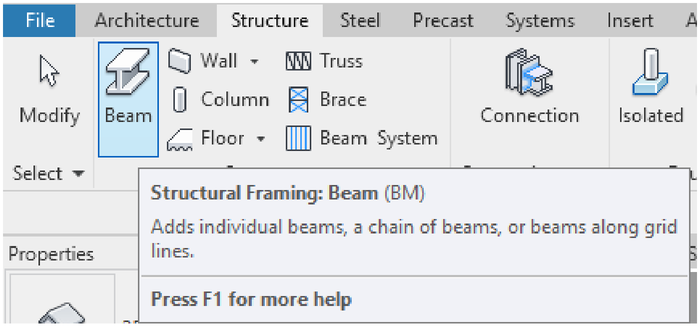


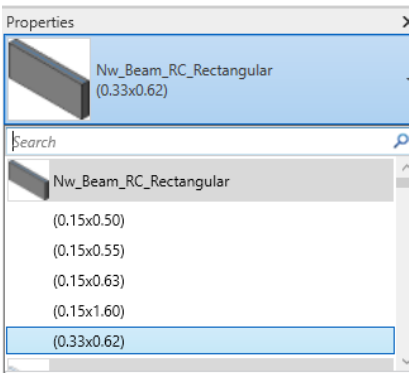
c. Wall

In general, the handle of the beam should connect to the centerline of its wall support except lintel beam which can be joined to the end of the wall. In the latter case, the beam handle can attach to edge of the wall end.

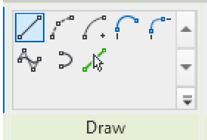


4- To model a regular Beam, from "Structure" tab → choose "Beam" command to insert a structural beam to the model → Choose from "Properties" the wall type that you need.

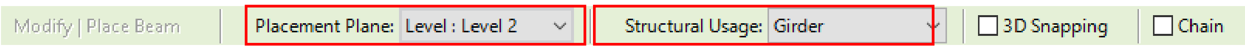




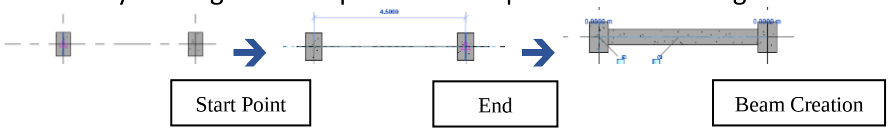
5- From "Modify I Place Beam" → Choose line or any draw tools from the "Draw" panel.



6- On the "Modify I Place Beam" Option bar → choose the desired level to create the beam by "Placement Plane" dropdown list and the "Structural Usage" of the beam.

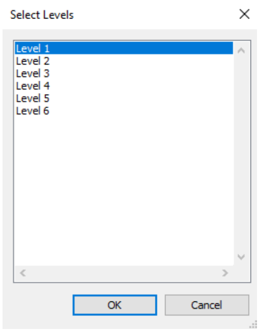


7- Sketch the beam by clicking the start point and endpoint in the drawing area.



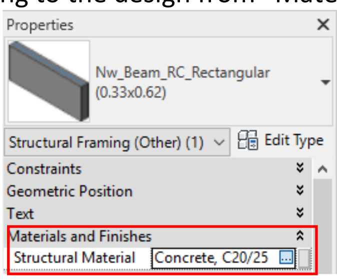
8- To align the side of the beam to the side of its supporter, click “Modify I Place Beam” tab → “Modify panel” → “Align” .

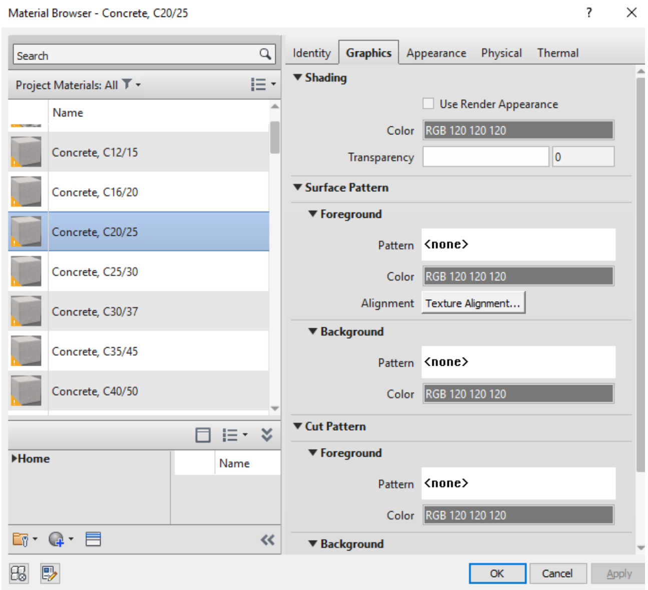
9- To model the beams across different levels, Select the desired beams → use “Modify” tab → the command “Copy to Clipboard ”, which allows you to copy the element → use “Paste” dropdown list on the same tab with “Aligned to Selected Levels ” → choose the floors you want to repeat the beams → “OK”.



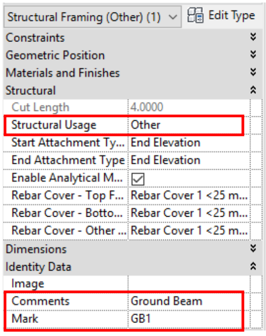
10- <u>To Modify the beam parameters</u>, Select the desired beam → change the parameters from “Properties” box:

(a) Change the “Structural Material” → pick the “...” → Choose the desired material according to the design from “Material Browser” box → “OK”.

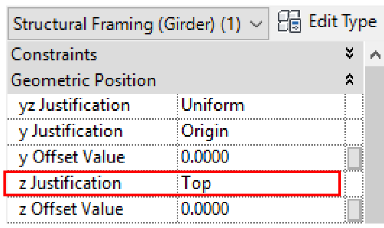


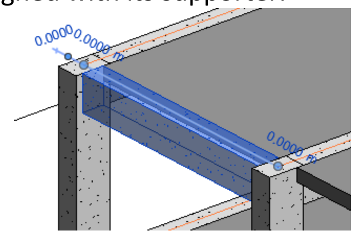


(b) To model special beams like cantilever, tie beam and ground beam, the modeler should from the "Structural Usage" dropdown list ➔ select "Other" ➔ specify the structural usage of the beam in the "Comments" which can facilitate other model user to sort out the elements according to their structural usage within a model.

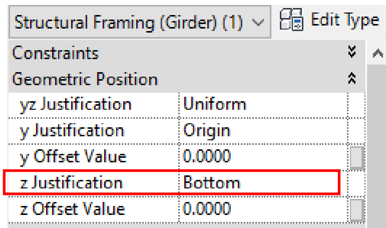


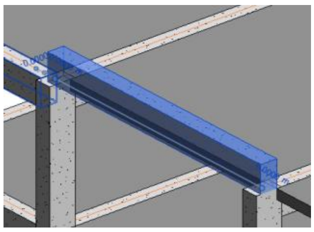
(c) The modeler should ensure that the "z Justification" value is "Top" which allows top surface of the beam to be aligned with its supporter.





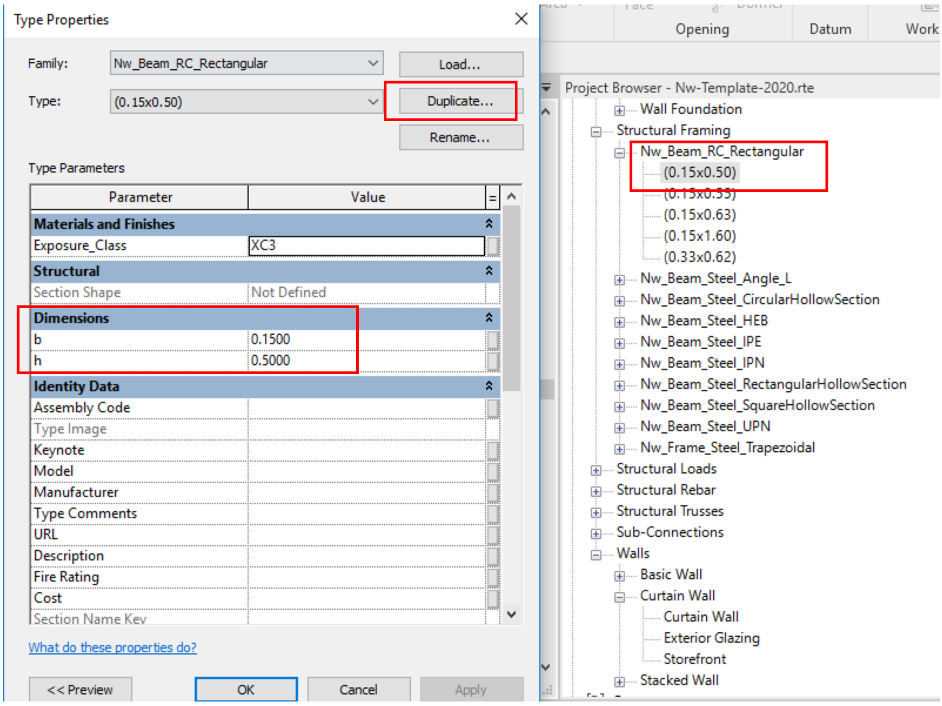
(d) To model inverted beam including lintel beam, from "z Justification" ➔ modeler should select "Bottom" instead of "Top" to align the beam with its supporter from the bottom surface.



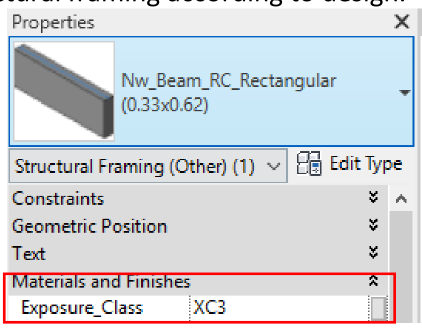


2) *Structural Framing Family Customization:*

1- For those element types not to be included in the column family types, the modeler should create a new structural framing family type according to required design dimensions by "double clicking" on the structural framing type in "Project Browser" box to open the "Type properties" box → pick on "Duplicate" to add the new type → change the naming of the new type to follow the naming convention of the structural framing types → change the new structural framing dimensions values to the new desired dimensions "b & h".



2- For each structural framing instance, it is the modeler responsibility to change the Exposure Class of the structural framing according to design.

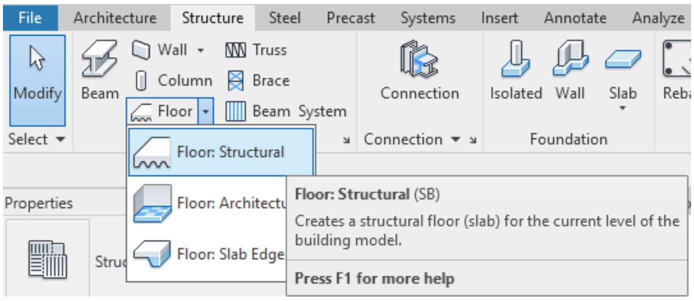


1.5 Slabs

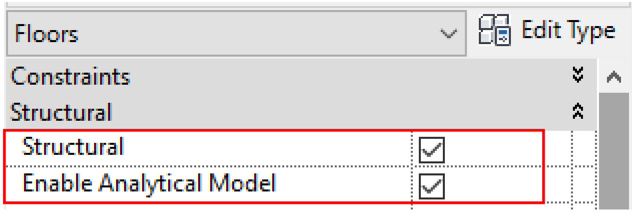
1) *Modelling approach:*

1- The modeler should choose appropriate types from "Floor" family according to the structural usage.

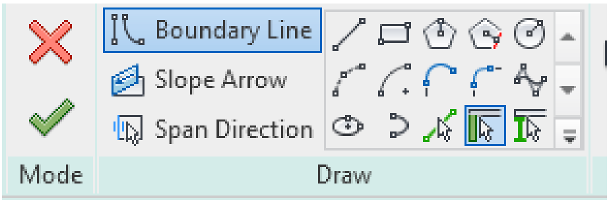
2- To model a slab, from "Structure" panel → choose "Floor" dropdown list → "Floor: Structural".



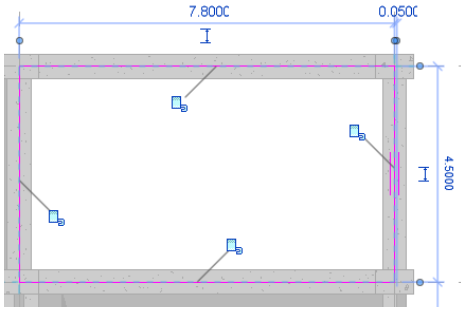
3- For the structural elements which included into the building analytical model, the modeler should check the "Structural" check box and "Enable Analytical Model" check box.
4- For those elements not to be included into the building structure analytical model, the element property "Structural" check box and "Enable Analytical Model" check box should be unchecked.

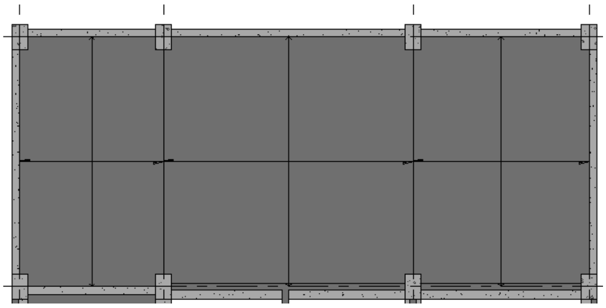


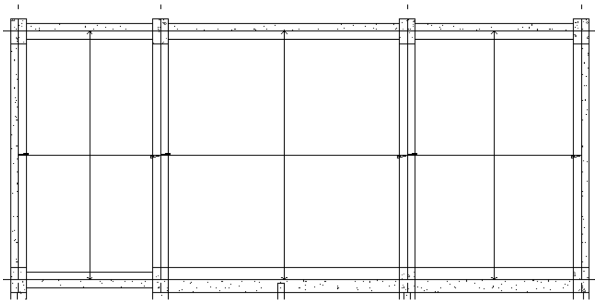
5- From "Modify I Create Floor Boundary" → Choose the "Boundary line" by any draw tools from the "Draw" panel.



6- All slab elements should be modeled ***"panel by panel"***.
7- For all Suspended slabs "One-way slabs & Two-way slabs" boundaries should be defined as follow:
(a) The boundaries of the slab to be aligned with <u>the center lines of the supporting elements</u> "Walls & Beams".
(b) The boundaries of the slab to be aligned with <u>the edge of the supporting slab</u>.



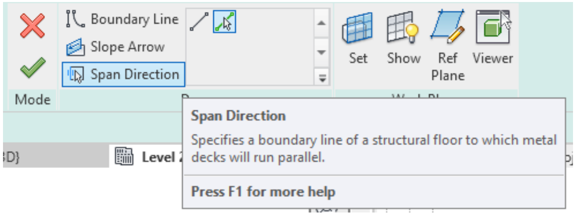




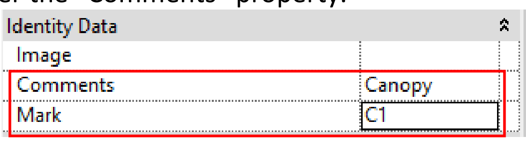
8- For flat slabs floor system boundaries should be located at the centers of the supporting columns.

9- The modeler should use from "Modify I Floors" → "Geometry" panel "Join" to eliminate the solid lines between the slab's panels.

10- The modeler should ensure the correct "Span Direction" for one-way slabs, from "Modify I Edit Boundary" → "Span Direction" → Pick the direction of the one-way slab.



11- The modeler should specify the slab elements according to their usage to facilitate the QTO process under the "Comments" property.

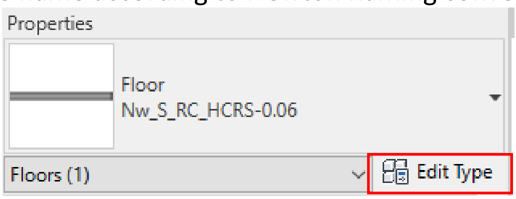


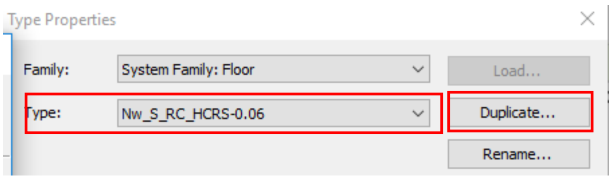
2) Structural Floor family customization:

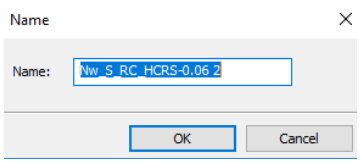
1- The Structural Floor is a system family which means that the family file cannot be created for Floor, but it could be defined as a new floor type for individual models.

2- Some commonly used floor types have already defined in the Newton model template. For those floor types are not included in the floors system family, the modeler should create a new floor type according to required design aspects.

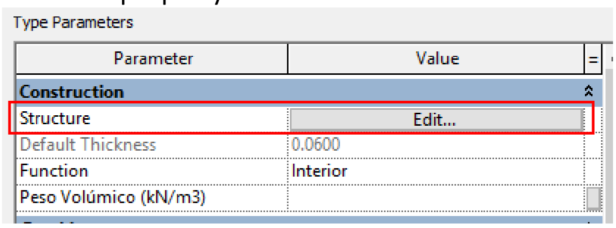
3- To create a new floor type, pick on "Edit Type" from "Properties" box ➔ choose the Type that you want to edit ➔ pick "Duplicate" to create a new wall type ➔ Change the new wall type name according to Newton naming convention.



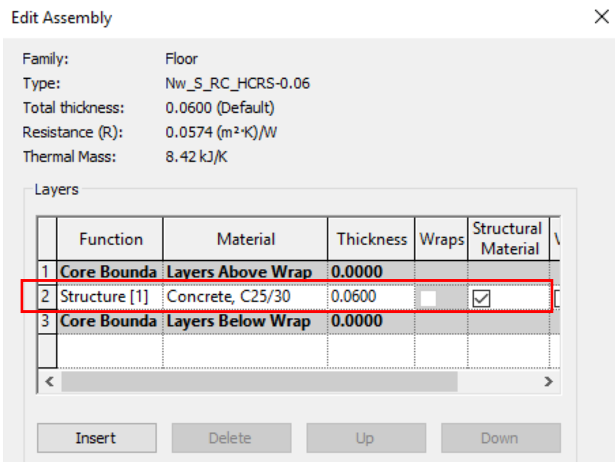




4- Click "Edit" for "Structure "property.



5- Change the "Material" of "Structure" and the "Thickness" to required value in the Edit Assembly dialog ➔ click "OK".



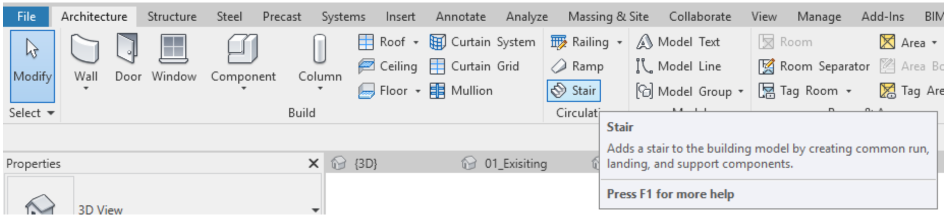
1.6 Staircases:

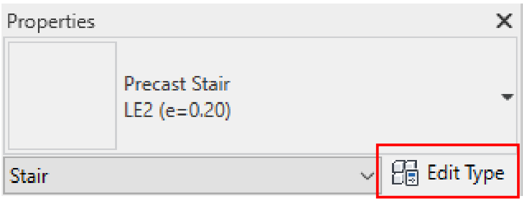
1) Modelling approach

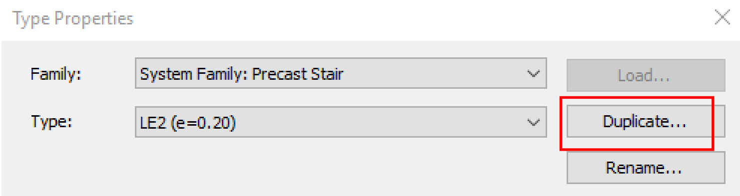
1- The elements modeled by Stair family is belonged to architectural model elements not the structural one.

2- All staircases are to be modeled as a composition of landings and stair flights.

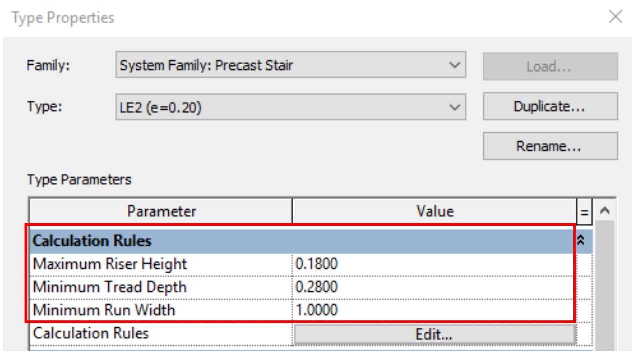
3- From "Architecture" tap → choose "Stair" → choose the desired stairs type from "Properties" box → Edit type → Duplicate from "Type Properties" box to create a new type with the desired dimensions according to the Newton naming convention.



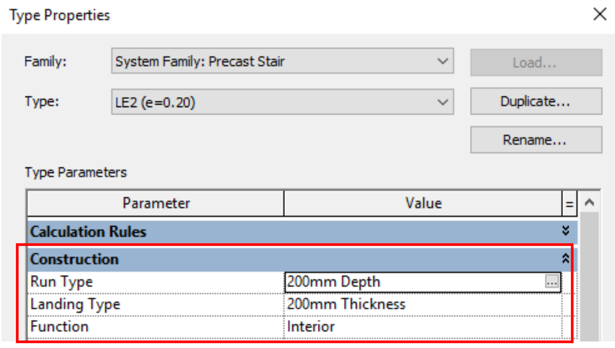




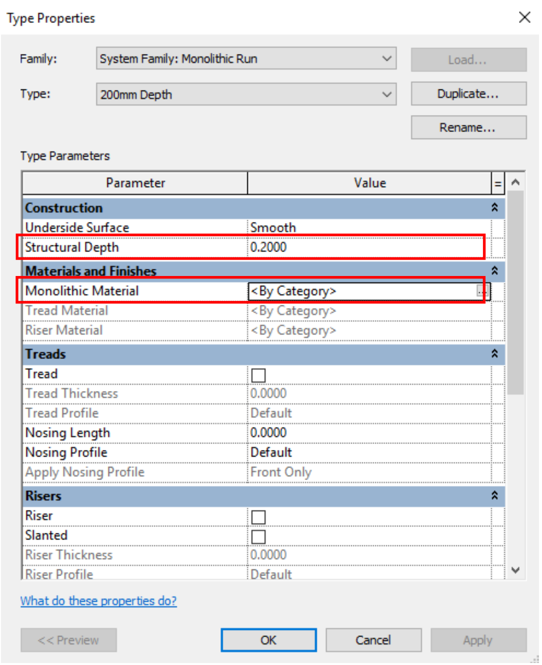
4- From the "Type Properties" box → change the "Calculation Rules" parameters to be matched with the staircase design.

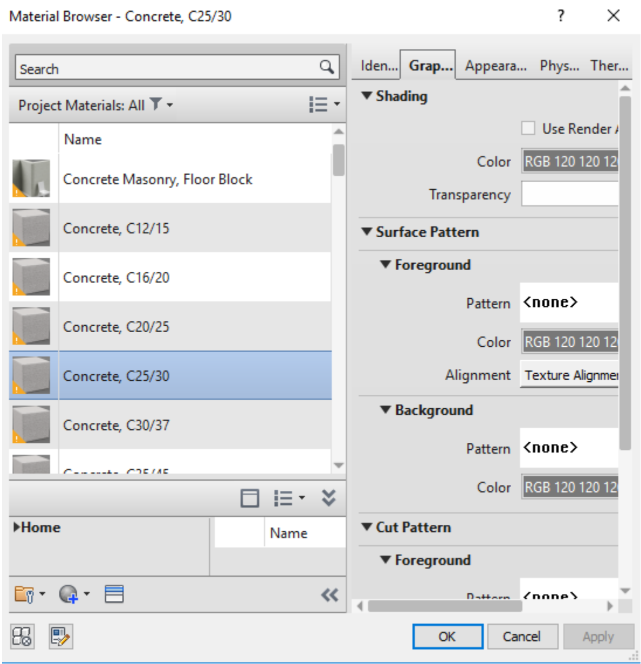


5- From the "Type Properties" box → change the "Construction" parameters for "Run Type" and "Landing Type" by clicking on "…".



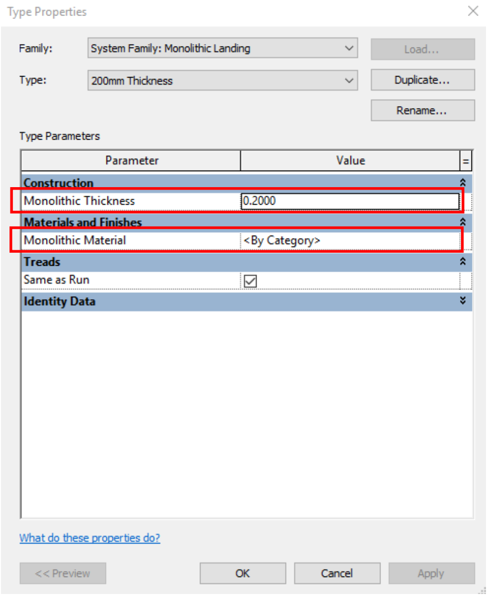
6- For “Run Type” parameter, open the “Type properties” box → choose “Duplicate” to create a new “Run Type” → Change the “Structural Depth” parameter and the “Monolithic Material” → “OK”.

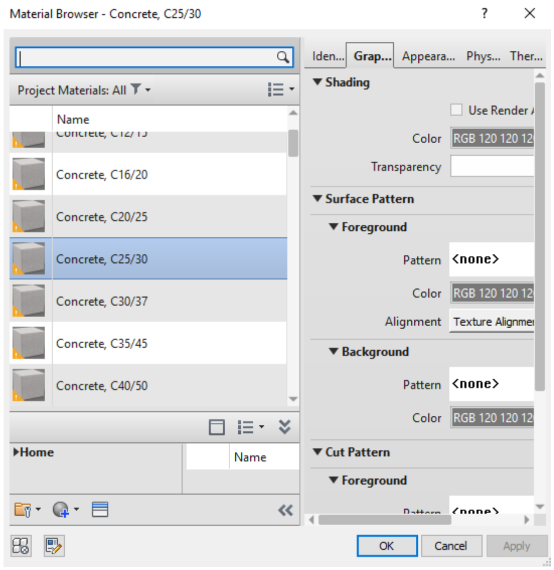




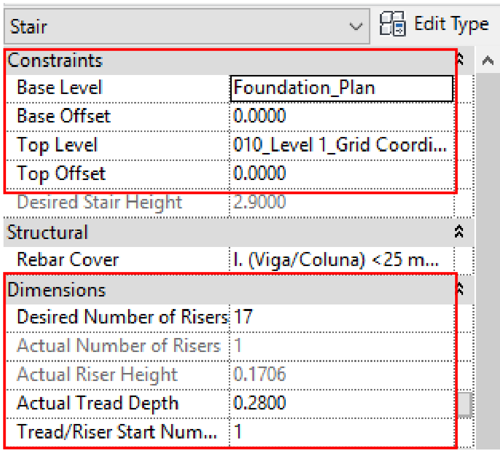
7- The modeler should ensure that the “Nosing Length” parameter value is 0.00.

8- For “Landing Type” parameter, open the “Type Properties” box → choose “Duplicate” to create a new “Landing Type” → Change the “Monolithic Thickness” parameter and the “Monolithic Material” → “OK”.



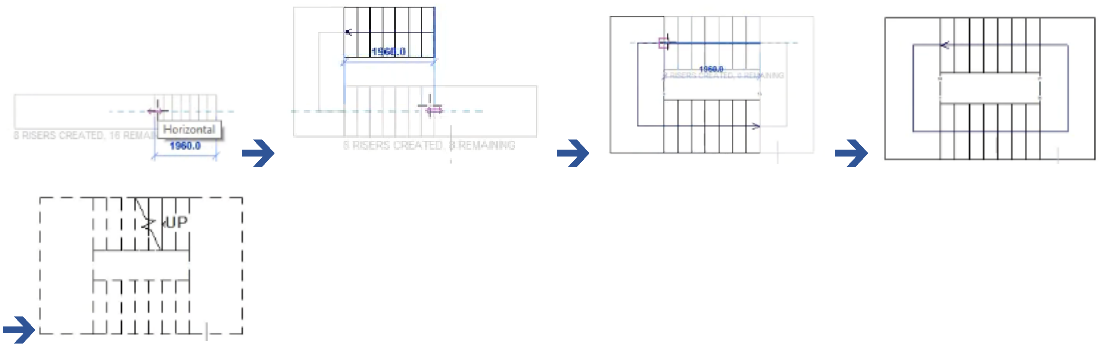


9- For the “Run” , from the “Properties” box ➔ change the “Constrains” parameters and the “Dimension” parameters.

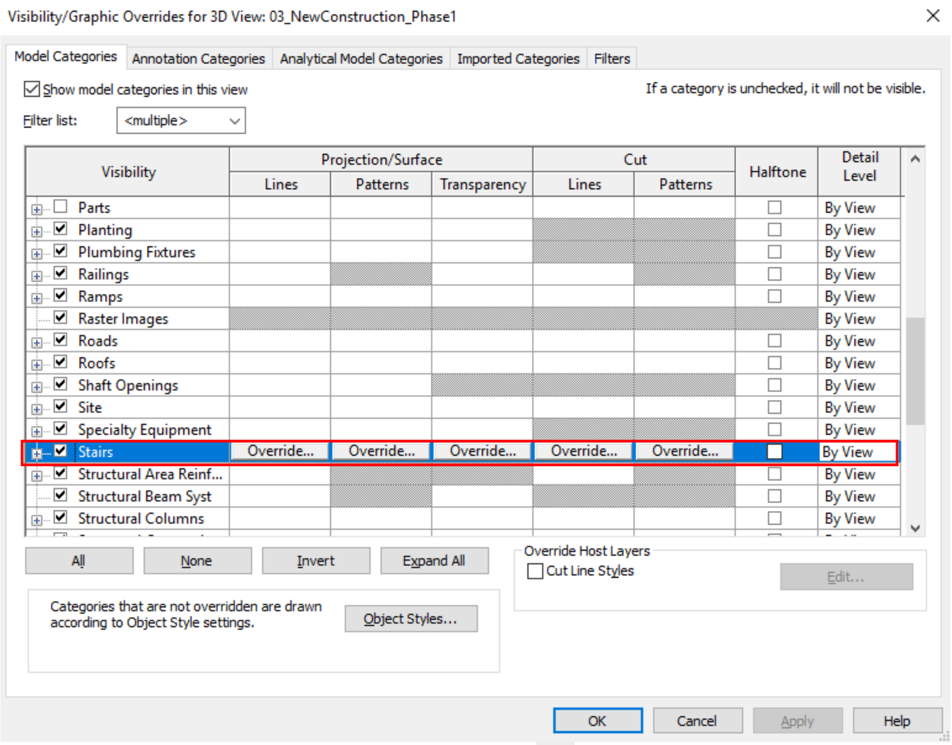


10- From “Modify I Create Stair” ➔ change the “Location Line” and the “Actual Run Width”.

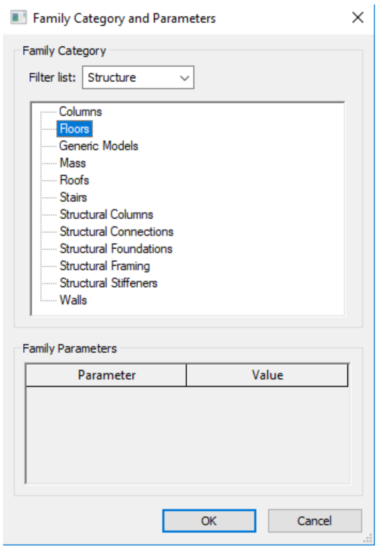
11- Start to model the staircase ➔ While modeling it, it appears the number of risers created and the number of remaining risers, and the landing is created automatically ➔ Pick on “Finish Edit Model” .

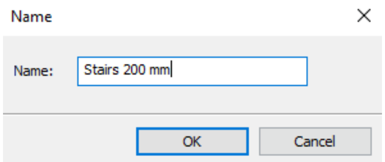


12- If the stair does not appear in the View, change it from the “Visibility/Graphic Overrides” box or type from keyboard “VV” → “Model Categories” tab pick on “Stairs” checkbox.

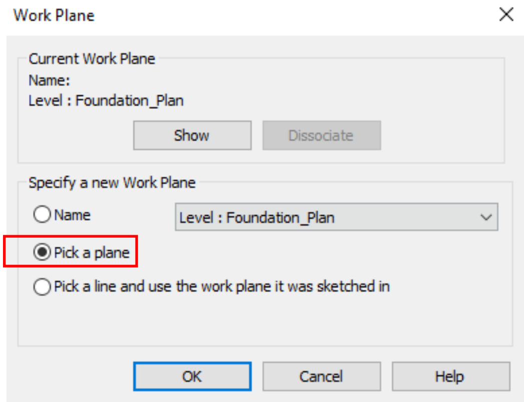


13- From “Structural” tab → choose “Component” dropdown list → “Model in place” → from “Family Category and Parameters” box, choose “Floors” → change the name of the “In place model” → “OK”.

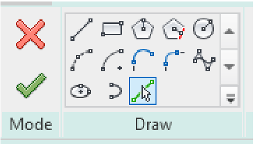




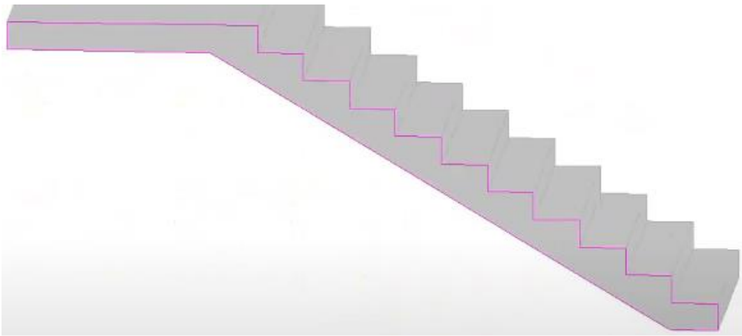
14- Pick on “Set” to identify the “Work Plan” ➔ from “Work Plan” box ➔ choose “Pick a plan” ➔ choose the side view plan of the stairs.

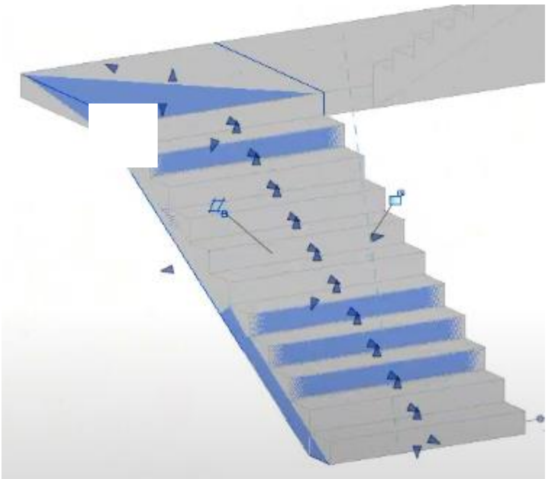


15- From “Forms” panel ➔ Pick on “Extrusion” ➔ from “Draw” panel ➔ choose the drawing tool to create the stairs cross section.

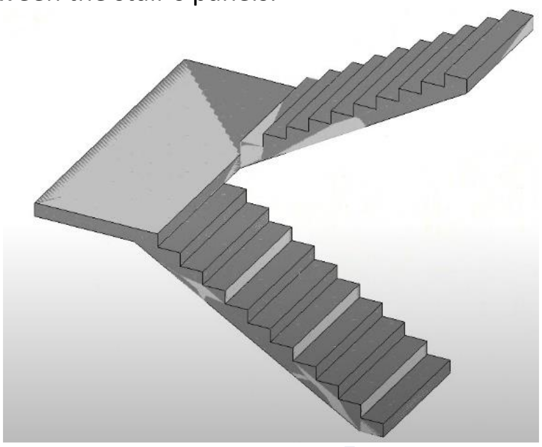


By the drawing tool "Pick Line" → pick on the outer perimeter of the stair cross section → Pick on "Finish Edit Model" → Attach the created extrusion model to the other side of the stairs to be at the same width of the architecture stairs → "Finish the Model" .

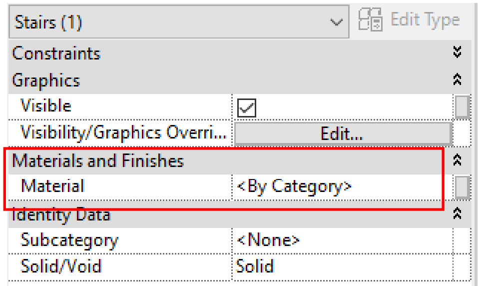


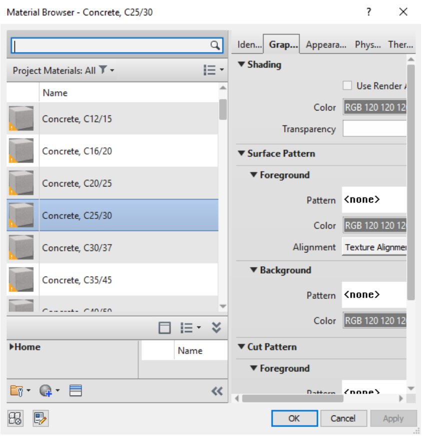


16- The modeler should use from "Modify I Extrusion" → "Geometry" panel "Join" to eliminate the solid lines between the stair's panels.

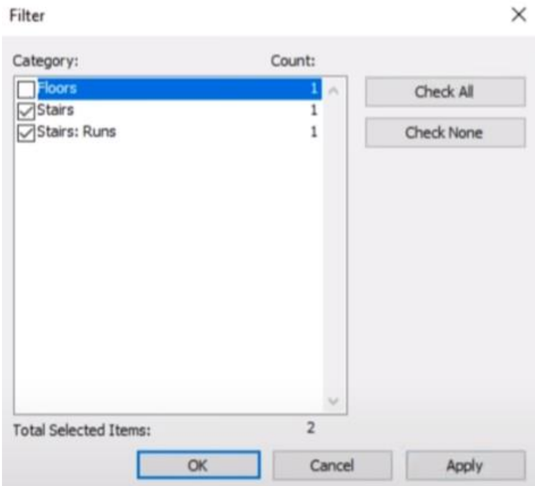


17- From the created stairs model "Properties" box → change the material → "OK"



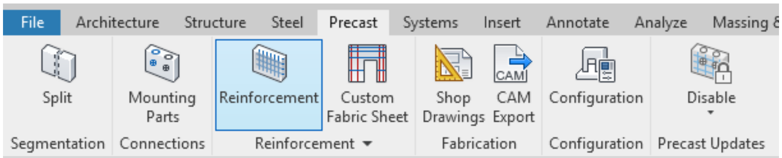


18- The modeler should select the stairs ➔ use “Filter”  command ➔ uncheck the “Floors” ➔ Delete the other categories ➔ “OK”.



1.7 Precast tap:

1- Precast tab is a new standard tab in Revit 2021. The precast tools are only used to the structural system elements “Walls & Floors”.

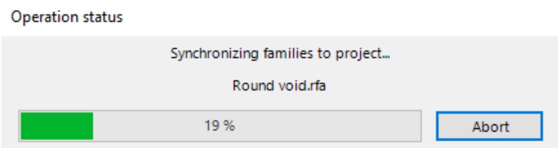


2- The modeler should model all semi or fully precast slabs as suspended slab with appropriate material specified for that kind of construction.

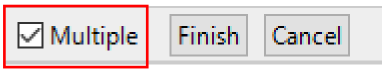
3- The modeler can only use precast tools and apply changes to structural system elements “Structural walls & Structural floors”.

1) Split Tool *:*

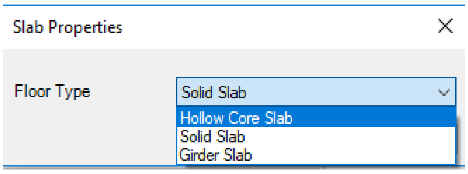
1- By picking on “Split Tool”, it is going to synchronize some families to the project, so the modeler should wait for that.



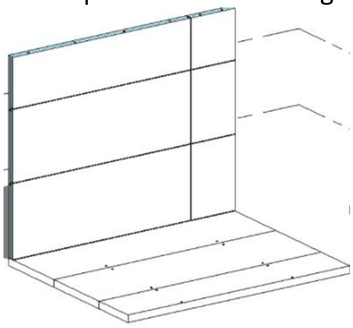
2) The modeler should check “Multiple” checkboxes to select more than one element ➔ Select the elements ➔ “Finish”.



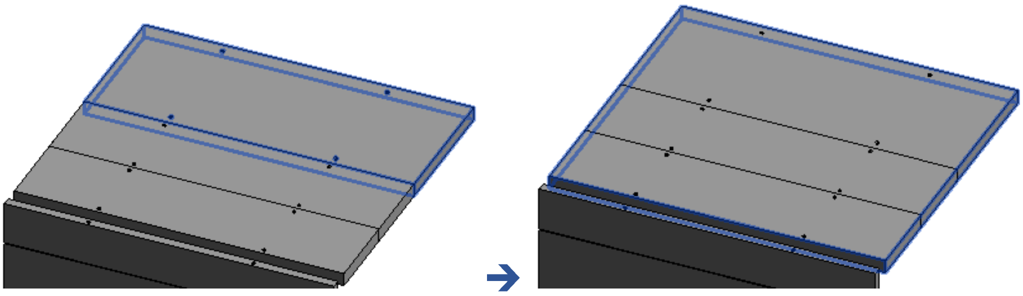
3) After selecting the elements, the modeler should choose the “Floor Type” from “Slab Properties” box.



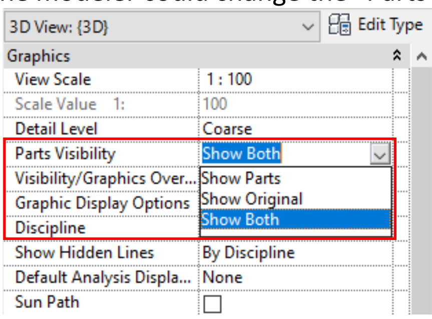
4) The selected elements have been split into different segments.



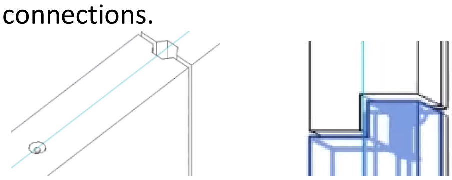
5) The modeler should take into consideration that when Revit divides the elements “Walls & Floors” into precast elements, now it is using parts of the original elements. So, the modeler can select individual part of the original element or can select the whole original element by change the selection using “tab” key from keyboard.



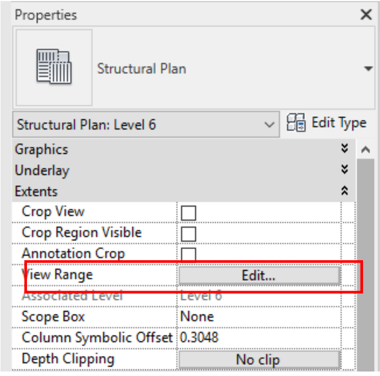
6) From “Properties” box, the modeler could change the “Parts Visibility” property ➔ “Apply”.

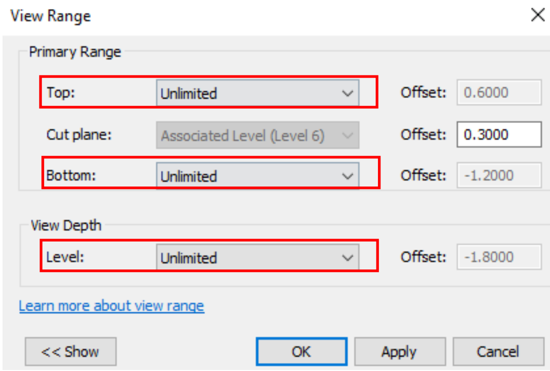


7) The “Show Parts” value allows the modeler to preview the details of the precast parts “the holes between the walls – the connections.



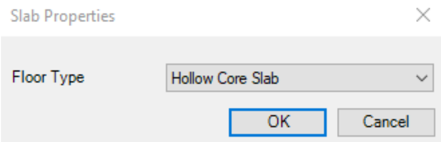
8) For the “Structural Plan”, the modeler should “Edit” the “View Range” property change the “Top & Bottom & Level” to be “Unlimited” to show all the element parts in the view → “OK”.



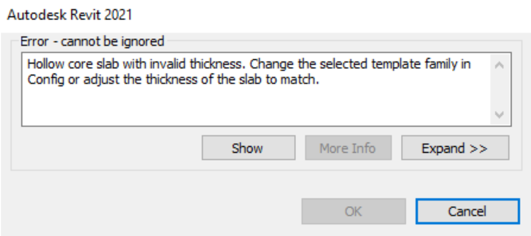


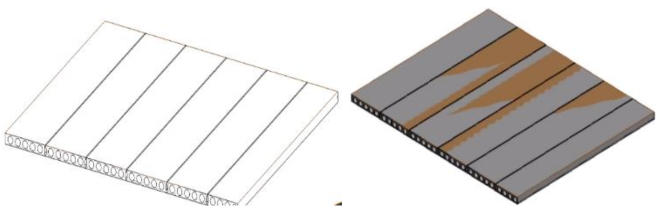
9) For Hollow core slab:

(a) “Precast” tab → select the slab → “Split” → choose the “Floor Type” to be “Hollow core slab” from “Slab Properties” box → “OK”.



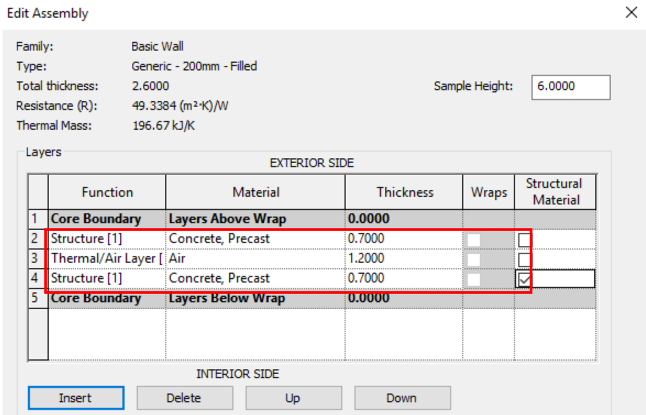
(b) If Revit gives an error warning with invalid slab thickness, the modeler should create a new floor type with a new thickness that could match with the hollow core slab requirements.



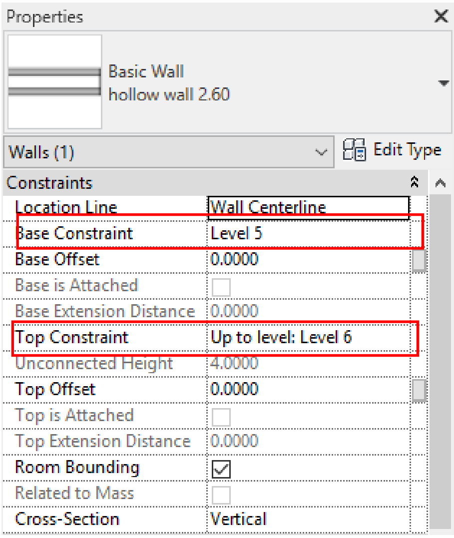


10) For Hollow Wall & Double Wall:

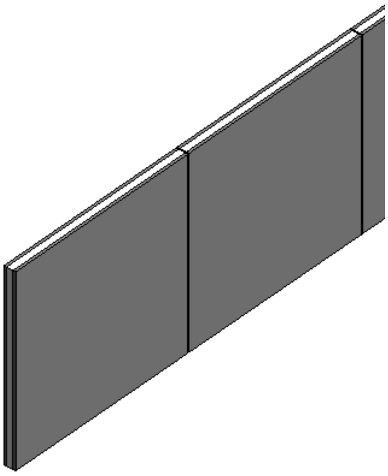
(a) To create a hollow wall which could modeled out of two layers and in between of them could insert sort of thermal insulation or air, the modeler should create a new wall type → use “Insert” to add two “Structure” layers and “Thermal/Air Layer” between them → change the “Material” and the “Thickness” with the desired material and thickness of all layers. “Check Walls family customization subsection”.



(b) The modeler cannot split the hollow walls by the height but can split it by levels identification. So, the modeler should change the constrains parameters from "Properties" box.

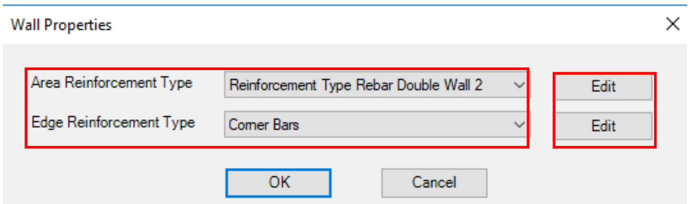


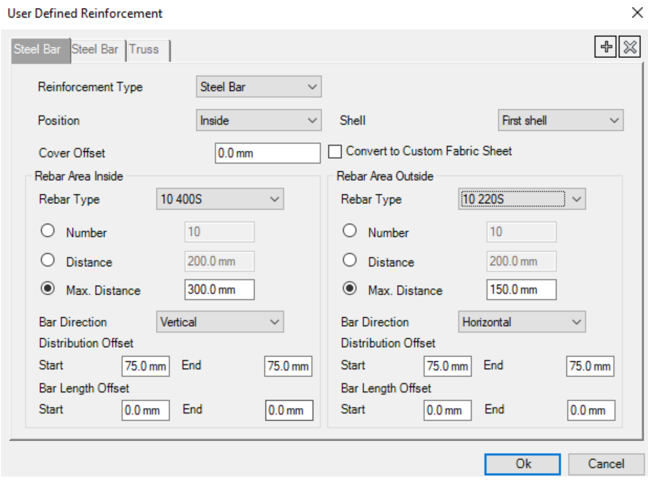
(c) From "Precast" tab ➔ "Split" ➔ select the desired wall

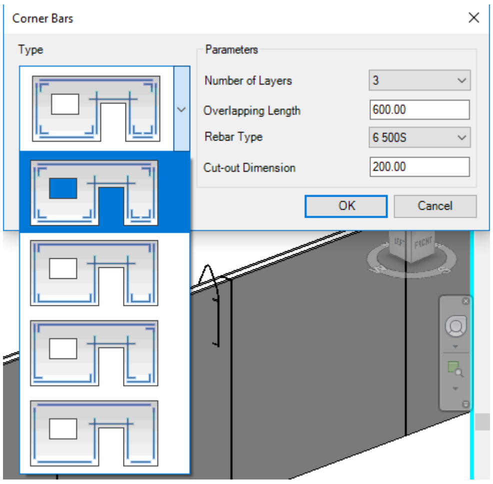


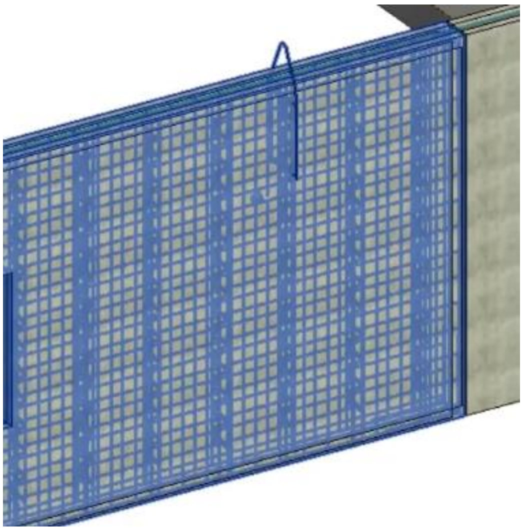
2) *Reinforcement Tool* *:*

1) The modeler should pick the "Reinforcement" tool ➔ select the elements ➔ "finish".
2) Revit is going to ask about the "Area Reinforcement Type" and "Edge Reinforcement Type" ➔ The modeler should choose the desired from the dropdown list ➔ "OK".
3) The modeler could change the rebars direction, distribution, and type & The edge configuration from "Edit" or from "Configuration" tool.

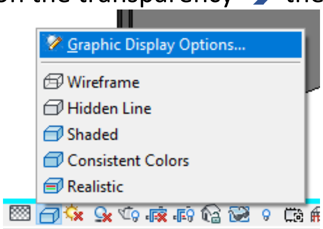


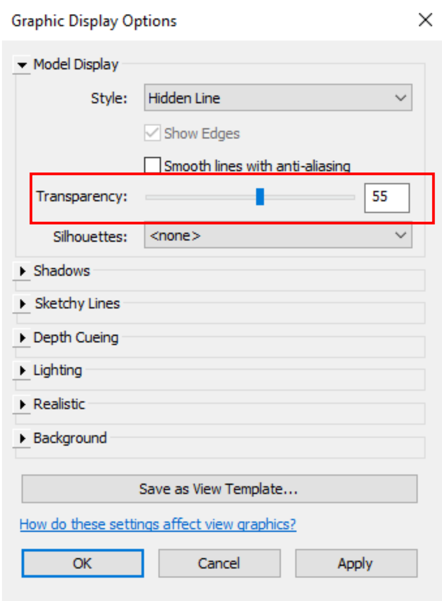




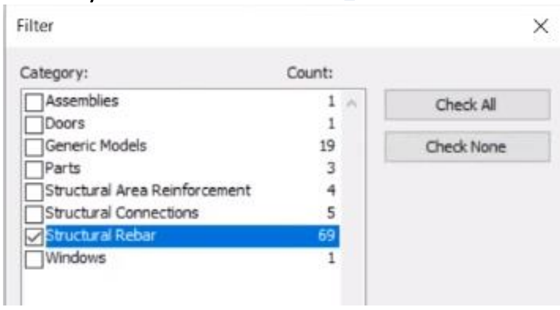


4) If the modeler wants to enhance the viewing of rebars → select "Graphic Display Options" from "Visual Style" icon  → turn on the transparency → the rebars appears like simple line work.

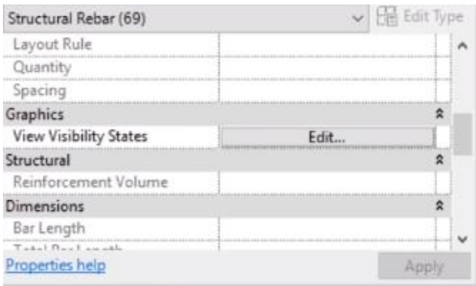


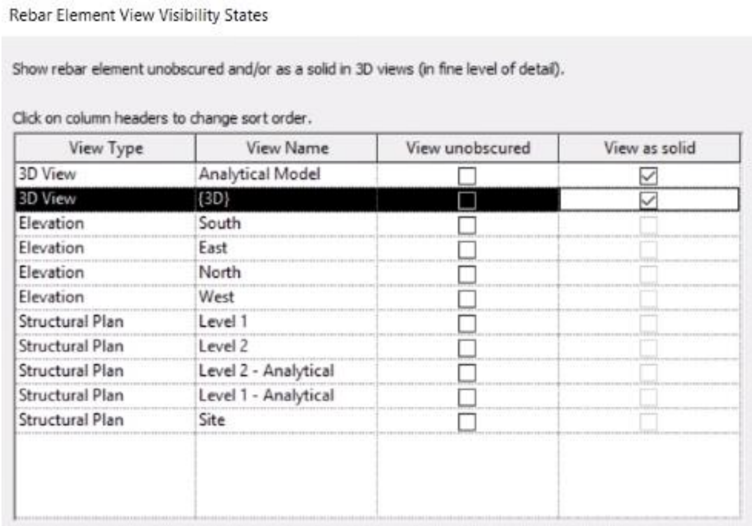


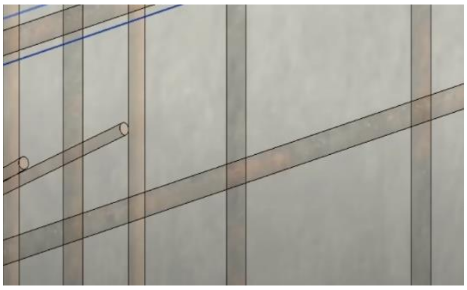
5) After that, the modeler makes selection for the desired element → from "Filter" command → select only "Structural Rebar" → "OK".



6) From "Properties" box, the modeler could change the "View Visibility States" → "Edit" → check the checkbox of "View as solid" for the "3D View" → "OK" → change the level of detail to be "Fine".

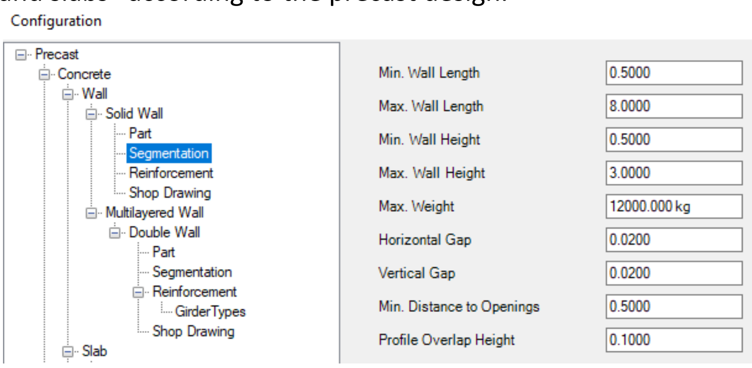


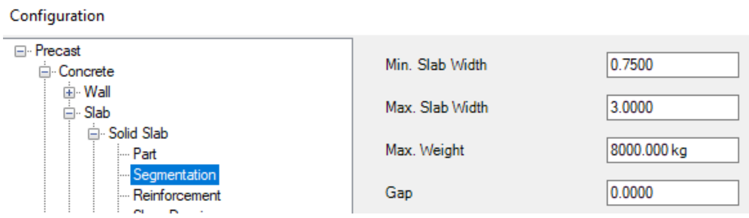


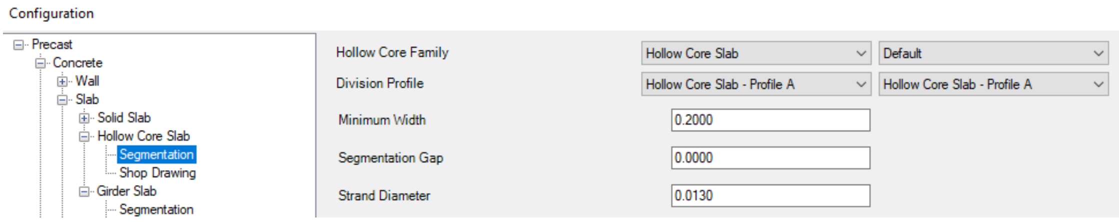


3) Configuration Tool  *:*

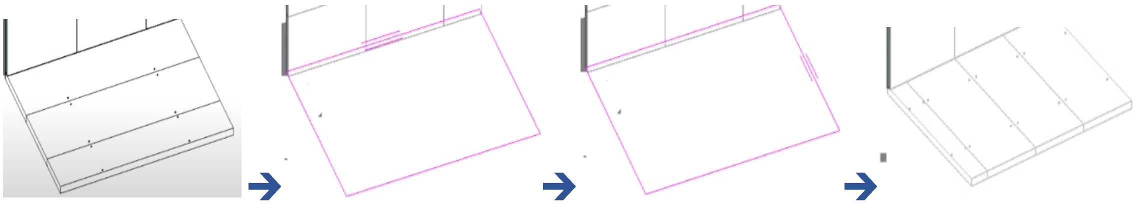
1) The configuration panel controls all the settings related to the other tools and the rules of splitting the element into segments.
2) The configuration panel contains a "Precast" list divided into "Wall" list, "Slab" list and "Built in parts" list.
3) The modeler could control the dimension of the created segments from "Segmentation" sub-list for both "walls and slabs" according to the precast design.



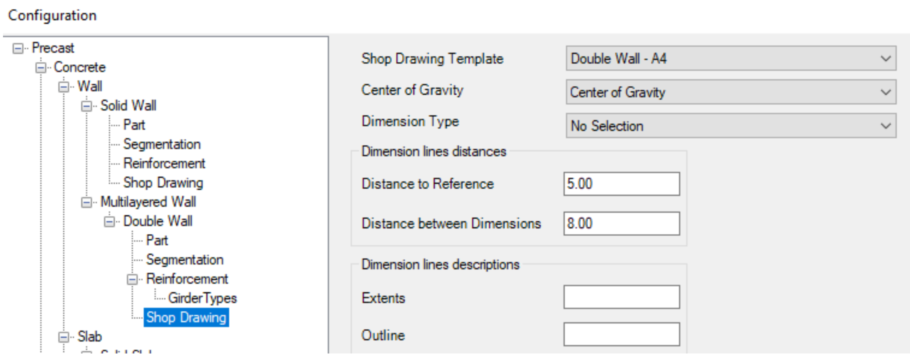




4) If the modeler wants to change the span direction of the segments of a particular floor, → Select the floor before splitting → "Edit Boundary" from "Modify I Floors" tab → choose "Span Direction" → pick on the other floor direction → "Finish".



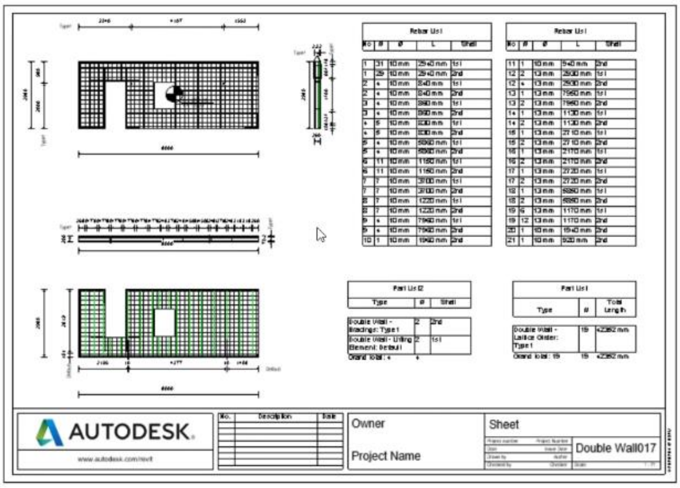
5) From "Reinforcement" sub-list, the modeler could edit the "Reinforcement" direction, distribution, and type & The edge configuration as I mentioned in "Reinforcement Tool" subsection.
6) From "Shop Drawing" sub-list, the modeler could change "The Template & Center of Gravity & Dimension Type.



4) Shop Drawings Tool  *:*

1) The modeler should pick the "Shop Drawing" tool → select the elements → "finish" Revit will create all necessary shop drawings documentation for the elements "Rebar List Template & Details Sheet for side, plan, elevation and section view", Also, the modeler could edit each view individually.

<Double Wall Rebar List Template>				
A	B	C	D	E
No	#	Ø	L	Shell
1	31	10 mm	2940 mm	1st
1	29	10 mm	2940 mm	2nd
2	4	10 mm	840 mm	1st
2	4	10 mm	840 mm	2nd
3	4	10 mm	860 mm	1st
3	4	10 mm	860 mm	2nd
4	5	10 mm	830 mm	1st
4	5	10 mm	830 mm	2nd
5	4	10 mm	5860 mm	1st
5	4	10 mm	5860 mm	2nd
6	11	10 mm	1150 mm	1st
6	11	10 mm	1150 mm	2nd
7	7	10 mm	3700 mm	1st
7	7	10 mm	3700 mm	2nd
8	7	10 mm	1220 mm	1st
8	7	10 mm	1220 mm	2nd
9	4	10 mm	7960 mm	1st
9	4	10 mm	7960 mm	2nd
10	1	10 mm	1960 mm	2nd



APPENDIX 2: MODELLING CHECK LIST

Items	Description	Yes	No	N/A	Remarks
2	**Modelling of Structural Elements**				
2.1	**Columns**				
2.1.1	each str. column has been defined between appropriate levels “floor by floor”.				
2.1.2	Top level of the str. columns have been extended to top level of slab being supported.				
2.1.3	Irregular shape columns have been modeled as per design assumption.				
2.1.4	Structural usage loaded in Structural columns.				
2.1.5	For the elements not to be included into the building structure analytical model, property “Enable Analytical Model” should be unchecked				
2.1.6	For the elements to be included into the building structure analytical model, property “Enable Analytical Model” should be checked				
2.1.7	A descriptive comments have been added to Comments property where necessary for those elements which are not used as normal columns.				
2.1.8	For each column instance, change the Exposure Class of the column according to design.				
2.1.9	check that the used material is the desired one according to the design.				
2.1.10	Do you create a new column type ? If yes, check for every new type:				if No, skip to 2.2
2.1.10.a	Change the name of the new type to follow Newton naming convention.				
2.1.10.b	Change the dimensions of the new type to follow the design dimensions.				
2.1.10.c	To add a new coulmn family, return to the BIM Manager.				

2.2	**Walls**				
2.2.1	each str. wall has been defined between appropriate levels “floor by floor”.				
2.2.2	Top level of the str. walls have been extended to top level of slab being supported.				
2.2.3	Structural usage property has been choosen for each wall .				
2.2.4	Walls connections have been checked.				
2.2.5	Proper Interior/exterior position of walls have been checked.				
2.2.6	For the elements not to be included in analytical model, uncheck the element property “Structural” checkbox.				
2.2.7	For the elements to be included in analytical model, check the element property “Structural” checkbox.				
2.2.8	A descriptive comments have been added to Comments property where necessary for all walls.				
2.2.9	Parapets have been placed at correct level.				
2.2.10	Parapet walls have been modeled as individual wall spanned between piers edge.				
2.2.11	For parapet walls and piers, the base Level and the top Level should be assigned with identical level together with the Top Offset made equal to the required parapet height.				
2.2.12	piers have been modeled with structural column family element.				
2.2.13	for parapet walls, The “Enable Analytical Model” property box has been unchecked				
2.2.14	the irregular walls divided into basic wall which modeled by the ordinary way, and irregular part which modeled by "Model In Place".				
2.2.15	Do you create a new wall type ? If yes, check for every new type:				if No, skip to 2.3
2.2.15.a	Change the name of the new type to follow Newton naming convention.				
2.2.15.b	Change the material and the thickness of the "Structure" layer property.				
2.3	**Beams**				
2.3.1	All continuous beams have been modeled span by span.				
2.3.2	All beams have been connected to their supports with proper method.				
2.3.3	Structural usage property has been choosen for each beam .				
2.3.4	Beams should be Joined with connected slab and wall elements.				
2.3.5	For Special beams like cantilever, tie beam and ground beam, the structural usage has been chooses as "Other".				
2.3.6	For Special beams like cantilever, tie beam and ground beam have been specified in Comments property				
2.3.7	For ordinary beams, “z Justification” value is “Top”.				
2.3.8	For inverted & Lintel beams, “z Justification” value is “bottom”.				
2.3.9	For each beam instance, change the Exposure Class of the beam according to design.				
2.3.10	check that the used material is the desired one according to the design.				
2.3.11	Do you create a new beam type ? If yes, check for every new type:				if No, skip to 2.4
2.3.11.a	Change the name of the new type to follow Newton naming convention.				
2.3.12.b	Change the dimensions of the new type to follow the design dimensions.				
2.3.13.c	To add a new beam family, return to the BIM Manager.				

2.4	Slabs				
2.4.1	All slab elements have been modeled panel by panel.				
2.4.2	Wall attached to the top level of slabs being supported.				
2.4.3	Slabs joined with all neighbor slabs				
2.4.4	For the structural elements which included into the building analytical model, the “Structural” and “Enable Analytical Model” checkboxs have been checked.				
2.4.5	For the elements not to be included into the building structure analytical model, “Structural” and “Enable Analytical Model” checkboxs have been unchecked.				
2.4.6	All Suspended slabs boundaries have been aligned with the center lines of the suppoting "Beams & Walls".				
2.4.7	All Suspended slabs boundaries have been aligned with the edge of the suppoting "slabs".				
2.4.8	All flat slabs boundaries have been located at the centers of the supporting columns.				
2.4.9	the correct “Span Direction” for one-way slabs has been checked				
2.4.10	A proper description has been applied to the Comments property of the floor elements which have specific usage.				
2.4.11	Do you create a new floor type ? If yes, check for every new type:				if No, skip to 2.5
2.4.11.a	Change the name of the new type to follow Newton naming convention.				
2.4.11.b	Change the material and the thickness of the "Structure" layer property.				

2.5	Precast tab				
2.5.1	From configuration tool, the rules of splitting segments, distribution of reinforcment and shop drawings properties have been controled.				
2.5.2	Precast slabs have been modeled as suspended slabs with appropriate material.				
2.5.3	the correct floor type has been choosen after selecting the precast slabs.				
2.5.4	For the "Structural plans", the view range properites have been changed into "Unlimited".				
2.5.5	Revit warning for creating hollow core slabs have been checked.				
2.5.6	For hollow wall, it is modeled as two "structure" layers and "Thermal/Air Layer" between them.				
2.5.7	the correct thicknesses and matrials have been choosen for all types of precast slabs and walls.				
2.5.8	The correct "Area Reinforcment Type"and "Edge Reinforcment Type" have been choosen.				