POLITECNICO DI TORINO

Master's degree in Civil Engineering

Master's Degree Thesis

The interoperability of BIM infrastructure software among the construction management

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Abstract

BIM (Building Information Modeling) technology was first proposed by Autodesk in 2002 and has been widely recognized by the industry worldwide. It can help achieve the integration of building information, from building design, construction, the operation to the building's full life cycle. At the end of the end, various information is always integrated into a three-dimensional model information database. The design team, construction unit, facility operation department, and owner can work together based on BIM, effectively improving work efficiency, saving resources, reducing costs, and Achieving sustainable development.

Interoperability in BIM using is a characteristic of this workflow, Ideally, the data model established through a series of BIM-related application software can be converted into each software for internal use. In this way, no matter where we are, the information will not be lost, and they have the application characteristics of each software themselves.

Key word: Building Information Modeling, Autodesk, building design, construction, Interoperability

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Chapter 1

Introduction

1.1 The current situation of BIM

The current BIM situation now in most place of the world is the Architects and engineers with construction experience are old and do not understand or want to learn BIM. Architects with BIM experience are relatively young and have little site experience.

This will increase the difficulty of communication within the company. For example, young architects sometimes invest much time on an unimportant point or over-model. The older generation of architects sometimes has deviations in project schedule control because they do not understand BIM. This problem can only be slowly adjusted in the process of practice.

With the development of the construction industry over the years, BIM has been initially applied to the construction industry and has demonstrated its substantial commercial value. Judging from the current application status, although BIM still has excellent limitations, practitioners all realize that the economic and social benefits created by the architectural design revolution led by BIM are only the tip of the iceberg.

In China, both the government and industry giants are far less optimistic about the development of BIM, and they have ambiguous expressions on digital goals and standard formulation, but the BIM trend is already evident. Compared with 2014, China's BIM penetration rate exceeded 10%, and BIM pilots increased by nearly 6%. Many design units are forming their own BIM teams. However, the progress is not ideal: those with rich engineering experience are trapped in traditional drawing thinking and inherent tool operation habits, and it is challenging to master BIM quickly; those who can quickly master BIM often lack engineering experience. Otherwise in most western countries, the owner sets up a professional consulting team, one-to-one design team, and strictly regulates the software type, data interface, information specification, and other details of the project launch process.

More bidding projects require the BIM mode of engineering construction. Some companies have begun to accelerate BIM-related data mining, focusing on the

application of BIM in engineering quantity calculations, bidding decisions, and practice BIM integrated project management.

1.2 Effective features of BIM

BIM can be applied in the design and can complete the life cycle of construction projects; designing with BIM belongs to digital strategy; BIM's database is dynamically changing and is constantly updated during the application process. BIM The standard is being studied and formulated, and the research team has achieved initial results. Enriched and enriched; it provides a platform for collaborative work for all parties involved in the project.

Using digital technology to provide this model with a complete construction engineering information database consistent with the actual situation. The information database not only contains geometric information, professional attributes, and status information describing building components but also status information of non-component objects (such as space and motion behavior).

BIM has the following characteristics:

- **Visualization**

Visualization in the form of "what you see what you get." For the construction industry, the real application of visualization is essential in the construction industry. For example, the construction drawings are often obtained, but each component's information is expressed in the pictures' lines. However, its simple structural form requires construction workers to imagine themselves. BIM provides a visual way of thinking, allowing people to form three-dimensional physical graphics from the past line-like components to display in front of people; now, the construction industry also has design renderings. However, this kind of rendering does not contain other information except the size, position, and color of the components and lacks the interactivity and feedback between different components. The visualization mentioned in BIM is a visualization that can form interaction and feedback with components. Since the entire process is visualized, the visualization results can be displayed in renderings and report generation. More importantly, the project Communication, discussion, and decision-making in the design, construction, and operation process are all carried out in a visual state.

- **Coordination**

Coordination is critical content in the construction industry. All the construction unit, the owner, and the design unit are doing coordination and cooperation. Once problems are encountered in the project's implementation, all relevant parties must be organized to start the design often. Due to the lack of communication between professional designers, various professional voices appear—coordination meeting to find the causes and solutions of various construction problems. Then make changes and take corresponding measures to solve the problem—the collision problem-between. The beams and other components of the pipeline are arranged after this, and the coordinated solution of collision problems like this can only be solved after the problem occurs. BIM's coordination service can help deal with this kind of problem so that BIM builds information models. Of course, BIM's coordination function does not necessarily only solve the collision problem between various disciplines. It can also solve such as elevator shaft layout and other design layouts. And the coordination of clearance requirements, the coordination of fire compartments and other design arrangements, the coordination of underground drainage arrangements, and other design arrangements, Etc.

- **Simulation**

In the design stage, BIM can simulate some things that need to be simulated in the design. For example, energy-saving simulation, emergency evacuation simulation, sunshine simulation, thermal simulation, Etc.; 4D simulation (three-dimensional model plus project development time) can be carried out in the bidding and construction phases, which is to simulate the actual construction according to the construction organization design Reasonable construction plan to guide construction. At the same time, 5D simulation (based on the 4D model plus cost control) can be carried out to achieve cost control; the subsequent operation stage can simulate the handling of daily emergencies, such as earthquake personnel escape simulation and firefighter evacuation simulation.

- **Optimization**

The entire design, construction, and operation process is a continuous optimization process. Optimization and BIM are not necessarily related, but better optimization can be done based on BIM, Information, complexity, and time. Without accurate information, reasonable optimization results cannot be made. The BIM model provides information about the building's actual existence, including geometric information, physical information, and rule information, as well as the actual existence information

after the building changes. When the degree of complexity is high, the participants' ability cannot grasp all the information, and certain science and technology and equipment must be helped. The complexity of modern buildings mostly exceeds the limits of the capabilities of the participants themselves. BIM and accompanying various optimization tools provide the possibility to optimize complex projects.

- **Graph ability**

The BIM model can draw conventional architectural design drawings and component processing drawings and make the project expression more detailed by visually displaying, coordinating, simulating, optimizing buildings, and issuing professional drawings and deepening drawings.

let us make an example to indicate the advantage of BIM workflow for construction. In the construction drawing stage, there is time-consuming and laborious but necessary work, which is to show the reserved openings of the electrical and plumbing on the wall and floor in the construction drawing. The construction unit needs to empty them when pouring and laying the wall. Structural engineers also need to adjust their own steel bar ratio chart according to it.

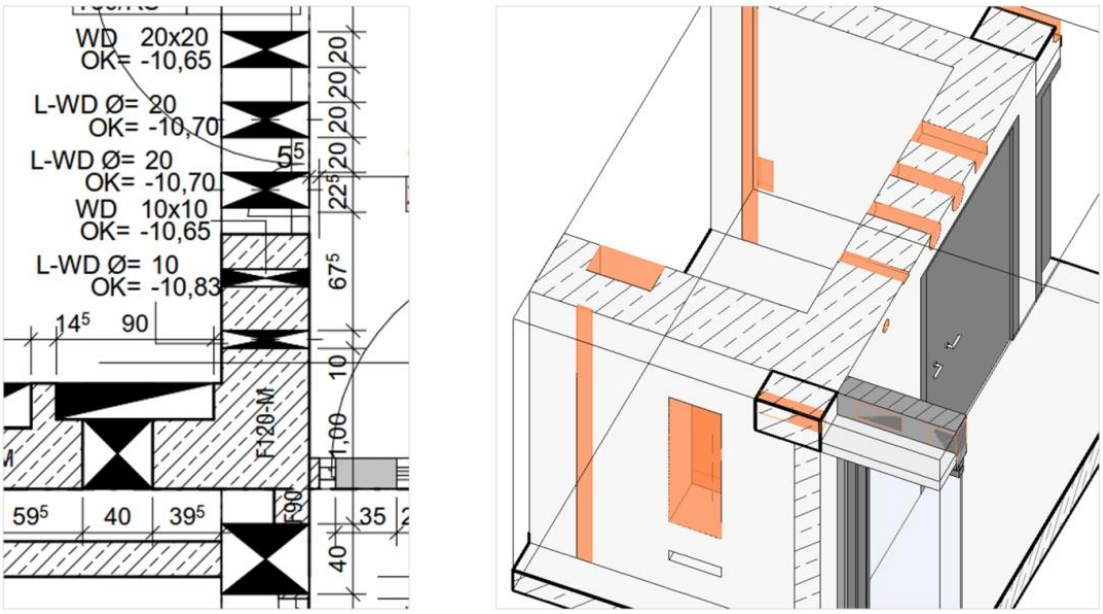


Figure 1 Comparison chart 2D-3D

Above drawing shown the location information of the reserved openings comes from electromechanical and plumbing engineers. The traditional method is to link these reserved openings to the architectural drawings as separate layers or 2D drawings. However, due to the limitations of 2D, it is difficult to check errors comprehensively. There are tens of thousands of reserved ports in a project, and if these problems are

only discovered during construction, the cost to all parties will be many times higher than in the design stage. Modeling with Revit 3D can be used to check errors in a comprehensive way. There is no need to judge by spatial imagination. Whether there is a fight between the two reserved ports at different elevations.

1.3 Structure of the thesis

The structure of this article is based on the BIM infrastructure, focus on three mainly part of BIM which are modelling, structure analysis and visualization shown as following image.

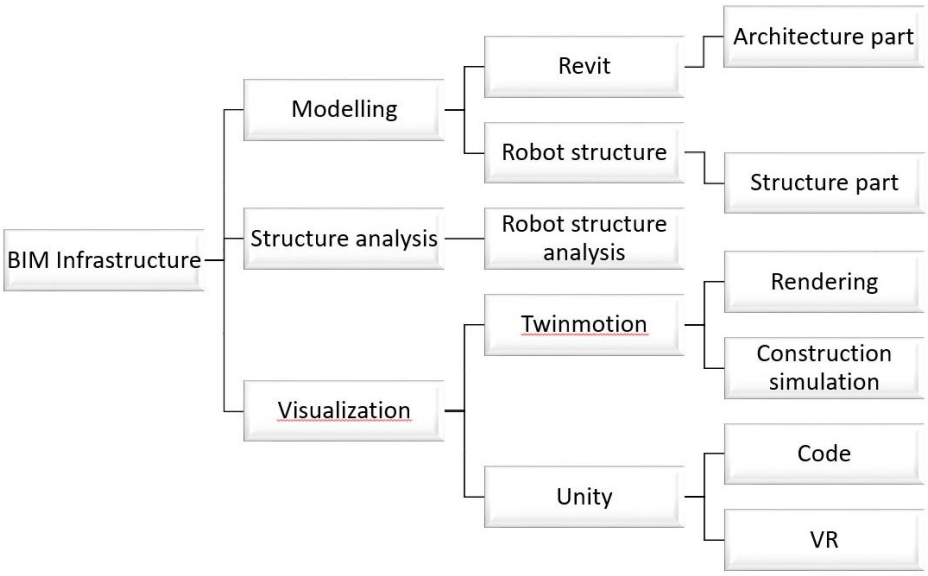


Figure 2 Thesis structure

Modeling

I selected Revit and Robot Structure Analysis from Autodesk company to be the modeling software to manage the architecture part of a hydropower plant in Pomaretto TO, Italy; Structure model part of control center of hydropower plant.

Structure analysis

To test the interoperability of structure analysis software, Robot structure to implement the structure analysis and test, which is more suitable for BIM workflow use.

Visualization

In this topic, in order to improve the graphical experience for the client who wants to go through this project, I mainly focus on rendering part by Twinmotion software based on Unreal engine and VR experience by Unity engine.

Chapter 2

BIM-based construction modeling

2.1 Modeling in digital and reality.

In my previous study experience, I was fortunate to participate in various practical activities, similar to the use of different props, such as chopsticks, A4 paper, and other essential tools to build a building model for various small challenges. In my most profound impression, my team and I used chopsticks to build a simple bridge structure and withstand the weight of a few bottles of mineral water. This activity has benefited me a lot, and it gave me a taste of the charm of the building structure. It is also a typical time case of building an architectural model entity.

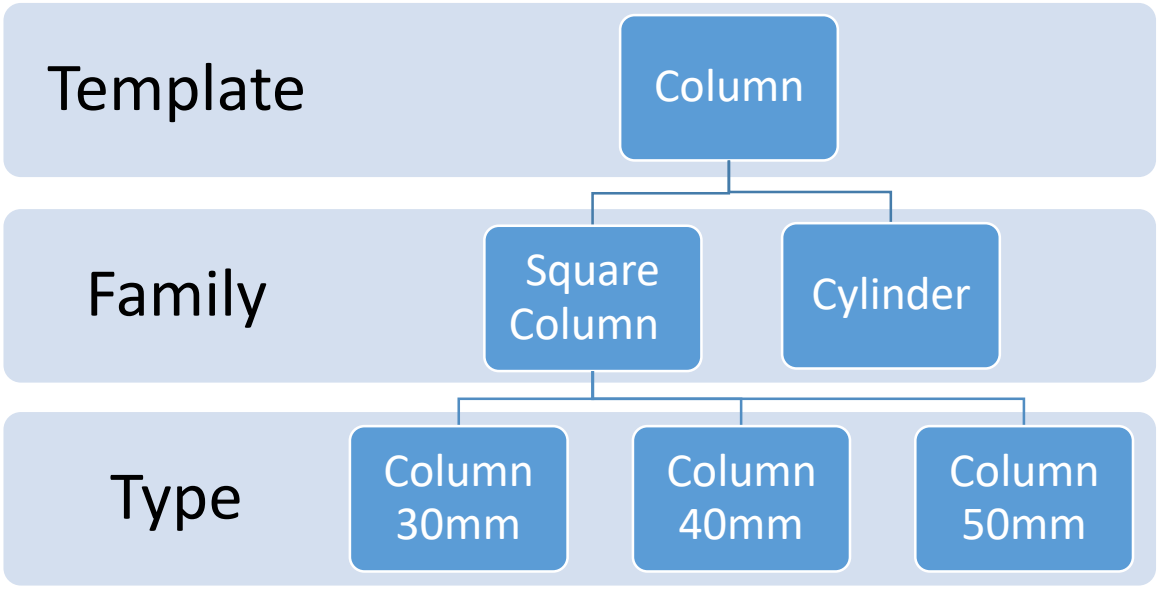
Time flies. Due to the development of computer technology, under the expected progress of hardware equipment and various software, electronic information technology has indispensable benefits for all kinds of projects, whether in automobiles, construction, aerospace, etc. Computer technology is present in all fields of simulation analysis. For the construction industry, computer technology is also indispensable. For the purposes of this article, it is a case of considering the combination of computer technology and the construction industry.

2.2 Modelling software introduction.

The Revit platform is a design and recording system that supports the designs, drawings and schedules required for construction projects. Building Information Modeling (BIM) can provide the information you need to use about project design, scope, quantity, and stage.

In the Revit model, all drawings, two-dimensional views, three-dimensional views, and schedules are the information representation form of the same primary building model database. When operating in the drawing view and the schedule view, Revit will collect

information about the construction project and coordinate it in all other manifestations of the project. The Revit parametric modification engine can automatically coordinate modifications in any position(model views, drawings, schedules, sections and planes).



Categories of component

In Revit, the concept of *family* can be imaged as "building blocks" or "accessories". All components can be called families. Wall families, beam families, axis lines, labels, and even lines are all families, so in the modeling process, we need to select the appropriate "family", the completed model can be accurate and the modeling speed is faster.

Template. If the family is an "accessory", then the template is an "accessory box". To create different models, we need to use different templates. For example, to create a building structure model, we need to use a building template, and to create an MEP model, we need to use a system template. Setting in the software and loading time of different families, you can also create your own templates according to the actual needs of the company's project, which is more convenient for the operation of the software.

2.3 Revit for construction modeling part

2.3.1 Introduction of company

SIED Energia is the name of the company where I had completed my internship project, it is an energy provider company. Water has been used for the production of power force since ancient times: initially for handling of millstones and knitting machines up to the generation of electrical energy, originating from hydraulic engineering works that have given a start to hydroelectric power plants.

Hydroelectric energy is one of the most important sources of renewable energy. It has no negative effects on the climate, it is efficient, and particularly suited to South Tyrol, which, due to its mountain landscape and central position in the Alps is perfect for the exploitation of this source for the production of clean energy.

The Ferrero Group, through the S I E D and its subsidiaries, only in the national territory, manages a park of 17 power plants.

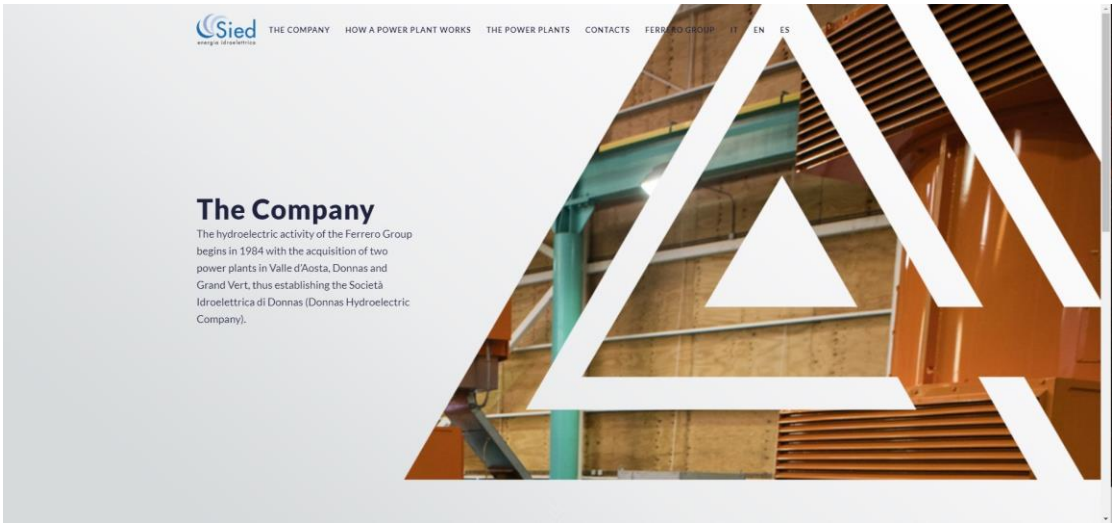


Figure 3 SIED Energia website

2.3.2 Overview of project

One of the 34 hydroelectric power stations is my job content in which my part is to complete the model of this hydroelectric power station according to the CAD file which collected by some original construction drawing, for anything else not complete part could be collected by UAV scanning the complete construction in order to obtain the document to improve the model. The second central part is to complete the virtual

reality technology of the construction to use BIM to check mistakes, fire engineering, etc.

The project is called PACI, which stands for hydroelectric plants automation project in Via Riccardo Balmas 10063 Pomaretto TO. which is a hydropower plant is the science and technology that studies technical and economic issues such as engineering construction and production operations that convert water energy into electrical energy. The water-energy used by hydropower is mainly the potential energy stored in the water body. In order to convert water energy into electricity, different types of hydropower stations need to be built. Initially, by using the newest version of Revit at that moment (version 2020), but in case it does not work for the project due to the file of 2019 version is not suitable for version 2020, therefore I need to adjust it in order to adapt the version problem, this is the first feature of Revit I ever know before I use it, which old version files adapt in new version software but if vice versa does not work.

As shown in the follow images, the entire project was divided to several part, there are three main part which are “Opera di presa” is the intake structure; “Vasca di carico” is the loading tank “Bacino” is the water basin “Fabbricato centrale” is the control center and connection part “Adduzione” is the connection pipe.

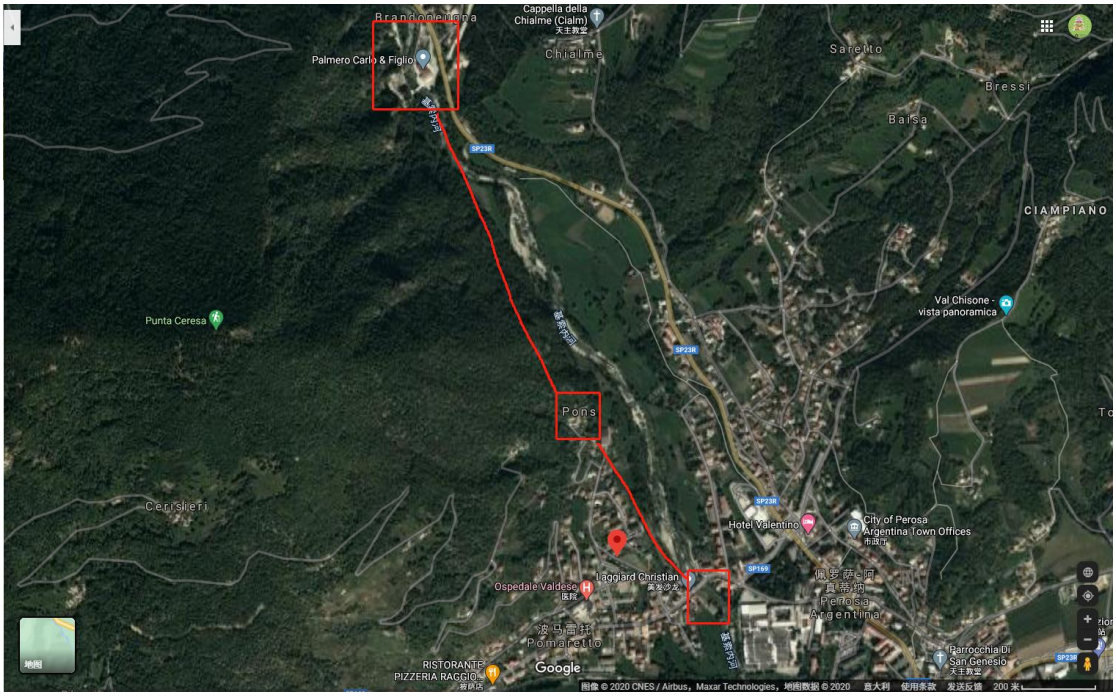


Figure 4 Google satellite map of project

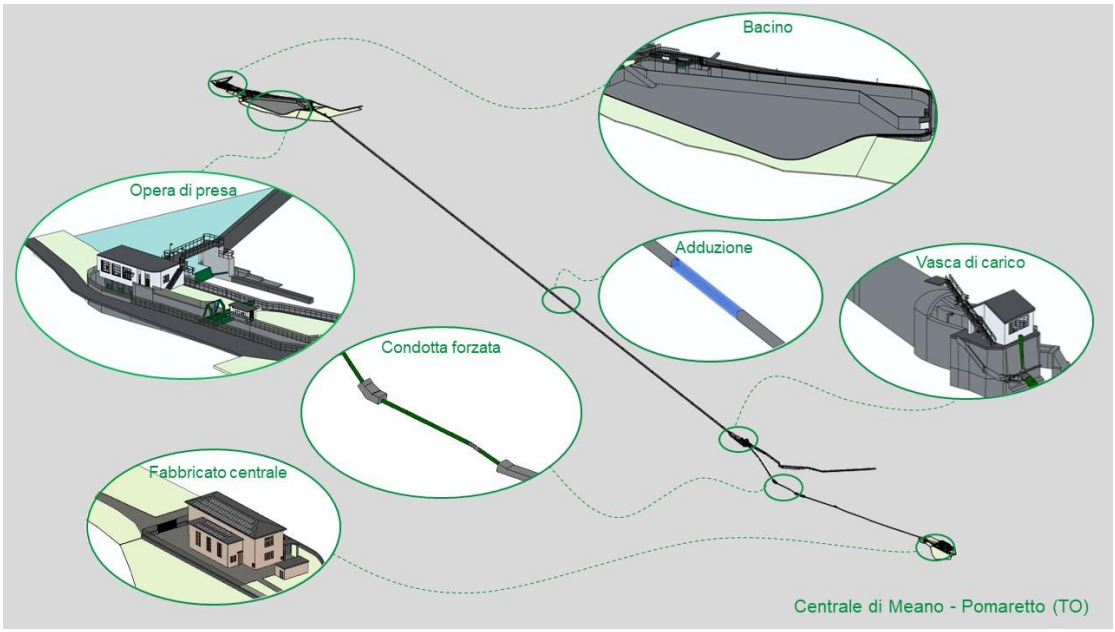


Figure 5 Project overview

2.3.3 Architecture modeling process

“Opera di presa” is the intake structure works are series of systems that allow water to be drawn from natural cycles. Generally these works are located far from inhabited centers. These works represent the first part of a hydroelectric or aqueduct plant.

“Vasca di carico” is the spillway of the loading tank which located in the middle position of the project, the function of loading tank is linked up to the intake structure and control center and in case could use to split the residual water.

“Fabbricato centrale” is the control center of the entire project including distribute the water volume and input in the equipment to create the electricity.

Firstly, related to the CAD masterplan of the hydropower plant and some CAD drawings about the overflowing canal. All job needs to mention that is about level in the project, for example as the requirement needs to make these hole coincidence to each other correctly. Pay attention to set every level of project according to the standard. Like the image below, the instruction of level, left column above sea level elevation and right column Revit model level elevation, according to this to set the level.

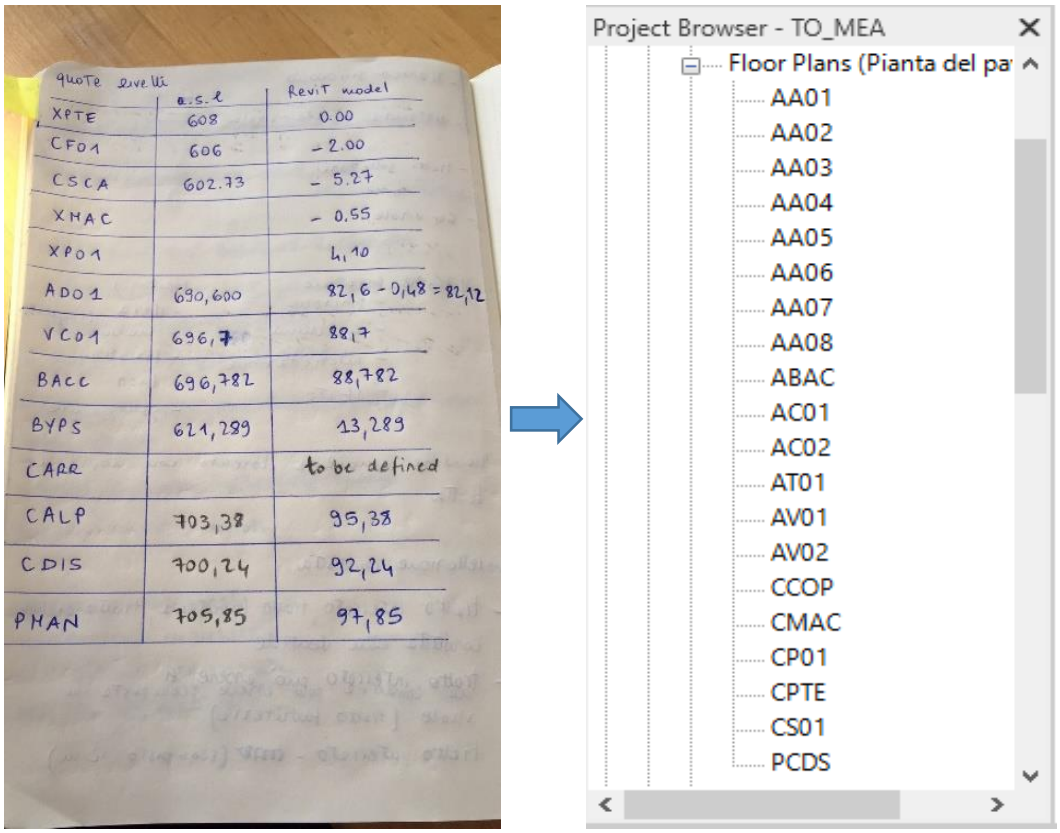


Figure 6 Related Level information in Revit

The tunnel that connects the reservoir to the loading tank. From the starting point to the end point of the tunnel there is a difference in height of 2.22 m. I created the first and the last part of the tunnel and should create the central part of about 2 km. Each family must be about 50 meters.

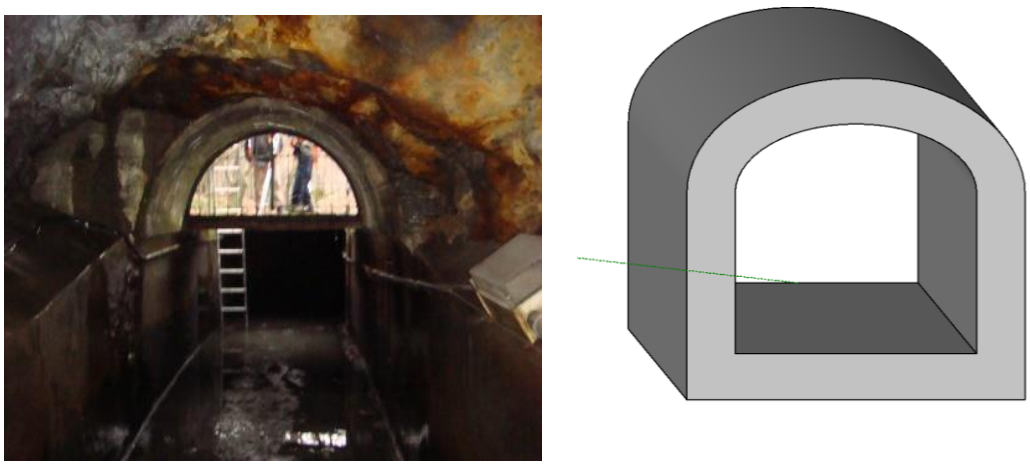
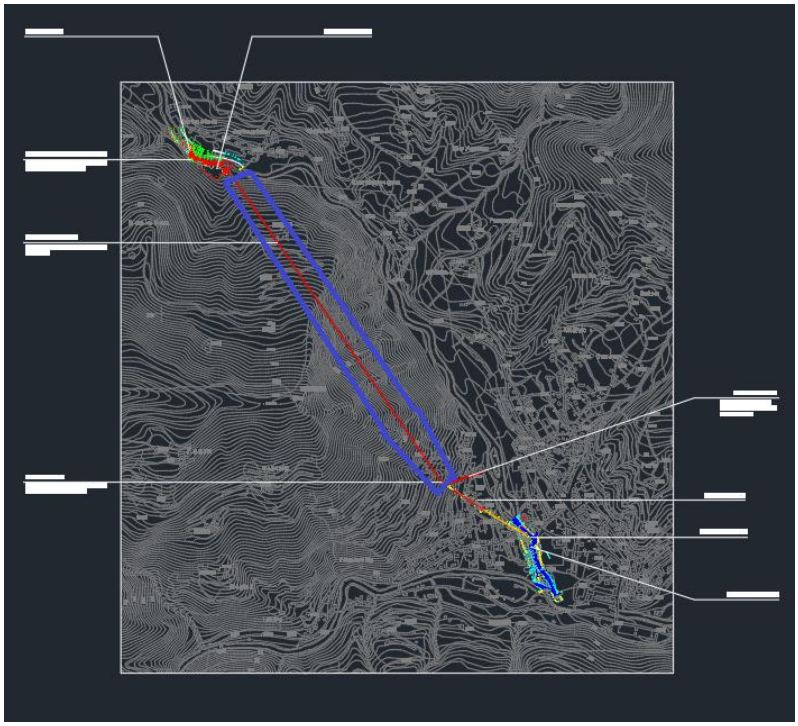


Figure 7 Tunnel sample

From start to end, the height is just 2.22m but it is 2000meter tunnel that will be sepa rated this 2.22m for rotation, for the inclination, I want to verify the calculation of tha t, I calculate as follow: 2.22/2000=0.00111, $\tan^{-1}(0.00111)=0.0635$, this is the rotate degree of every block should follow.



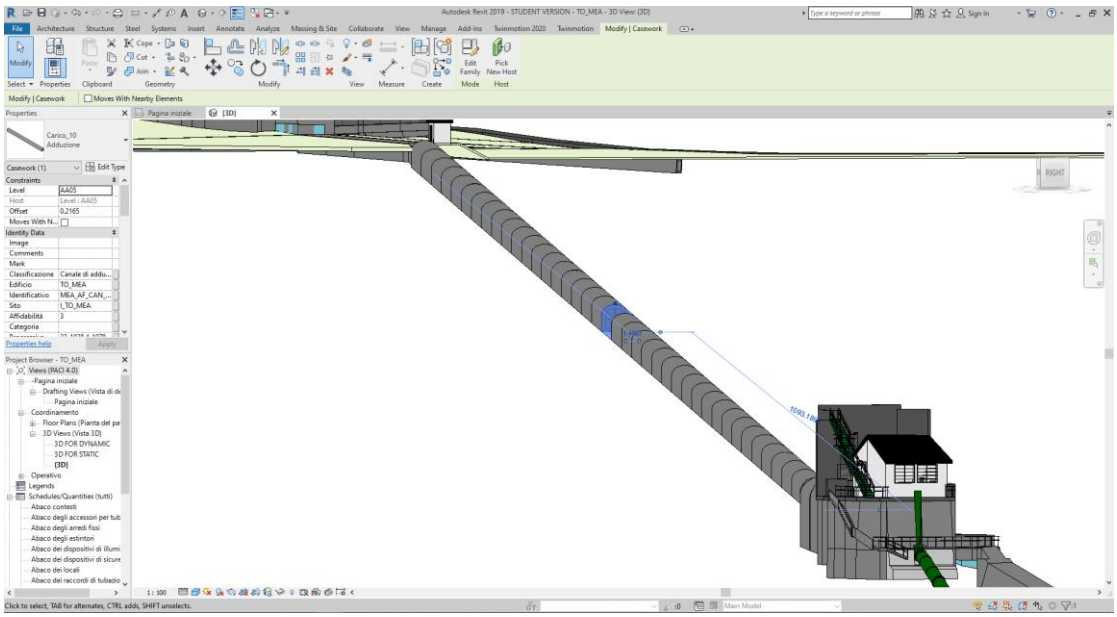


Figure 8 Tunnel corresponding sample

Then next work that l have to create the drain tank family and the drain canals families, I'll upload scans of those parts to google drive. They are images, so I can insert them inside the families, but I must scale them before modeling. The drain tank is located exactly below the central building.

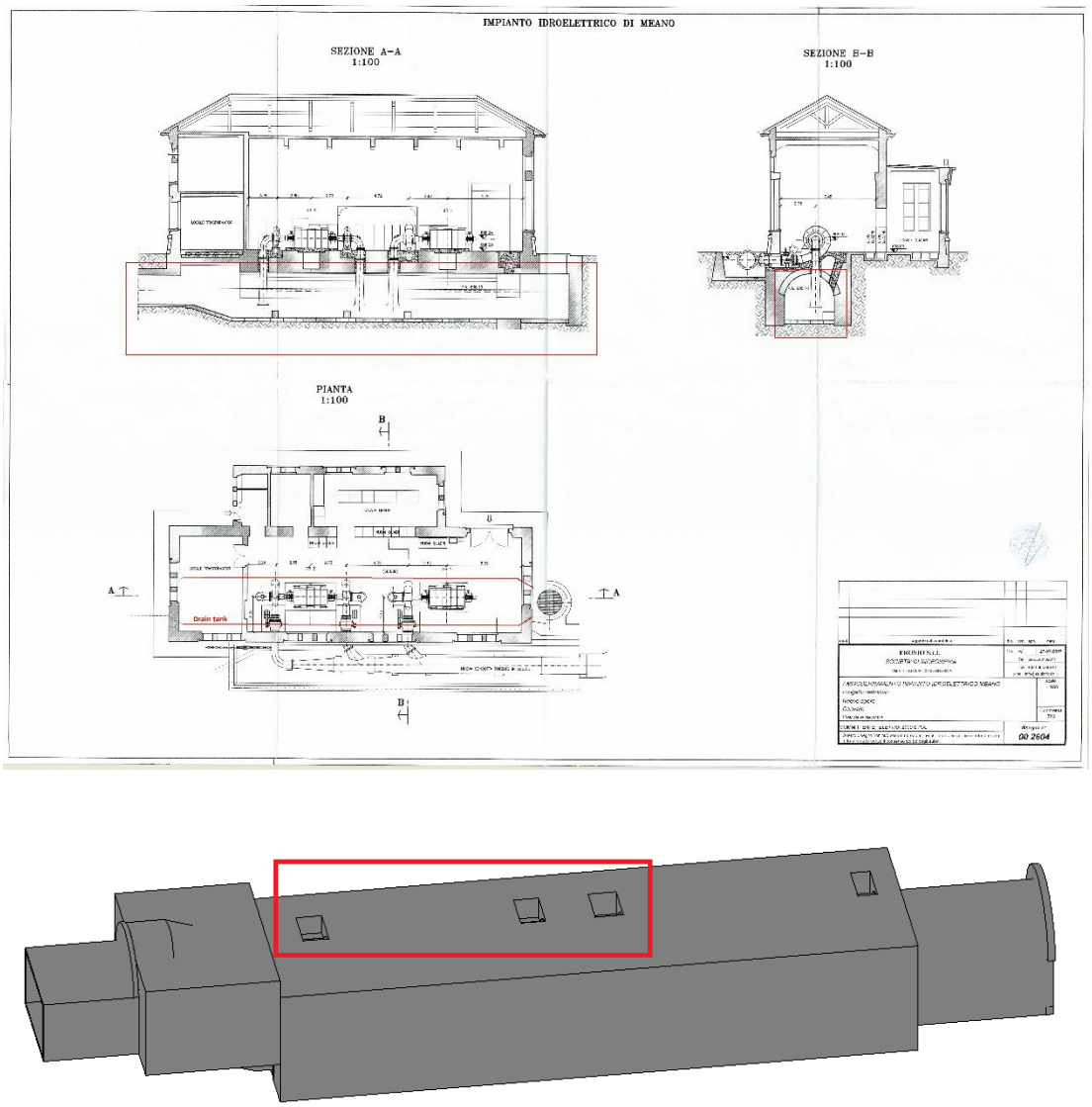


Figure 9 Model corresponding to PDF

Using the PDF drawing for the overflow canal modelling. the model and in the image the part to be modified, the drain tank at that point ends and there is an opening at the top when compare to the reality.

About the next part to model, the penstock, the penstock consists of several elements: pipes, saddles, concrete blocks and expansion joints. as the CAD file the penstock can

be split into three parts, the above-ground section, the underground section and the section of collectors that arrive at the power plant.

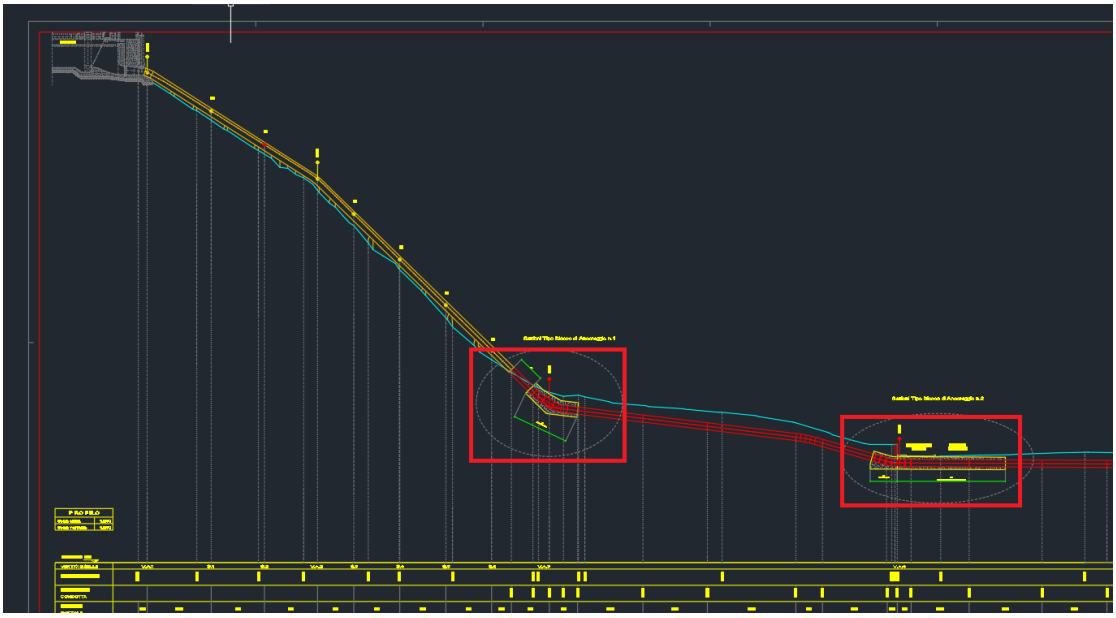


Figure 10 Real pipe corresponded to CAD

The saddles are present only in the above ground section and for the project we decided to represent them all with the same size and call the family: Saddle. For saddles I can create them with a medium size (length, thickness and height) between the saddles present in CAD files, so that they do not overlap the pipes, but all with the same size.

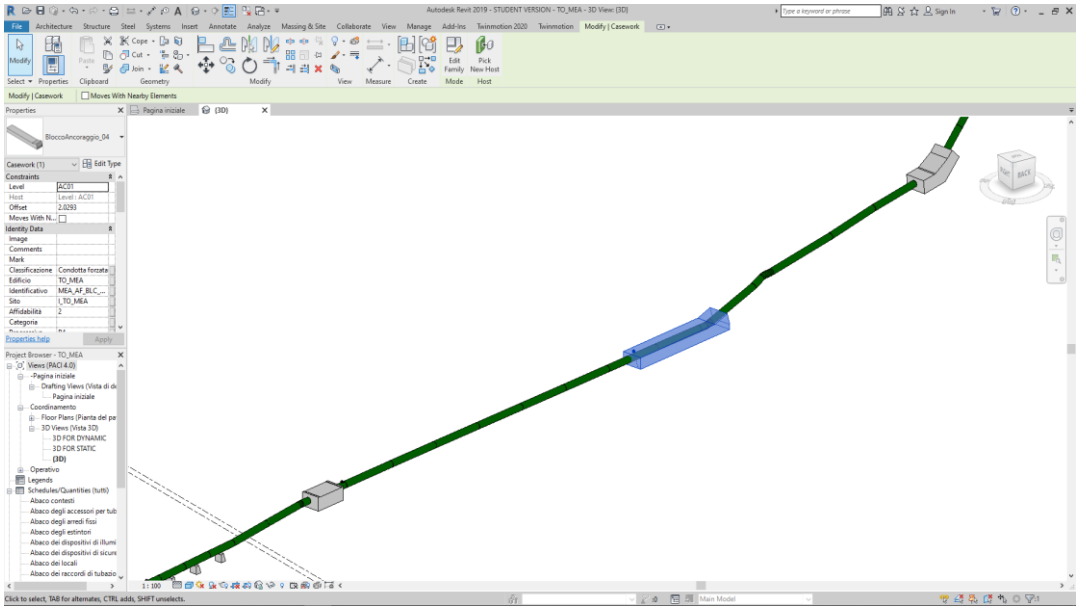


Figure 11 Related model in Revit

The image below is a ferrule is the section between the two arrows shown in the photo, where there is the end of each piece of pipe, I also need to create them as well.

Each ferrule is identified by a red spray number, in above ground penstock there are 21 ferrules, on the other hand the underground part must be subdivided according to the scans.

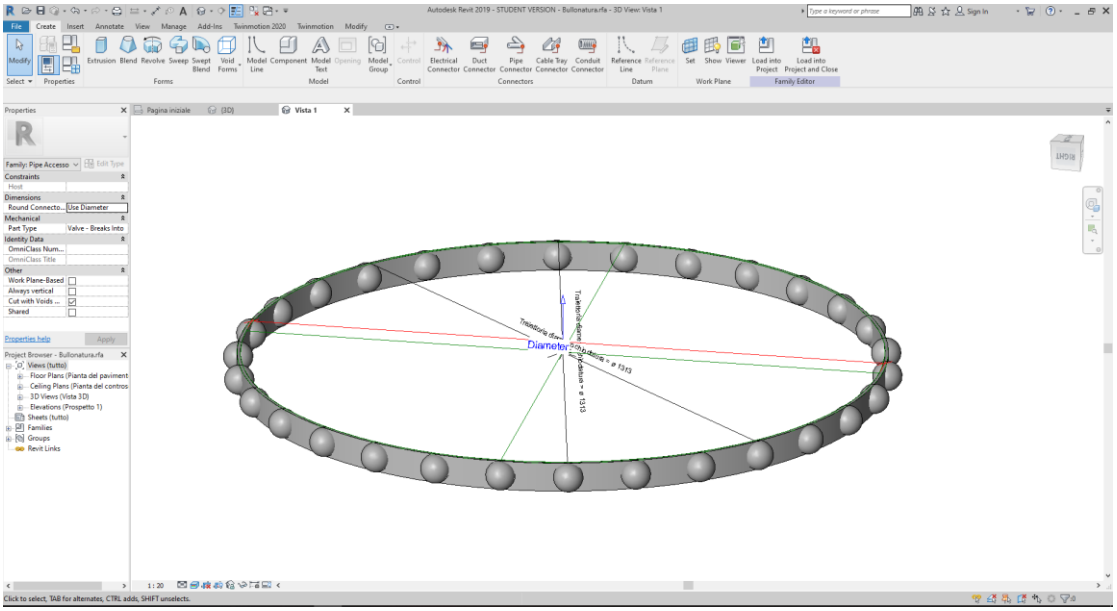


Figure 12 Related model in Revit

About some connection between each pipe which needs to find some solution to deal with that due to cannot be connected very well like below

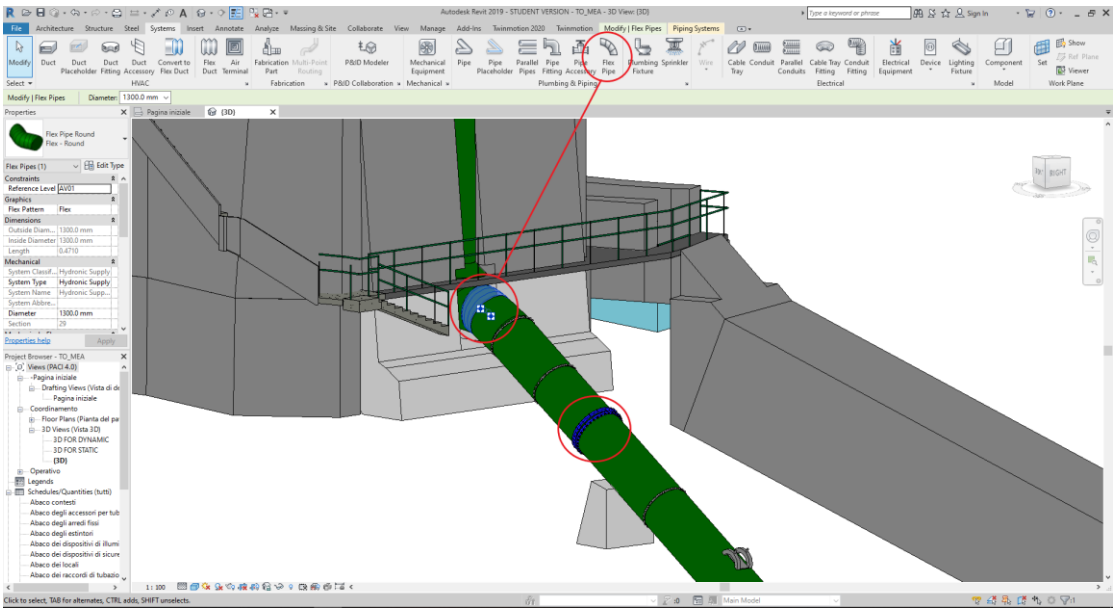


Figure 13 Related model in Revit

Flex pipe is a type of Revit pipe that I could use to replace pipe fittings when Revit gives an error, follow is another connection of pipe.

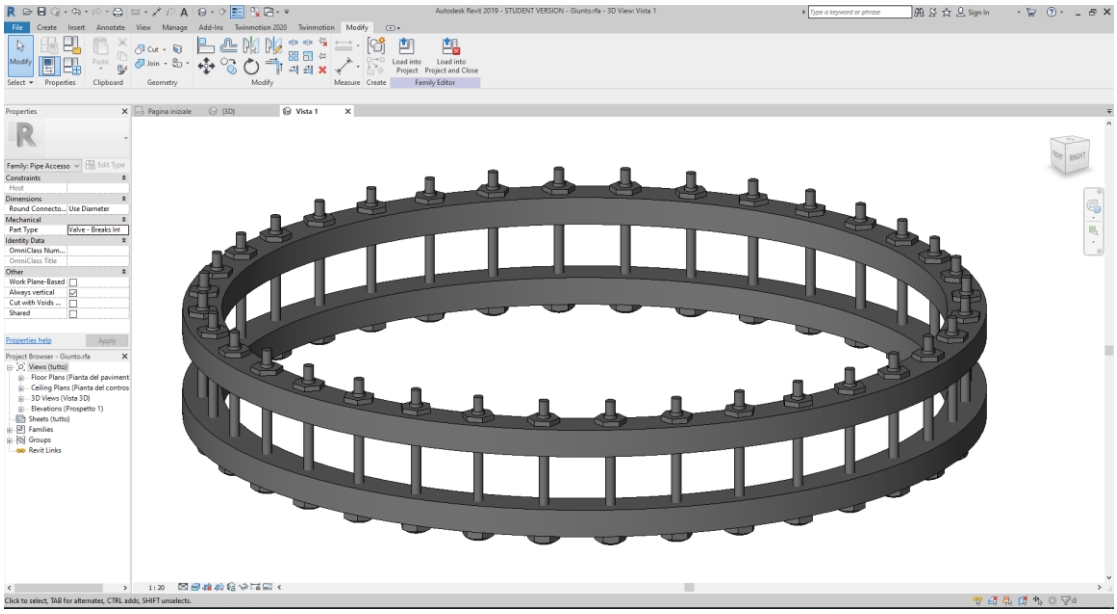


Figure 14 Related model in Revit

There are a few things to change, in ferrule family when I change value in parameter diameter the family is partially modified.

Here needs to create a TYPE (not Instance) parameter Diameter that changes Family Type inside the main project. As an example, for Family Valve, more types depend on Valve Diameter. I created a parameter of the number of ball/bolts in both the ferrule and expansion joints, and they could be adjusted diameter as well. Now I am trying

how to change inside diameter or outside diameter in order to adapt pipe size, but it does not work; software reminds me it's locked. I think the problem is because when I extrusion, I have to parameter separately outside diameter and inside diameter.

If not to do so when we change diameter (whatever outside or inside), the ferrule will be locked, the shape will not be changed; I think this is the problem. Double time of extrusion for inside diameter and outside diameter and separately parameter them, then when you want to change diameter by parameter, change both side-diameter by the same ratio, they will get a new shape of the ferrule or expansion joints.

Here needs to lock parameter when I create the shape to avoid this problem

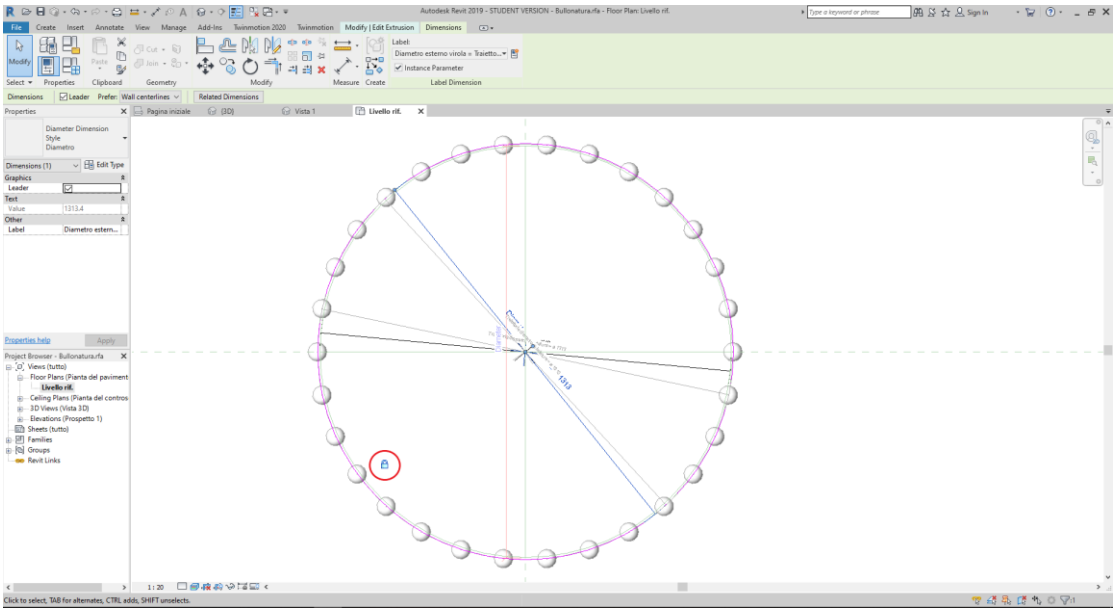


Figure 15 Lock feature logo in Revit

Following the photos to create the roof, stairs, windows.

Figure 16 Model comparison

Until now the architecture modeling part is almost finished.

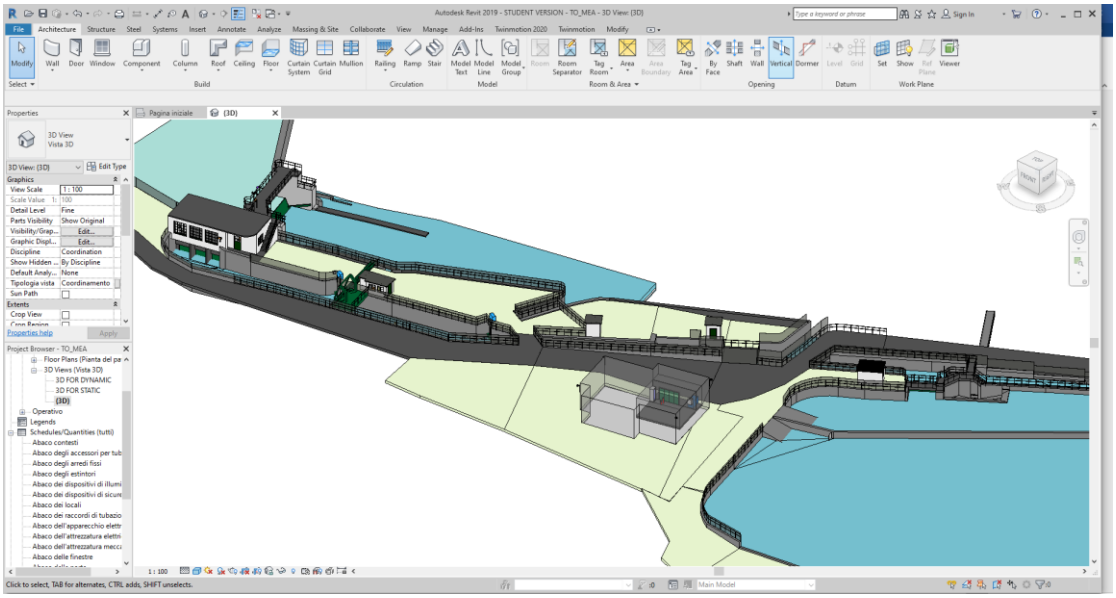


Figure 17 “Opera di presa” and “Bacino”

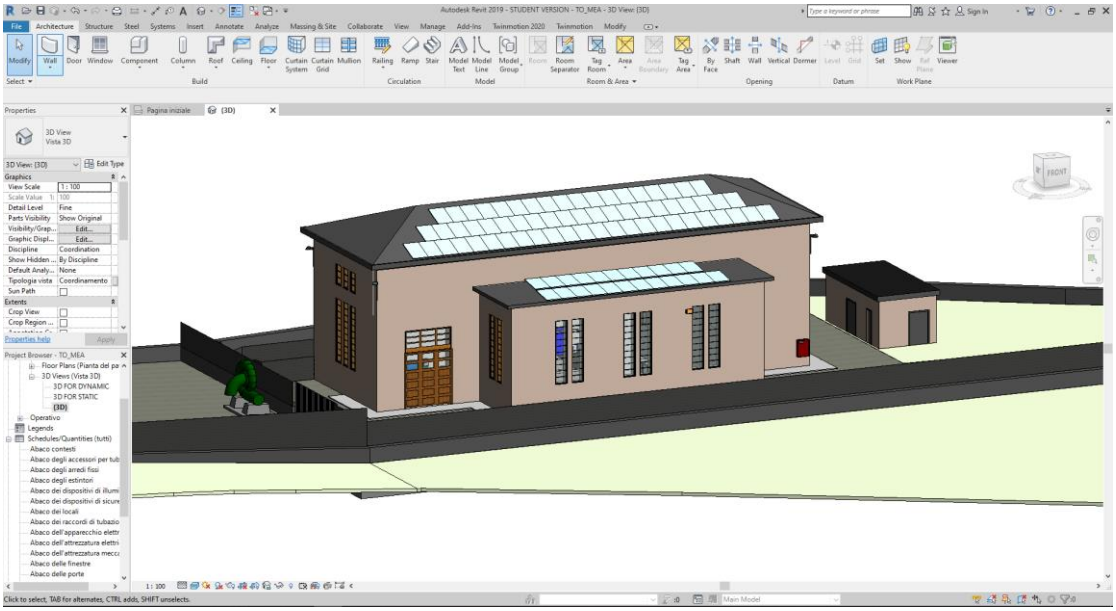


Figure 18 “Fabbricato centrale”

Chapter 3

BIM-based structure analysis

3.1 BIM structure analyze software introduction

Robot Structural Analysis Professional is structural load analysis software that verifies code compliance and uses BIM-integrated workflows to exchange data with Revit. It can help you to create more resilient, constructible designs that are accurate, coordinated, and connected to BIM.

ROBOT STRUCTURAL ANALYSIS PROFESSIONAL

We will develop an understanding of the analytical model that Revit software builds concurrently with the creation of structural geometry. We will then explore the Structural Analysis for Revit feature, which enables static and gravity analyses to be performed on the cloud directly from Revit software.

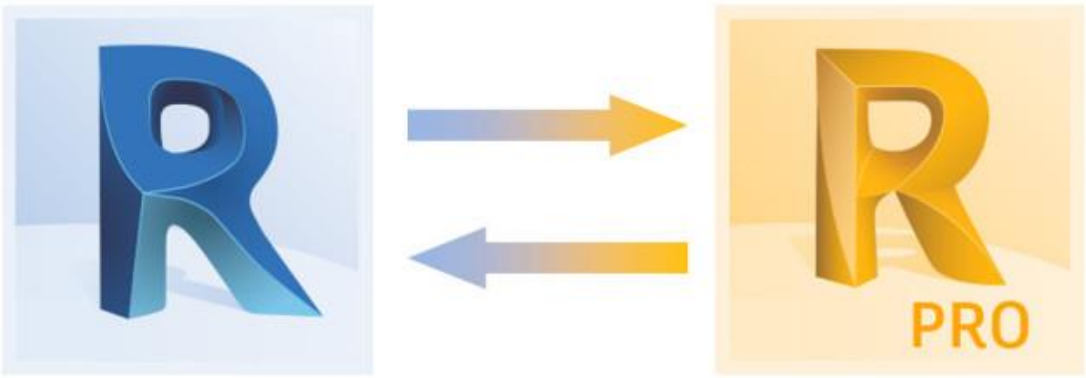


Figure 19 Revit to Robot structure analysis

Some structural engineering firms begin the design process by creating documentation. Others start by creating an analytical model. The link between Autodesk Revit software products and Robot Structural Analysis Professional supports both of these workflows. However, there are some advantages to starting the design process with a model in

Revit software instead of with Robot Structural Analysis Professional. When the toolkit for Autodesk Revit is installed on the same computer as Revit software, new commands are added to the Revit user interface that provide a link between the two products. This link enables the Revit user to send a Revit model to Robot for analysis and design, and to update the Revit model based on the results of the analyses.

- **Sending a model to Robot**

After selecting the Robot Structural Analysis link, the user has the option to send a model to—or update a model from—Robot Structural Analysis Professional. The software can also transfer static analysis results calculated in Robot Structural Analysis Professional to Revit. These results can then be used in the Revit documentation.

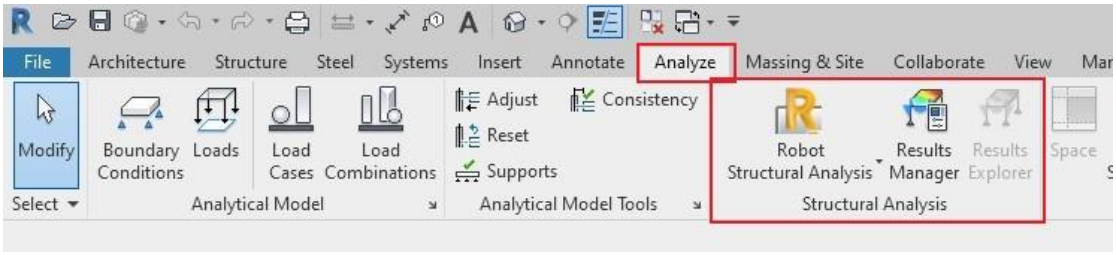


Figure 20 Installed command in Revit

- **Updating a Revit model**

The options for updating a Revit model from Robot Structural Analysis Professional are similar to the options for sending a model. Note that in addition to updating the entire model, selected elements in Revit software can be updated. If the "Select modified elements in Revit Structure" option is checked, Revit will highlight all the new or revised elements that were updated from Robot, enabling the user to more easily review the model.

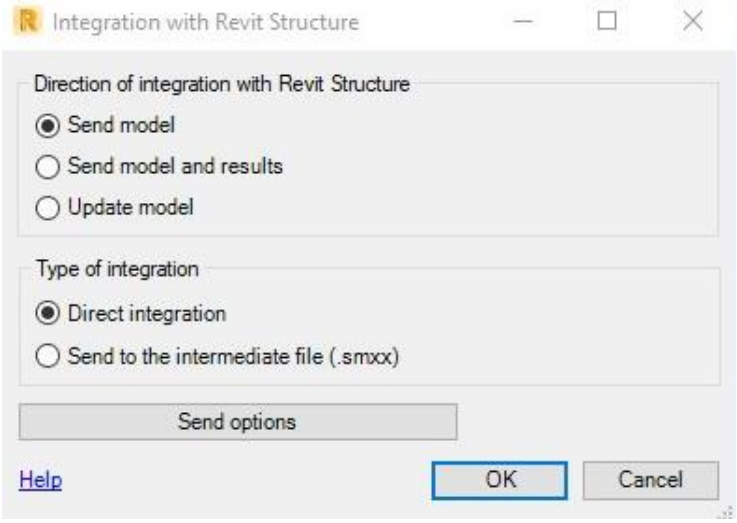


Figure 21 Options for updating

3.2 Structure analyze related to the "control center"

3.2.1 Structure Analytical Model in Revit

- **Link architecture**

Revit user could create an analytical mode after 2015 version of Revit, Autodesk combined three civil-related field (Architecture, structure and MEP) together in a unique software. On 30 June, 2018, Autodesk discontinued sales and support for Structural Analysis for Revit, so Structural Analysis for Revit is no longer available. but still have individual interface for the structural analytical model.

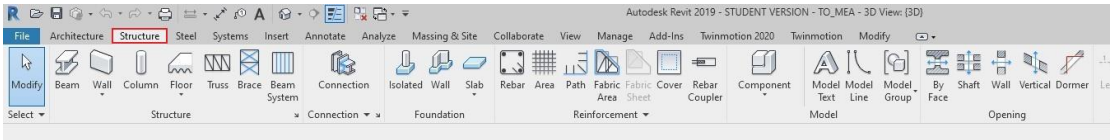


Figure 22 Structure panel

The structure analytical model creation process is same as architecture process, for structural engineering, offering cutting-edge tools for designing solid structures and publishing clear, easy-to-share documentation. Due to the software features we can create the structure model by dealing with the architect model. Normally there's

nothing wrong with the architect. But we do need to know what they're doing in terms of building footprint. This where linking comes in handy. The objective is to link in the architectural model which we created before. Then we will pin it down and check out the halftone underlay settings. Under models, we can open an existing model, either we can start a new model, in our case we link with an existing model.

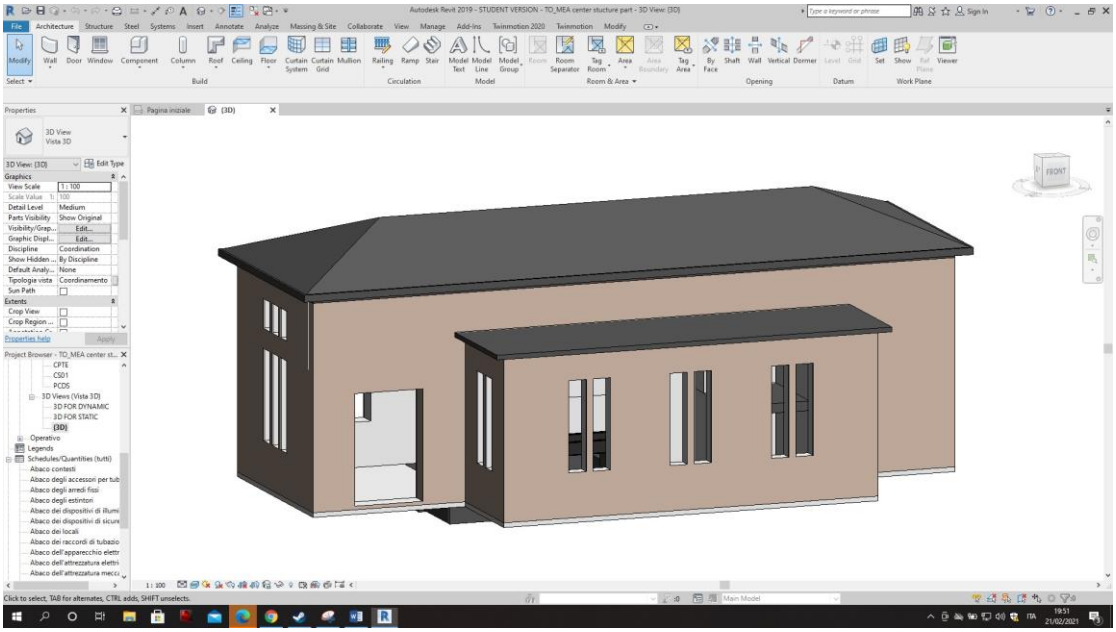


Figure 23 Structure model reference

By isolating some categories of family like window, door, additional objects, etc. we can insert the isolated structure model into new project in order to be a reference object for structural modeling.

- Grids, column and foundation

We will add grids to the exterior architectural walls' core center line, and then we will add some grids to some of the significant demising partitions within our model. With a structural grid in place, adding columns is a snap. We need to think about the main thing while adding columns because the Revit structure likes to look up. When we add a column, we must specify the height of the columns as we're adding them.

To start thinking about foundations. The first thing that comes to mind when thinking about foundations are foundation walls. Setting up a foundation wall thickness and adding it to our model's base underneath the exterior architectural walls. Those walls we just added need something to bear on. This is where bearing footings come in handy. Revit likes to call them wall footings by looking at the button makes adding a wall, but that is not the case. It is adding a strip footing that is hosted to a foundation wall.

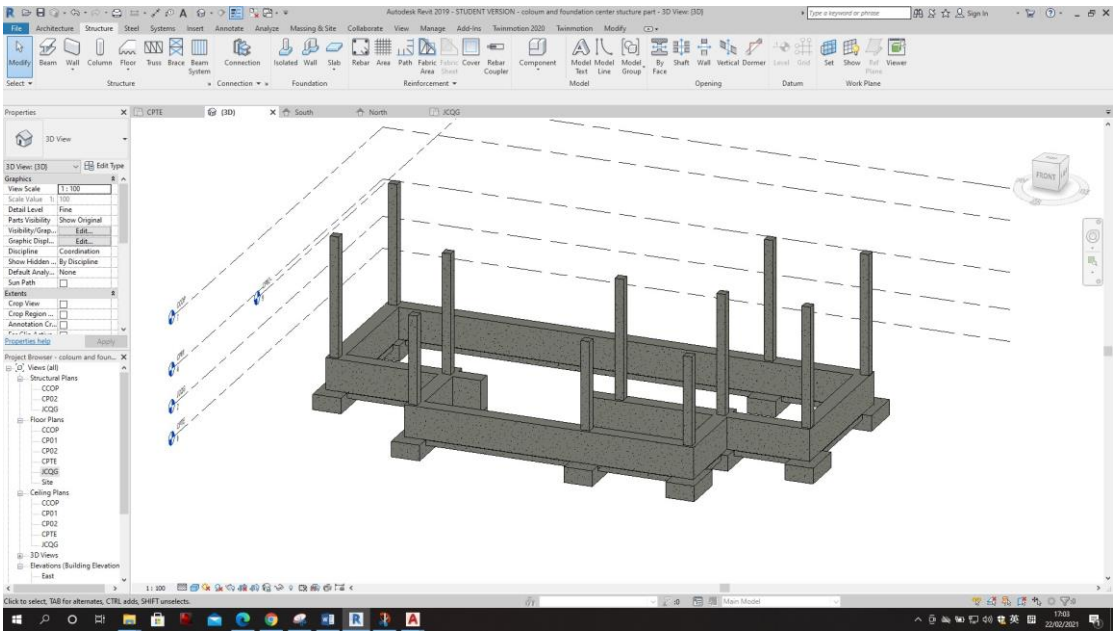


Figure 24 Column and Foundation

- Steel framing, floors and slabs

Start adding some steel beams for our model. The first type of beams I would like to add is the larger perimeter beams surrounding the smaller beam systems or the filler beams. It is the perimeter framed and in place, we can fill in the gaps. To add our filler beams, we can use what is called the beam system. Just specify the beam type and the spacing. Looking at slabs. There are two central systems; one is a slab on grade, while the other is a slab with metal decking. The add a slab-on-grade, We need one thick material. It is going to be concrete. We can duplicate the existing 300-millimeter generic floor and modify it to suit our needs. The next type of floors we need to add are concrete floors with metal decking. We will not have to do that much. We just need to tweak some dimensions to make the architectural floor thickness. We picked framing instead of lines for our slab, and we are going to need to cantilever the edges. This allows us to stop the decking to allow for a thicker slab at the edges of our framing, and since we pick the centerline for beams, we will have to set our detailed level to fine and look at where the edge of that beam is. Finally need to thicken our slab edge around the perimeter. The objective is to create a slab edge. We will modify the size and material, then add them to the model.

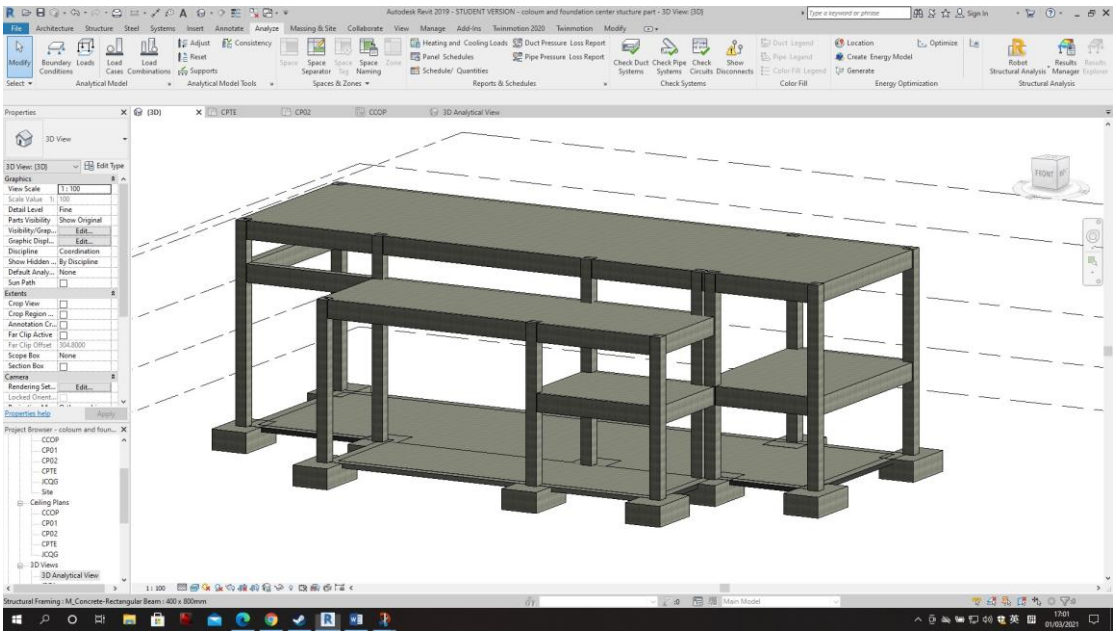
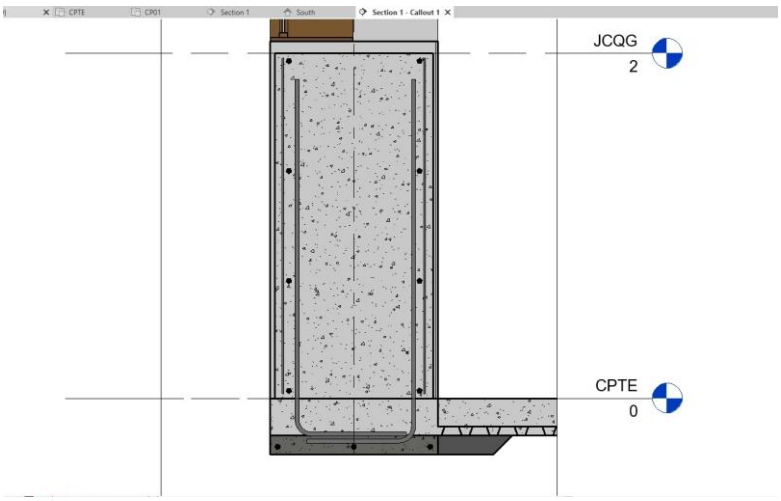


Figure 25 Steel framing, Floors and Slabs

- Reinforcing

Add some reinforcing for the structure is necessary. In a foundation wall situation there are a few different ways we can add reinforcing. The way we are going to do it here is to use perpendicular reinforcing. We will also have the choice of the rebar gauge as well as the spacing. Secondly, we can add some rebar going the other way by Adding rebar perpendicular to the cover and sketching rebar to look any way we want. By sketching rebar, we add the dowels that pin two different concrete systems together, such as walls and footings and walls and slabs. Lastly, we can get the same vertical and horizontal configuration by placing a slab in an area. So what we can do is to place area reinforcing in our slab. In this part we can create sectional views and enlarge views.



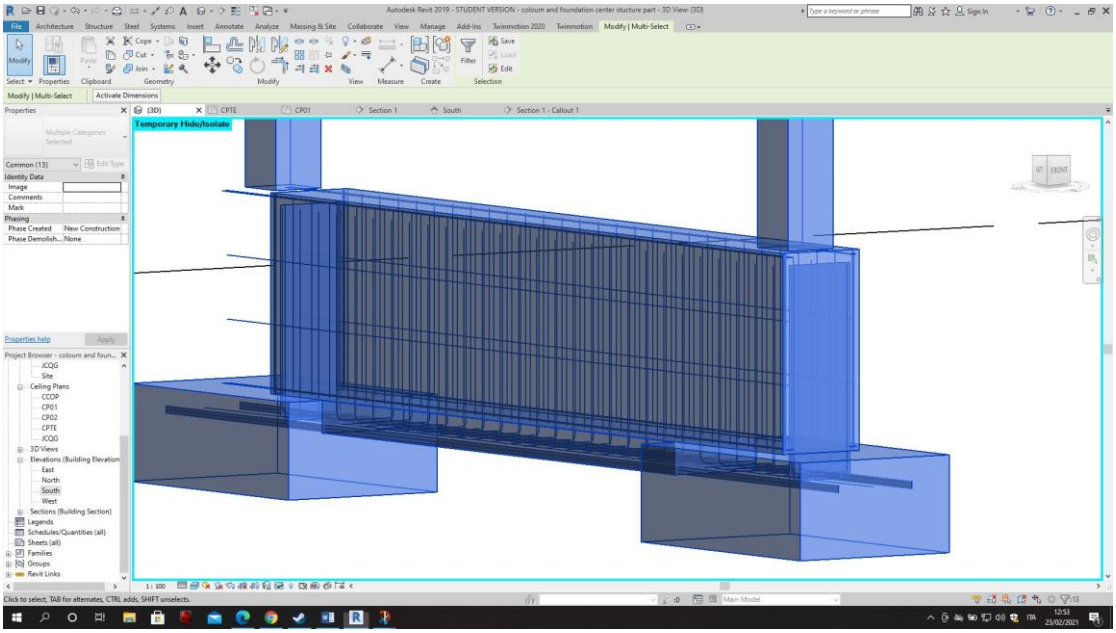


Figure 26 Reinforcing

3.2.1 Analytical Model feature in Revit

An analytical model is a simplified 3D representation of the full engineering description of a structural physical model. The analytical model consists of those structural components, geometry, material properties, and loads, that together form an engineering system. In our case, after filled out the analytical model, we can start do add boundary condition to implement the analysis.

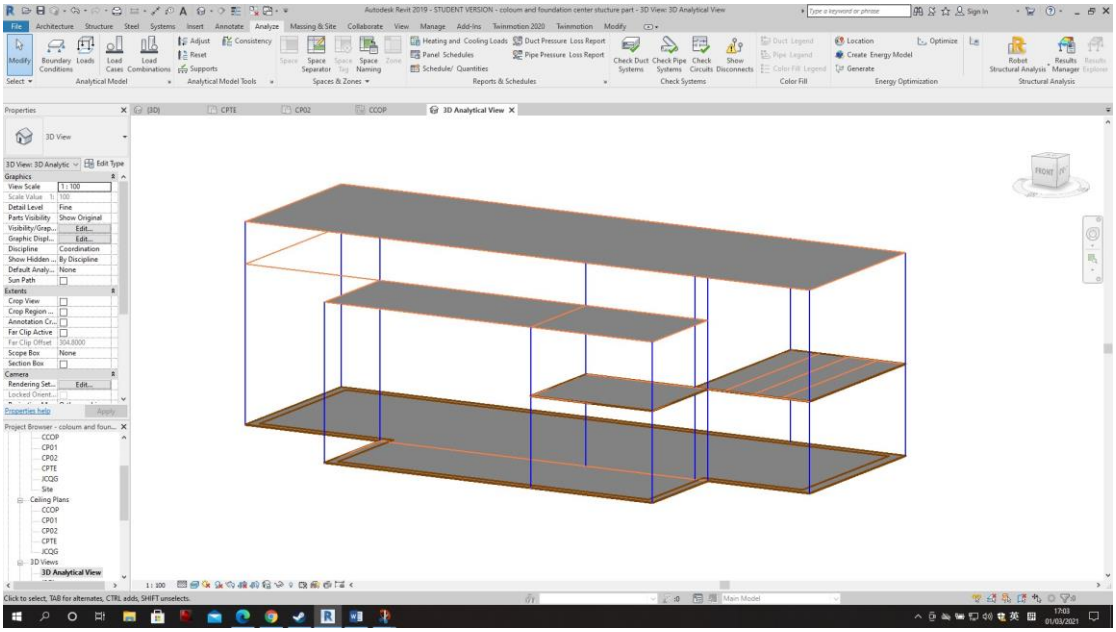


Figure 27 Analytical Model

In particular, it is consisted by following structural elements:

Foundation: From the model, it is observed how the foundations designed with reinforcement concrete footing for support the columns, having dimensions of 2600 x 1650 x 1100 mm, and I designed it is uniform rectangular footing foundation.

In the perimeter of the structure designed with Strip foundation for support wall element also for support soil pressure around the building, having dimension of 850 mm and base level of -185cm from the ground surface.

Structural elevation system: the load-bearing structure mainly consists of reinforced concrete frames, with 652-1002-355-175-62-495 mm of span in x direction connected with reinforcement concrete beam, and reinforcement concrete column with maximum dimension of 500*500mm, for Y direction the span by 500-700 mm without connection of beam system.

The beams are flat beam and dimension of 400*800 mm, the inter-floor slabs present are made of cement slab with 20cm of thickness and the direction of slab is one-way slab with y direction and also it's the same in hole structure. And its supported by beams in x direction.

Roof: From the archival documentation can be notice that the roof designed with inclined truss structure, inclined truss beams are supported by beam in x direction with dimension of 400*800 mm.

- **Analysis of load**

After the load confirmed we could add some structural settings like configuring materials of floor and roof, load cases need to be considered as well. The evaluation of the representative value of gravity load, non-structural loads G2 takes place considering the floors, the perimeter walls and the internal dividing elements, structure self-weight G2 takes place considering the also the roof, and for live load Q1 we could consider as 2kN/m2. These loads must be analyzed as they constitute a fundamental element, the representative value of gravity load considered like below:

- ✓ For slab G=G1+G2+Q1
- ✓ For roof G=G1+G2

a) Dead load of G_1 (for slab and roof)

G1 for 1m2						
	Width [m]	Length [m]	Thickness [m]	number	density	G1 [KN/m2]
SLAB	1	1	0.08	1	25	2
BEAMS	0.12	1	0.2	2	25	1.2
					total	3.2

Table 1 Dead load of G_1

b) Permanent non-structural load G_2 (for slab)

G2 for 1m2						
	Width [m]	Length [m]	Thickness [m]	number	density	G2 [KN/m2]
floor	1	1	0.07	1	22	1.54
mortar	1	1	0.02	1	21	0.42
mat	1	1	0.04	1	18	0.72
plaster	1	1	0.02	1	17	0.34
partitions						1.2
					total	4.22

Table 2 Permanent non-structural load G2

c) Permanent non-structural load G_2 (for roof)

Roof						
	Width [m]	Length [m]	Thickness [m]	number	density	G2 [KN/m2]
floor	1	1	0.02	1	22	0.44
mortar	1	1	0.02	1	21	0.42
mat	1	1	0.04	1	18	0.72
plaster	1	1	0.02	1	17	0.34
imp layer						0.1
					total	2.02

Table 3 Permanent non-structural load G2

We have our analytical model, then just put the boundary conditions on the model. We have one of three ways we can do this. In this case, we want to add a point boundary condition. We are going to snap to all of the bottoms of our piers and pilasters. It is straightforward to do in a wireframe view. Then do the same thing to the bottom and top of our columns.

Figure 28 Boundary condition panel

We can place an area load in a few different ways. One is to be physically hosted to an element. The other is to sketch the area load. We can be in an analytical model as well, or we can be in a physical model. Both are the same thing, just with our visibility graphics different. Then notice our forces; we can change them right here. If we have Fz one, if it is a negative value, it will be coming down. Moreover, if it is a positive value, it will look at it as an uplift. It can be a reaction or not, but the nature of this load will not be a reaction.

And then we have many different choices now. To add a hosted area load, we can select our slab. That is going to give us a hosted area load. So it is going to take care of the entire floor. So if we select this area load we can have our load case to select.

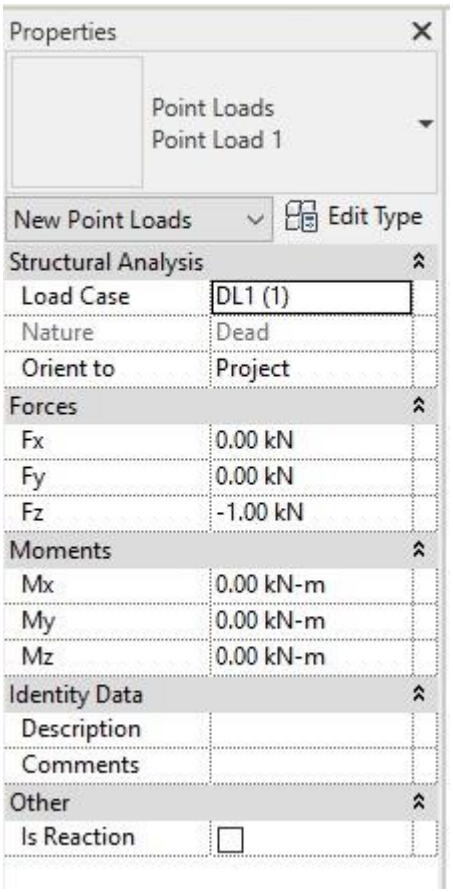


Figure 29 Apply load tab

Notice that these load can be applied on Robot software as well by means of schema as follow:

Carichi:1

	Condizione	Tipo di carico	Lista									
	1:DL1	(EF) uniformi	37	PX=0,0	PY=0,0	PZ=-7,42	locale	non proiett.	assolute	Limits	MEMO :	
	1:DL1	(EF) uniformi	36	PX=0,0	PY=0,0	PZ=-7,42	locale	non proiett.	assolute	Limits	MEMO :	
	1:DL1	(EF) uniformi	40	PX=0,0	PY=0,0	PZ=-5,22	locale	non proiett.	assolute	Limits	MEMO :	
	1:DL1	(EF) uniformi	41	PX=0,0	PY=0,0	PZ=-5,22	locale	non proiett.	assolute	Limits	MEMO :	
	2:LL1	(EF) uniformi	37	PX=0,0	PY=0,0	PZ=-2,00	locale	non proiett.	assolute	Limits	MEMO :	
	2:LL1	(EF) uniformi	36	PX=0,0	PY=0,0	PZ=-2,00	locale	non proiett.	assolute	Limits	MEMO :	
*												

Table 4 Load table

According to the load condition that we suppose before, we have our certain value of load so we can put them to our model in order to proceed the next step.

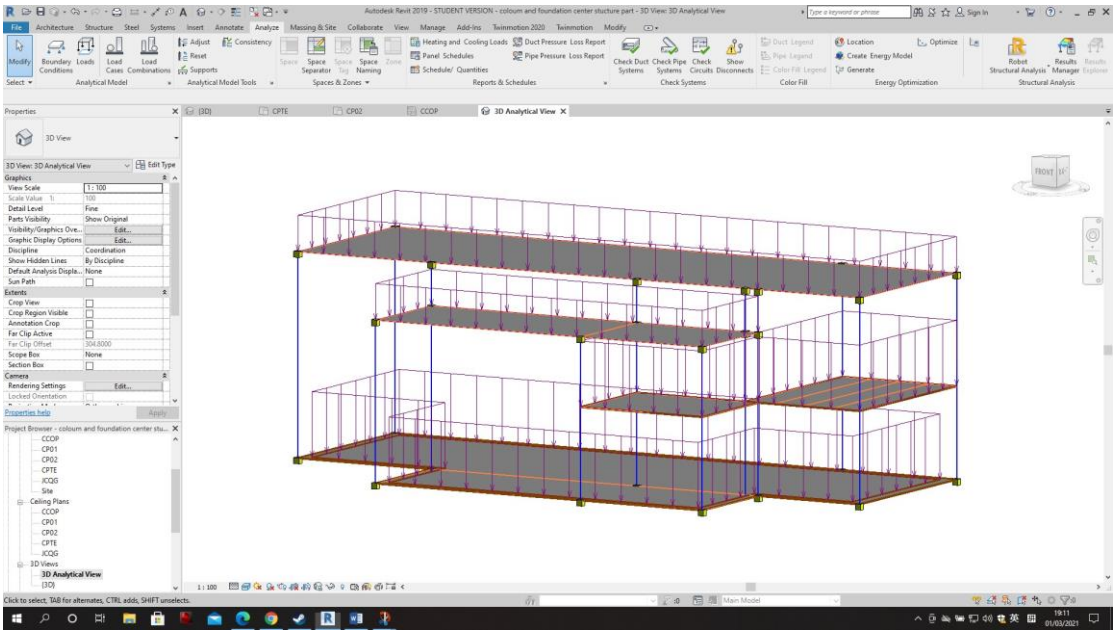


Figure 30 Load applied model

3.2.3 Advanced Analytical Model tools in Robot

- **Analytical check tools**

Before sending a Revit model to Robot Structural Analysis Professional, it is important to check member supports and perform analytical/physical model consistency checks. These checks will also help prevent the creation of duplicate nodes and the generation of other errors or warnings when linking to Robot.

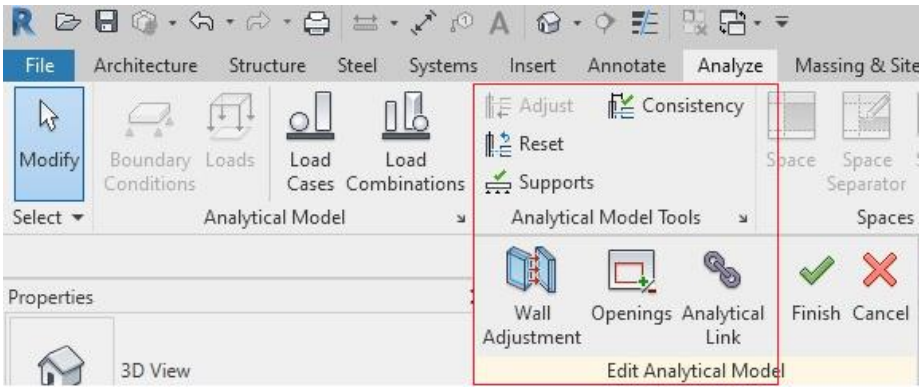


Figure 31 Analytical check tool

In the analytical check tool panel, the feature to check wall adjustment, opening and analytical link to individually adjust and check if the walls, opening of project align or not, and check if there are some point of elements connect or not.

- **Sending model**

Although we can place and configure loads and load cases in Revit, we cannot do analysis in Revit. Therefore Robot Structure Analysis comes into usage. We have a direct link to an analysis program that works seamlessly back and forth. To send this model over to Robot, we need to open the structural model that we have been working on, or open any model to send to Robot.

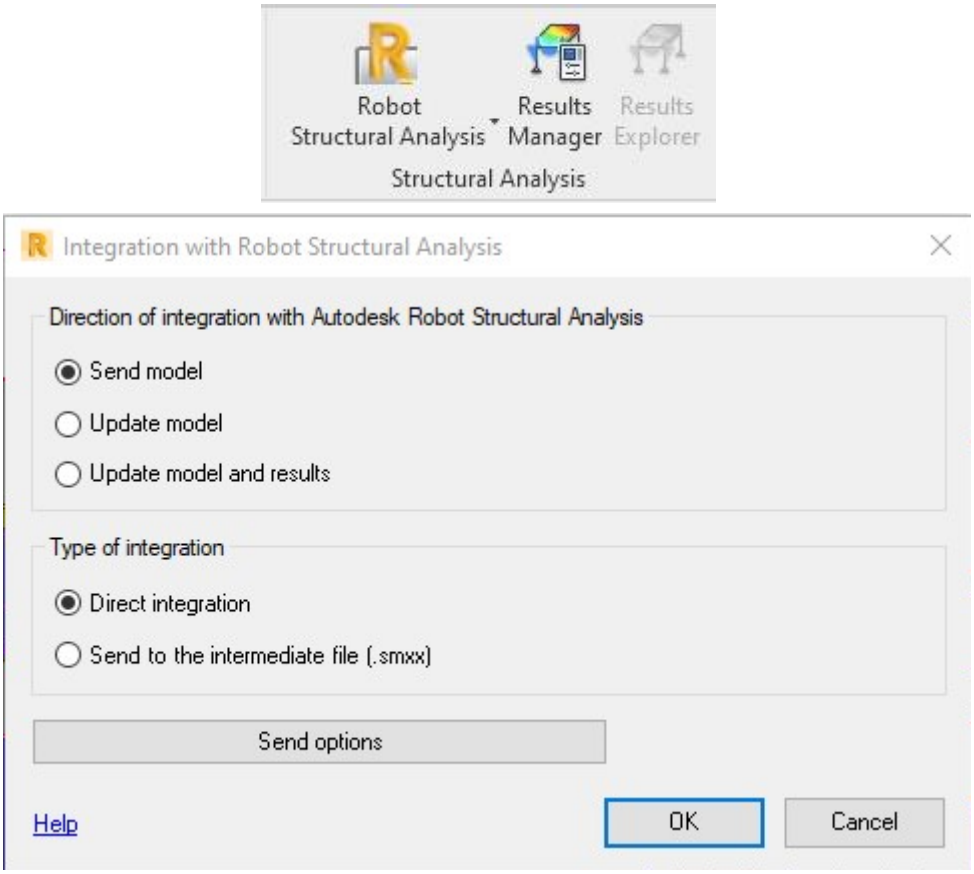


Figure 32 Structural analysis panel

We do have send options, specify the case that contains self-weight, DL1. We can just use whatever the default top one is. DL1 actually works perfectly. Using plan view's backgrounds could be selected by transfer tab, it can be choosing the other option to Robot in order to work that well for me. Sending to Robot Structural Analysis completed. we do have an events report which is excellent feature that could notice us and also provide the warning list of transformation.

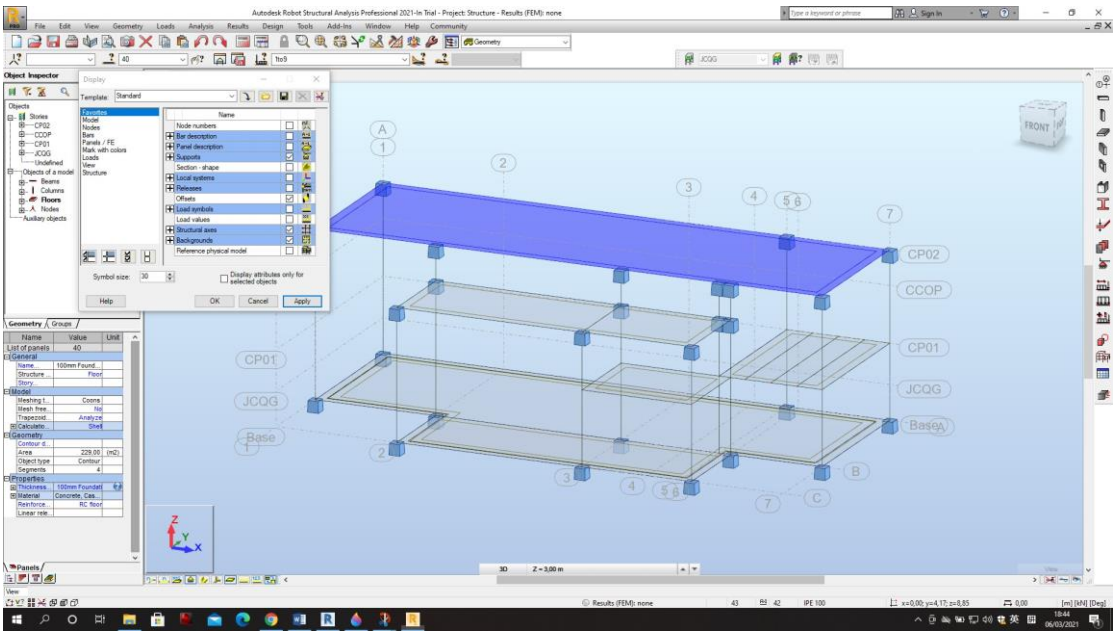


Figure 33 Robot software interface

So in robot, we'll run that model that we exported. Sometimes our loads are not showing up, but boundary conditions are there. So what I would like to do is go to the View tab, go to display. Here is all the stuff we have turned on or off. We have our object inspector which is the project browser. So we have our stories, meaning our levels. And we have objects of a model. So if we go through the interface, we will see that we have that element and we have our properties can be changed. When we change these properties, these properties will go back into Revit once we send this model back. In geometry, if we go into the penthouse, we can drill in, we can see all the beams in our penthouse.

Since Robot is a finite analysis application, it makes sense that we could make load combinations right here. So means we did not need to do any placement of loads over in Revit. Automatically create some load combinations. We can select full automatic combinations; we can click more, and the regulations have been changed. We have our load cases. They are all turned on and going to make all of these combinations. We can add groups, relations. It seems pretty straightforward, but we just automatically generated all of our load combinations.

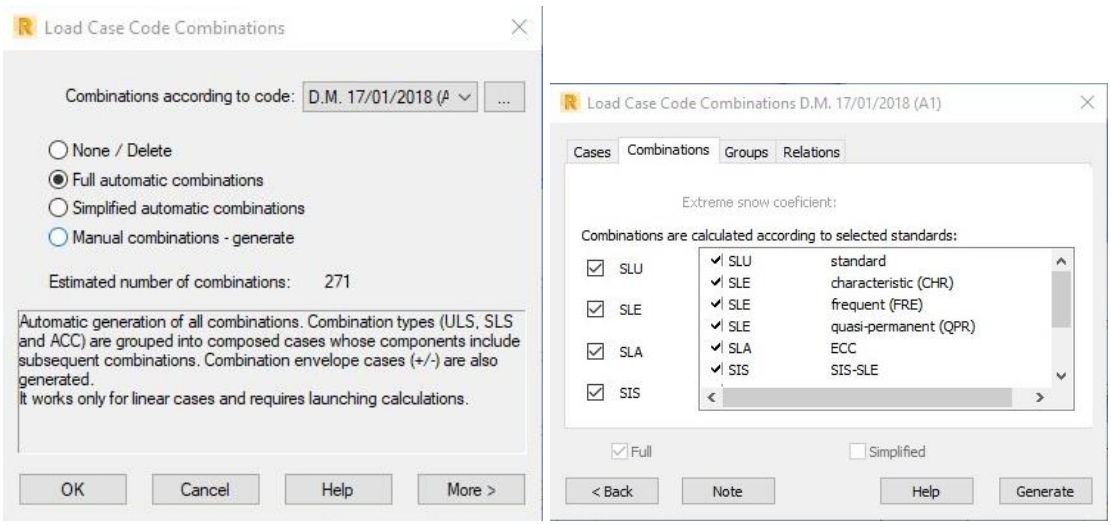


Figure 34 Robot load combination

- **Finite element mesh**

In order to analyze surfaces, we need to create a primary grid, a mesh. This will allow us to see where our surfaces are supported, or sagging, or deficient. A primary grid is needed to proceed with other analyses. In Robot, this little icon right options of FE mesh generation.

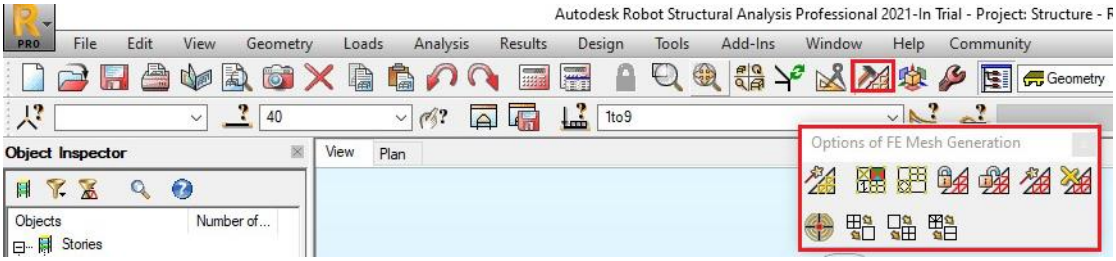


Figure 35 Robot finite element mesh panel

Mesh every panel in our entire model in our meshing options, after we create the mesh we are going to the generation of calculation model and selecting all of our surfaces, we can basically select it and start to run some analyses. If we zoom into our model, we can start seeing the grid where it is starting to show us exactly where that mesh is. Obviously, it is an over-exaggeration of how this will perform, but we can see where we have deflected, see our surfaces, and mesh back onto this stuff. And this can all be integrated back into Revit.

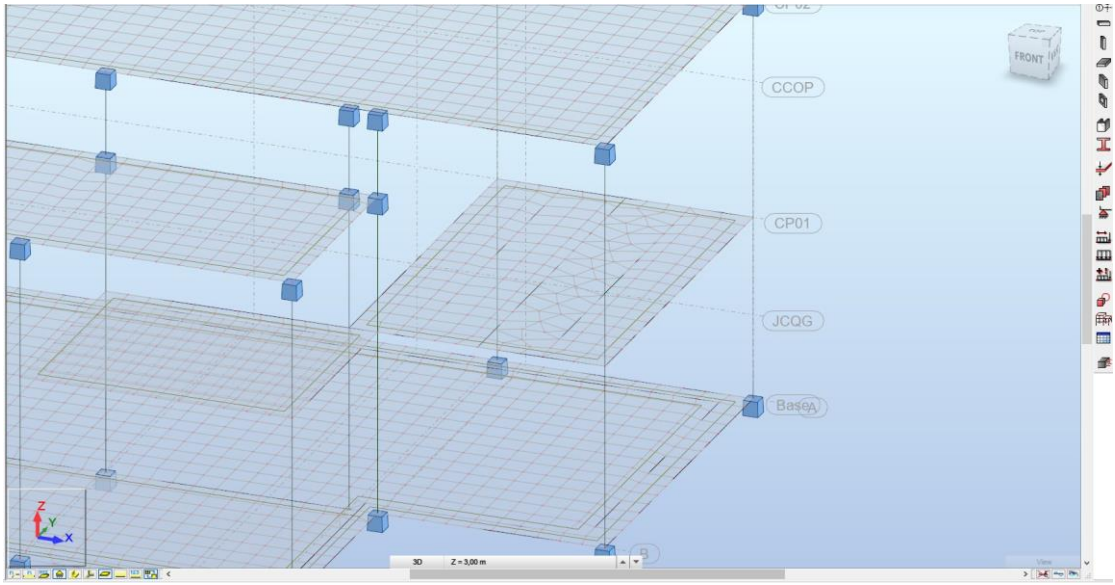


Figure 36 Robot finite element mesh

- **Performing analysis**

In this section, we can perform a simple sample analysis. I want to perform a basic analysis on all the DL1 cases we have in our model. Although this is a sample, this is how we can analyze all of the load cases.

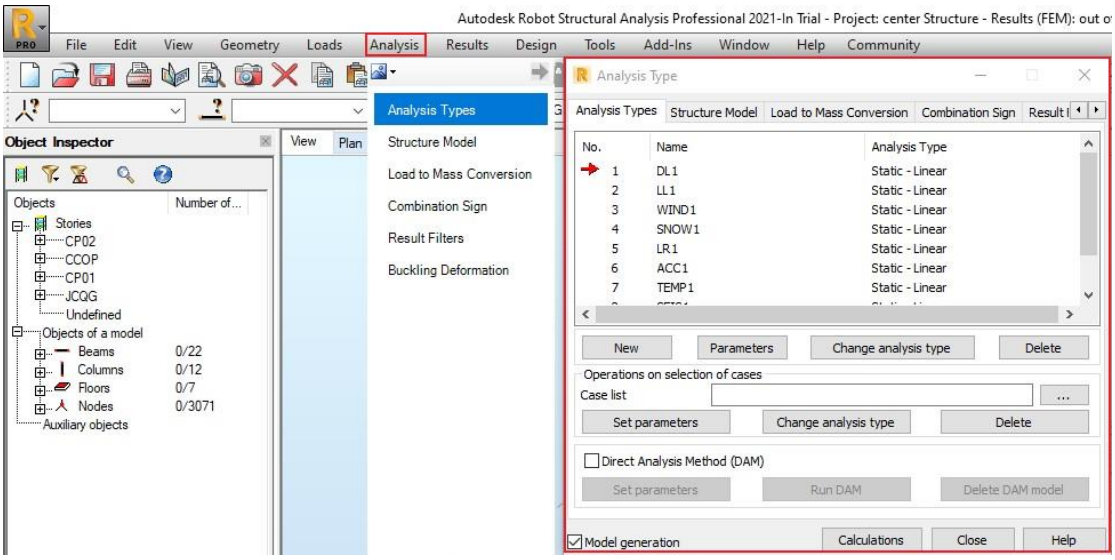


Figure 37 Robot Analysis panel

On the toolbar we can find analysis. Come down to *Analysis Types*. Here we have all of the analysis types that are in our model. We can always change the analysis type. We can change whatever case we want or create a new one. Here has a case list. So if we choose on this browse button, all of our case lists existed here. Just so happens that alphabetically, DL1 ， LL1 are I want. I used our model generation. After clicking on

calculations. Sometimes we can ignore all warnings and get the warnings later if it needs to modify something. Now is time to read our nodes. We know where those nodes are. They all seem pretty consistent to be in the same spot. Look down here at the very bottom, we can see a little green light. "Results available" then go to the results tab. from the "maps." we can see where we are starting to get sags due to moment, shear and displacement. If we look at the chart, purple is ominous and gets up to white which is fine.

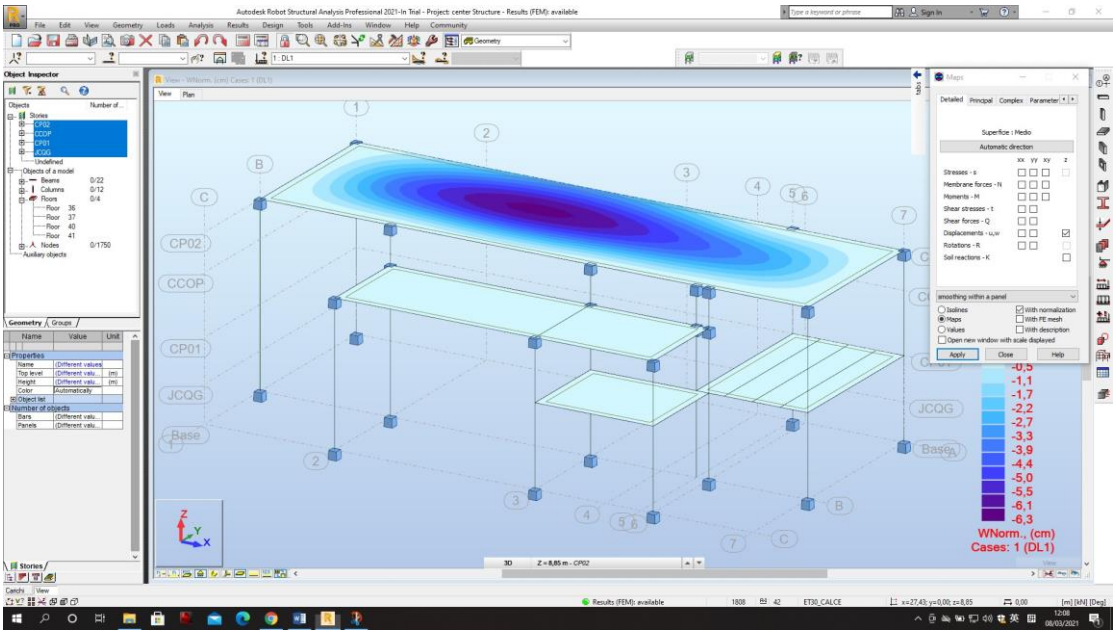


Figure 38 Error Displacement diagram

But as we can see from the displacement diagram, the displacement is too large to exist in this roof due to the span of the roof is too long, I found it is because when I created the structure model I did not create the beams within the roof which induced this issue, to solve this problem, I need to recreate the additional beam within the roof and distribute the self-weight of the roof and live load.

- **Updating model through both software**

I want to jump into Revit and bring our changes in from Robot, even we could do so in Robot but to test the updating feature we could have this process. The first thing we need to do is go ahead and perform another calculation to confirm the result again because we can update the result simultaneously. We will get a calculation message from which we do have some information to have an inspection, now we can jump into Revit. Of course, notice that here needs to open up the structure. rvt model because we have to open both software the updating process could be operated.

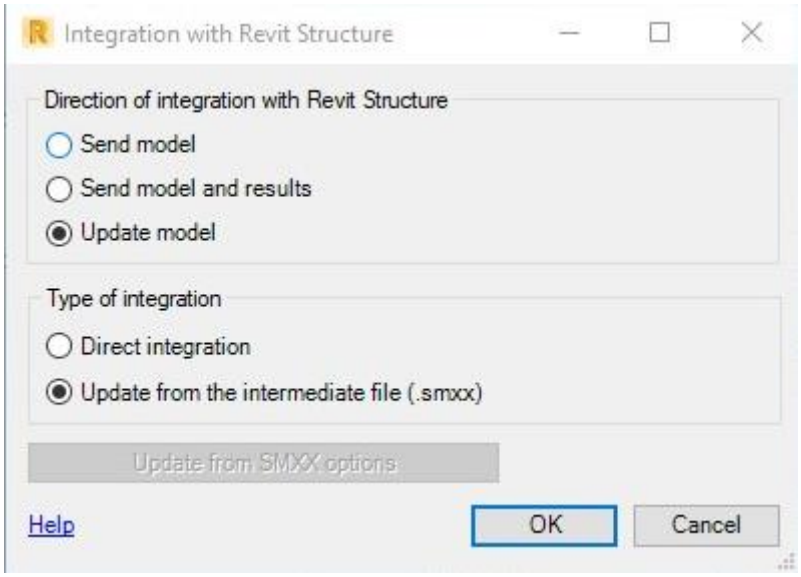


Figure 39 Update model

On the Analyze tab, go to Robot Structural Analysis and click on Robot Structural Analysis link. Click on Update model and results. The type of integration could be a direct integration. Therefore, it is going to send the results to Revit. Moreover, we can see it as an actual 3D view too.

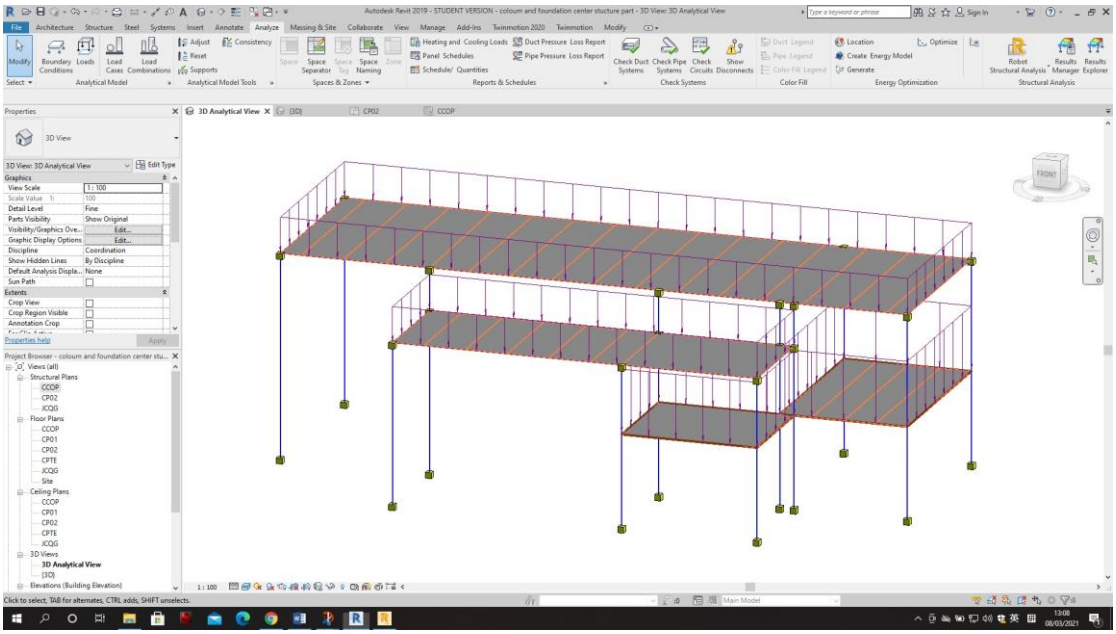


Figure 40 Update model

After the modification of slab and add the beam system for the long-span roof we go back to Robot structure and calculate again, obtain the final correctly result. Notice that even the deep blue shown in the floor but the exact value of displacement is acceptable.

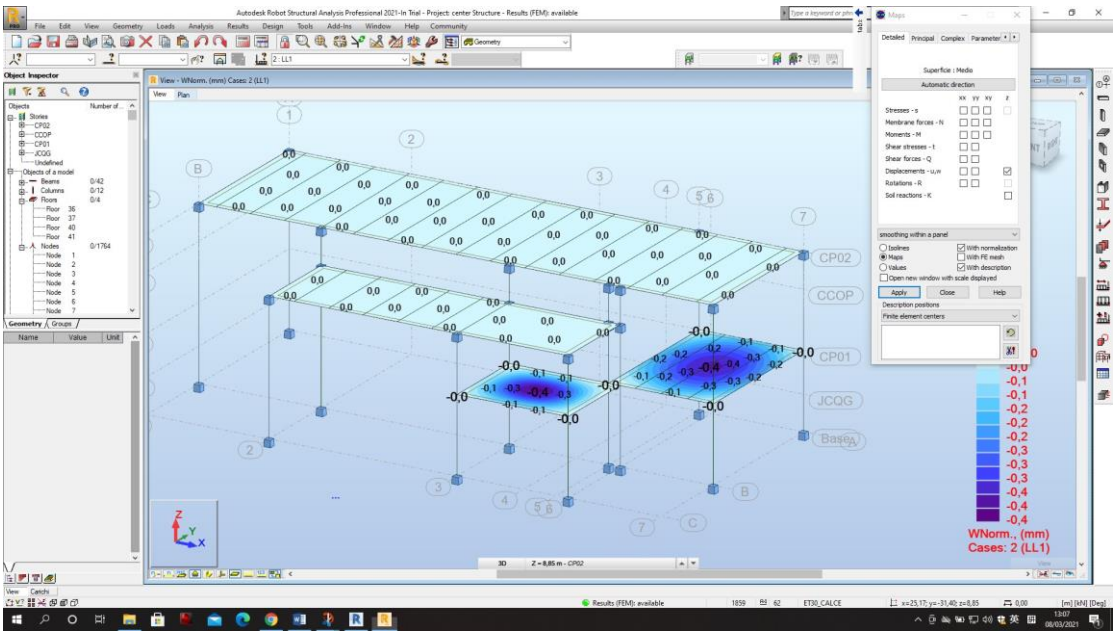


Figure 41 Modified Displacement diagram

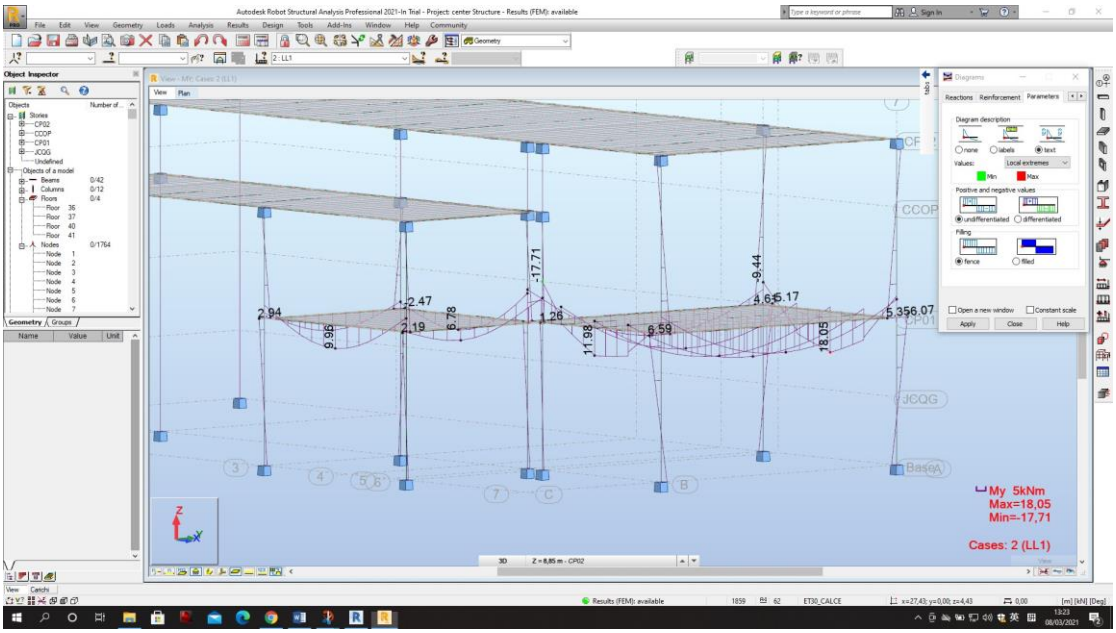


Figure 42 Moment diagram

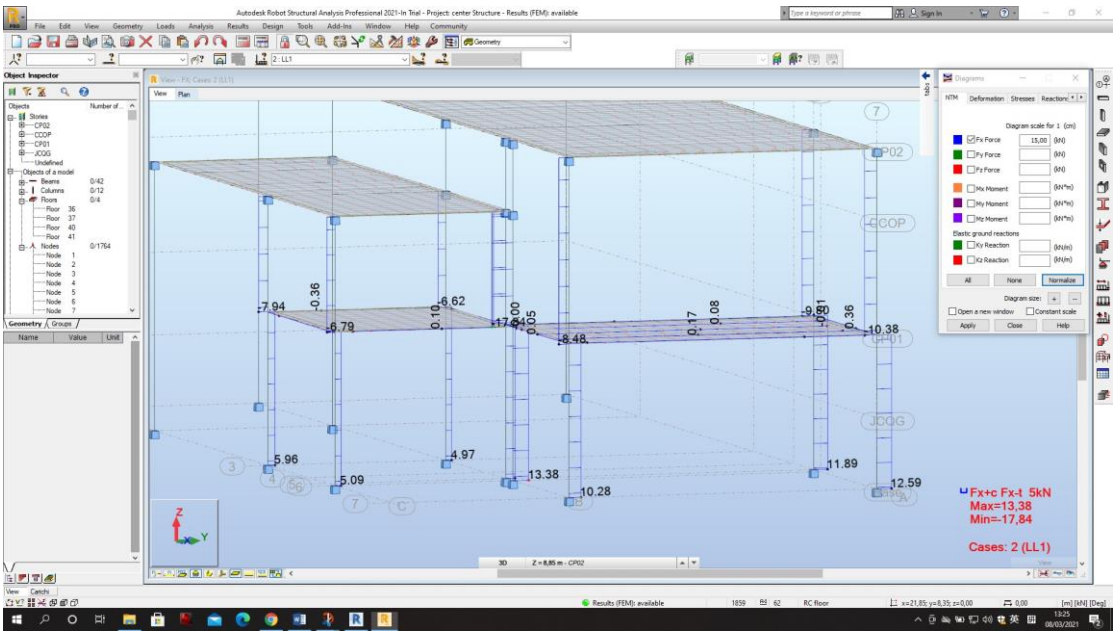


Figure 43 Axial force diagram

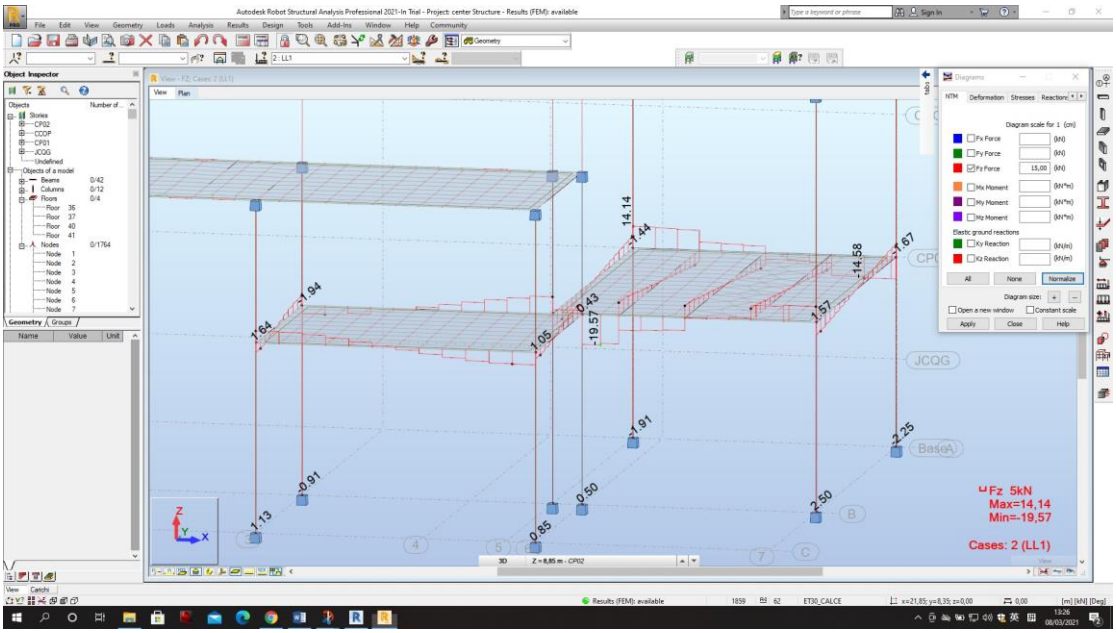


Figure 44 Shear force diagram

3.3 The interoperability of Revit and Robot Structural Analysis software

Revit and Robot belong to Autodesk's software, which is more compatible with other structural analysis software than Revit. At the same time, Robot has the advantages of friendly interface, strong operability, and efficient calculation, so its calculation results are often directly used as the basis for determining component size and reinforcement in many projects. It has the advantage of being able to import CAD drawings (both DXF and DWG formats), which is similar to Revit. Therefore, the preliminary base drawing processing is carried out through the CAD drawing platform, and then imported into Robot to create components and even form the entire structure by tracing points. This process is better than It is much smarter to directly define complex coordinates in Robot to model. However, in actual use, the two software cannot fully convert the construction parameters.

- **Scope of transferred model elements**

The following sections describe how model elements in Revit and Robot are transferred between the applications. The tables use these symbols to describe the transfer:

- **< >:** elements are transferred in both directions
- >or<: elements are transferred in that direction only
- NA: elements are not transferred
- P: elements are transferred one way with data preserved but not accessible

Any limitations related to the transfer of an element are noted as well.

1) Supports

Revit software		Robot Structural Analysis Professional
Isolated Foundation	>	Nodal Support
Point Boundary Condition	<>	Nodal Support

Table 5 Nodal Elements

2) Linear elements

Structural columns, framing elements, and braces modeled in Revit software are transferred to Robot as bar elements—Columns, Beams, and Simple Bars, respectively. Revit parameters such as Analyze as (for instance, lateral, gravity) and Framing Type (girder, joist) have no bearing on the Robot element.

Revit software		Robot Structural Analysis Professional
Line Boundary Condition	>	Linear Support
Wall Foundation	>	Linear Support
Structural Column	<>	Column
Beam	<>	Beam
Brace	<>	Bar
Curved Beam	P>	Discretized Beams
Beam System	NA	
Truss	NA	

Table 6 Bar and Linear Elements

Several of the Element parameters in Revit are transferred to and from Robot. Other Robot design parameters, such as slenderness and buckling coefficients, are preserved in the Robot model and are neither visible nor accessible to the Revit user.

Revit software		Robot Structural Analysis Professional
Analytical Link	>	Rigid Link
Cross-Section Rotation	<>	Gamma Angle
	P	Cable
	P	Elastic Ground
	P	Geometric Imperfection

Revit software		Robot Structural Analysis Professional
Analytical Link	>	Rigid Link
Cross-Section Rotation	<>	Gamma Angle
	P	Cable
	P	Elastic Ground
	P	Geometric Imperfection
	P	Non-linear Hinge
End Release	<>	End Release
	P	Member Type
	P	Inactive Status
	P	Shear force respect in deformation
	P	Tension / Compression Member
	P	Axial Forces Only

Table 7 Bar and Linear Element Parameters

Planar elements Area boundary conditions modeled in Revit are transferred to Robot as planar supports. Both pinned and user-defined supports are transferred. Planar supports in Robot are not transferred to or preserved in Revit.

Revit software		Robot Structural Analysis Professional
Area Boundary Condition	>	Planar Support
Foundation Slab	>	Floor
Structural Floor	<>	Floor
Structural Wall	<>	Wall
Curved Structural Wall	P>	Wall
Wall Opening & Window	P>	Opening
Door	P>	Opening
Vertical or Shaft Opening	P>	Opening
Slab Edge	NA	

Table 8 Planar Elements

Wall, vertical, and shaft openings, windows, and openings created by Editing Profile modeled in Revit are transferred to Robot as openings. The perimeter shape of a floor, wall, and slab, including arcs, are transferred as the contour shape of the panel in Robot. Doors modeled in Revit are transferred to Robot as part of the parameter panel definition rather than openings. No relationship is maintained between the Revit openings and the Robot openings. Therefore, any new openings created in Robot (or modifications made to existing openings) are not updated in Revit software.

Revit software		Robot Structural Analysis Professional
	P	Load Distribution
	P	Reinforcement Design Parameters
	P	Calculation Model
	P	Meshing Parameters
	NA	Emitters

Table 9 Planar Element Parameters

3) Loads

Loads, load natures, load cases, and load combinations are transferred between Revit and. Load elements created in Revit and transferred to Robot are editable. However, changes made in Robot are not propagated back to Revit software. Loads created in Robot are transferred to and preserved in the Revit model; however, they are hidden and are not accessible to the Revit user.

Revit software		Robot Structural Analysis Professional
Load Nature	<>	Load Nature
Load Case	<>	Load Case
Load Combination	<>	Load Combination
(Hosted) Point Load	<>	Nodal Load
(Hosted) Line Load	<>	Linear Load
(Hosted) Area Load	<>	Planar Load

Table 10 Load Elements

4) Concrete reinforcement

Structural rebar modeled in Revit software is transferred to Robot only for structural columns, beams, and spread footings. Area and path reinforcement and structural rebar modeled in other elements or modeled manually in Revit software are not transferred to Robot. Rebar designed in Robot for columns, beams, and spread footings are transferred to Revit.

Revit software		Robot Structural Analysis Professional
Area Reinforcement	NA	
Path Reinforcement	NA	
Structural Rebar	<>	Rebar
Revit Extensions Patterns	<	Revit Extensions Patterns
Revit Extensions Required Reinforcement	<	Required Reinforcement

Table 11 Rebar Elements

5) Other elements and element parameters

Materials, grids, and levels modeled in Revit are created as materials, structural axes, and stories in Robot. The bidirectional transfer of these elements is limited. Therefore, it is recommended that the user create and adjust these elements in Revit software. Many of the other project wide and structural analysis parameters in Robot are sent to and preserved in Revit software.

Revit software		Robot Structural Analysis Professional
Material	>	Material
Grid	>	Structural Axis
Level	<>	Story
	P	Global Mesh Parameters
	P	Active Section Databases
	P	Units
	P	Analysis Parameters
	P	Model Generation Parameters

Table 12 Other Elements and Element Parameters

Chapter 4

Customer-oriented visual display

4.1 Effects of visual display for customer

With the continuous popularization of BIM applications and the constant maturity of VR and AR technologies, the visualization value of BIM VR and BIM AR in the AEC (Architecture, Engineering & Construction) field will be highlighted, and applications based on 3D visualization will open up a The efficiency revolution of new architectural design and communication management. After using virtual reality technology, people are affected differently by the visual environment. This difference can help us better understand how individuals use visual information to explain their environment and how they react when performing other tasks.

Because the construction engineering market is large enough, Epic Games (a well-known American video game and software development company) no longer only authorizes third-party developers to do BIM service but instead uses acquisitions and self-developed methods to seize architectural BIM technology Service market, so the Twinmotion software that will appear in this article gradually enters everyone's field of vision. It was originally developed by Abvent based on Epic Games' UE4 platform. It is an architectural visualization toolkit used in architecture, engineering construction, urban planning and landscape engineering. Unity 3D is also ushering in corresponding products. Although it is slightly inferior in rendering capabilities, it has the advantages of Unity's better data integration capabilities and cross-platform distribution and interaction. It also has a large amount of data resources and program coding for people. Use, achieve a more open source and open operation mode.

I believe that as more and more available open-source engines are put into the field of construction engineering, a large number of affordable and easy-to-use BIM, BIMVR, and BIMAR tool software will become new production tools for construction engineers. At present, the price of such tools is generally high, the user experience is not perfect, and the user group is also small.

With the easy-to-use new tools and software adopted by the majority of technical personnel at the end of the industry, the construction engineering industry will usher in a new communication management efficiency upgrade. As for the currently talked-about collaboration platform and BIM management system, it may still rank behind the popularization of BIM tool software. With the skill level of front-line operators,

what is urgently needed is tool software on top of Revit, ARCHICAD and other design software to complete daily technical work. It is not only the tall BIM management platform that makes the model usable. Their efforts in the construction engineering industry have played a very good role in promoting the development of the construction industry informatization (BIM).

Therefore, visualization is the most significant point of the difference between traditional CAD and BIM. The visualization function based on BIM can improve the communication environment, enhance the viewing and reading ability of the project, and increase the building's authenticity and experience.

Follow are the features of visualization:

- **Design visualization**

The BIM tool has various visualization modes, including hidden lines, coloring with borders, and accurate rendering. In the design process, "what you see is what you get" is realized. And by creating camera paths, creating animations, or a series of images, we can show customers more intuitive design solutions.

- **Comprehensive visualization of electromechanical pipelines**

The MEP models are merged into an overall BIM model, so that the collision point between the electromechanical pipeline and the building is visualized in a three-dimensional manner. Finding the collision points in the 3D model, optimize the pipeline layout plan, and then output the map after optimization and adjustment.

- **Sisual collision detection**

In the past, the traditional 2D work mode often requires designers to check multiple drawings one by one, which takes time and effort and has high requirements on the workability, experience and spatial imagination of the inspectors, and many times they have to work hard. There are still a lot of mistakes and omissions.

Through the intuitive three-dimensional information model, we can perform visual collision check in the early stage, check the net height, and automatically generate collision reports, optimize the engineering design plan, and reduce the possibility of error loss and rework during the construction phase.

- **Visualization of the technical disclosure**

Traditional CAD drawings are brutal to show the arrangement of steel bars, but BIM can be used for dynamic demonstration, better showing the construction plan, which is conducive to construction and technical disclosure. Simultaneously, it can simulate on-site construction, visualize technology and safety to the operators, and intuitively reflect the construction and precautions of each process.

Intuitively, it guides the construction staff to perform correct and efficient work, thereby improving the quality of construction and also improving the ability to communicate with the owner.

- **Spatial visualization**

Use the BIM model to check in advance whether the construction equipment space is reasonable. Through the production of work sets and setting of different construction routes, the best equipment installation position and process can be obtained, which is more intuitive and straightforward, and the pipeline support is optimized through the model.

- **Visualization of construction organization**

In the 2D working model, virtual construction is difficult to achieve due to inadequate technical means and information collection. The construction is often determined by experience and forehead. It is often due to construction rework, material waste, and schedule delays. With the help of BIM, the construction process is simulated, the construction plan is determined, and the construction organization is carried out by creating building equipment models and turnover material models. Simultaneously, it realizes the visualization of complex structure nodes, presenting involved structure nodes in all directions, such as complex curtain walls nodes.

- **Visualization of construction progress**

The 3D visualization function plus the time dimension form a BIM 4D schedule management model, which can be used for virtual construction. Compare the construction plan with the actual progress intuitively and quickly anytime, anywhere, to facilitate timely adjustment and optimization of the construction plan, at the same time for effective collaboration. The 4D model can make the construction party, the supervisor, and even the owner leaders from the non-engineering industry understand the project's progress, the use of materials, the staffing, the site layout, and the safety

management a glance. In this way, the construction site monitoring management mode significantly Reduces construction quality and safety issues and reduces rework and rectification.

- **Three-dimensional rendering**

3D rendering can present existing or unbuilt projects with the closest real visual effect, giving the viewer a strong visual impact. Simultaneously, in the actual construction process, the actual project can also experience the effect when it is constructed.

4.2 Visualization software introduction

The visualization of construction units is generally to convert two-dimensional drawings into three-dimensional models, and then derive various usage methods, such as comprehensive pipe adjustment, clear height analysis, collision inspection, three-dimensional disclosure, virtual prototypes, etc. even the so-called construction simulation in the strict sense, these are all derivative applications of visualization. When visualization meets the most basic "seeing" needs, people will naturally pursue a better visual effect experience or a more realistic visualization.

There are so many software related to the BIM workflow including some visualization software, unless normal software for instance AutoCAD, Revit, civil 3D, there are some more professional visualization software which focus on rendering, customer experience from the project.

4.2.1 Twinmotion introduction

Twinmotion is a visual 3D real-time rendering software dedicated to architecture, urban planning and landscape visualization. It is the most superficial, fastest, most intuitive and most innovative real-time rendering and 3D interactive software today. It is suitable for projects of any scale, any equipment, any modeling software, and any level of operation. The famous Unreal Engine (Unreal Engine) is used as the central core engine to have more powerful rendering capabilities and compatibility. Imagine a quick process to transform your BIM or CAD model into a fantastic real-time experience.

Features of Twinmotion:

- Unprecedented real-time quality
- Easy to learn and use
- One setup, all your media
- Works with data, on mostly platform

- Bring the scene to life with smart assets

Figure 45 Twinmotion logo

4.2.2 Unity 3D introduction

Unity is a cross-platform of 2D / 3D game engine developed by Unity Technologies, which can be used to develop stand-alone games on Windows, MacOS and Linux platforms, video games on console platforms such as PlayStation, XBox, Wii, 3DS and Nintendo Switch, or Games for mobile devices such as iOS and Android.

The game platform supported by Unity also extends to the HTML5 web platform based on WebGL technology, as well as a new generation of multimedia platforms such as tvOS, Oculus Rift, and ARKit. In addition to being used to developing video games, Unity is also a comprehensive authoring tool widely used in architectural visualization, real-time 3D animation and other types of interactive content.

- Step by step comprehensive development environment and visual editing.
- Automatic resource import
- Free scriptwriting via C#
- High-quality video, audio, image and other processing engines are imported from outside.
- Multiplayer network connection function

Figure 46 Unity logo

4.3 Rendering by Twinmotion based on Unreal engine

4.3.1 Export from Revit

First of all, we need to connect the models to Twinmotion, normally we are not able to directly create the geometry models which we are thinking in our ideal from Twinmotion, therefore, in case needs to transfer the created model from model creator, the features direct one-click synchronization of geometry and BIM information from ARCHICAD, Revit, SketchUp Pro, Rhino (including Grasshopper), or RIKCAD model. Organization and hierarchy are retained, while native surfaces and 3D objects are automatically substituted for Twinmotion objects that react to the environment.

We just need to download and install the relevant plugin.

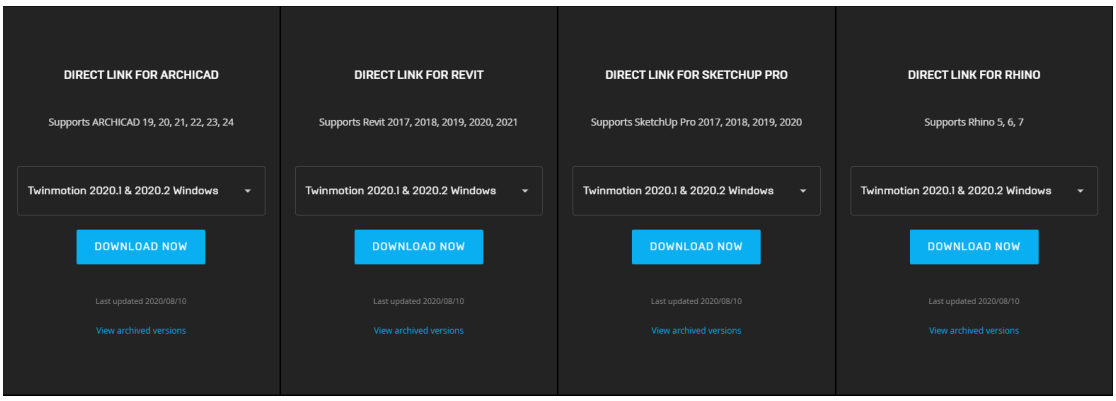


Figure 47 Revit plugin download

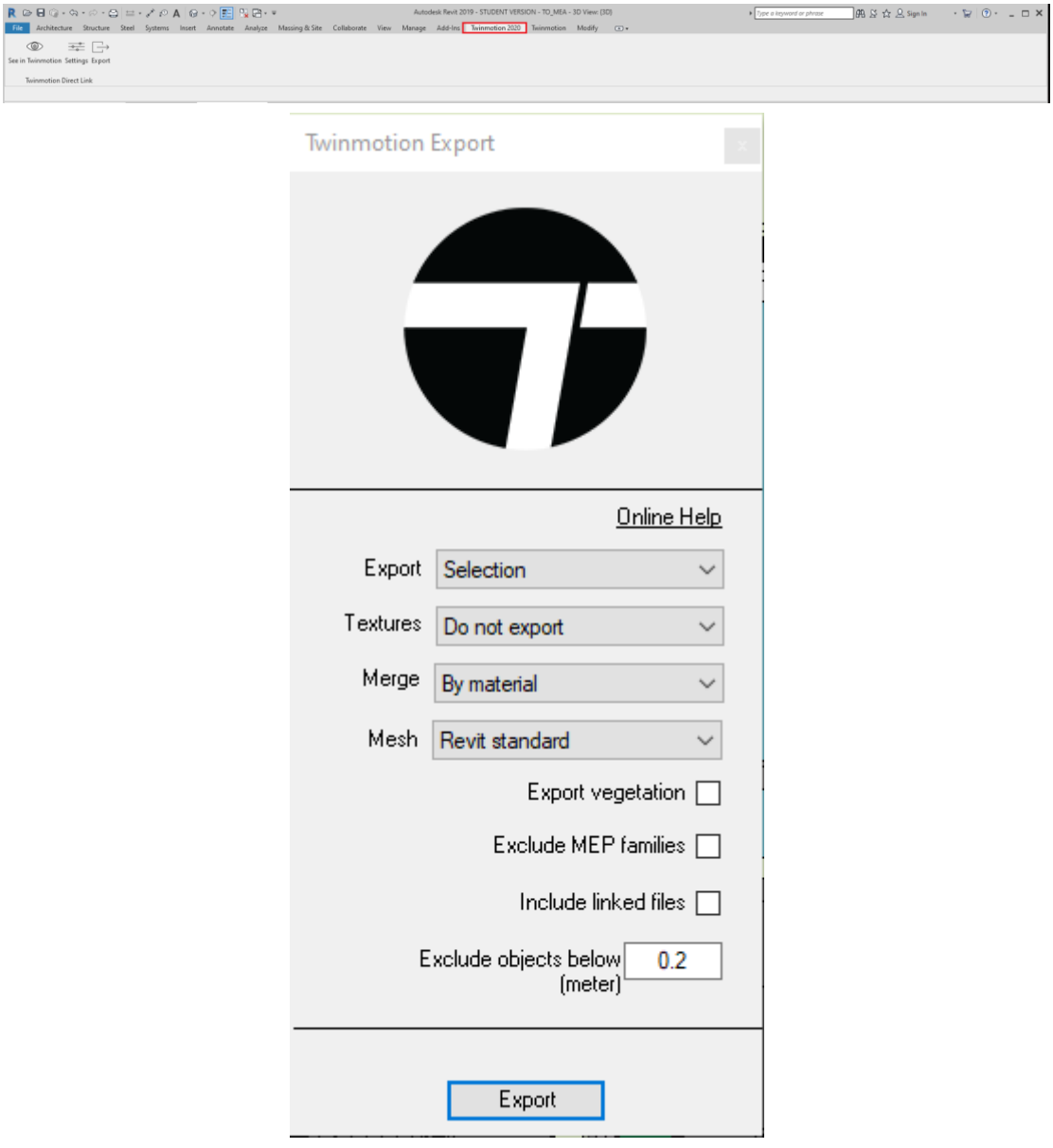


Figure 48 Export blanket

From the Revit plugin related to Twinmotion, there are some features that could be selected from the export blanket, export type, textures, merge by what and mesh type, as the image shown that if there are vegetation, MEP and linked files in the original model, this plugin could port them together into Twinmotion process.

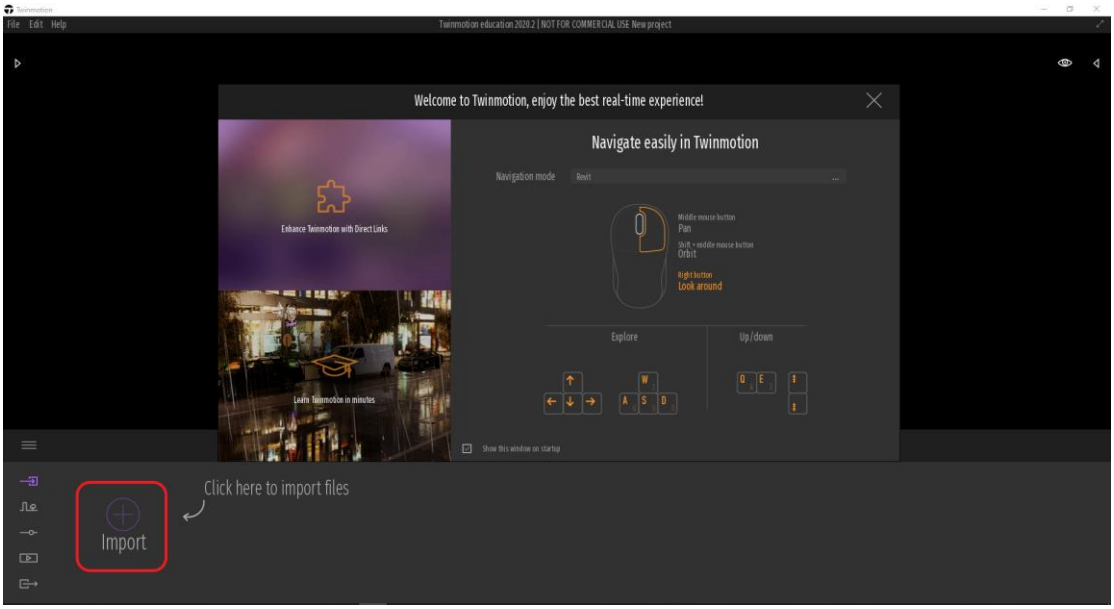


Figure 49 Import model

By directly importing the created model, all parameter information related to the model will be displayed in Twinmotion. Through a series of rendering operations, a single model can be presented more realistically. Providing real immersive and interactive experience can be used to review the design, construction, marketing and operation of buildings and infrastructure, and multi-party collaborative communication. Customers and future users can interact with the building environment virtually.

From the list, we can see that there are a variety of different objects available, including some types of objects as shown in the figure, materials, vegetation, objects, lights, characters vehicles and tools, for architecture, construction, urban planning, and landscaping professionals, Twinmotion combines an intuitive icon-driven interface. Even the construction machines included in the library.

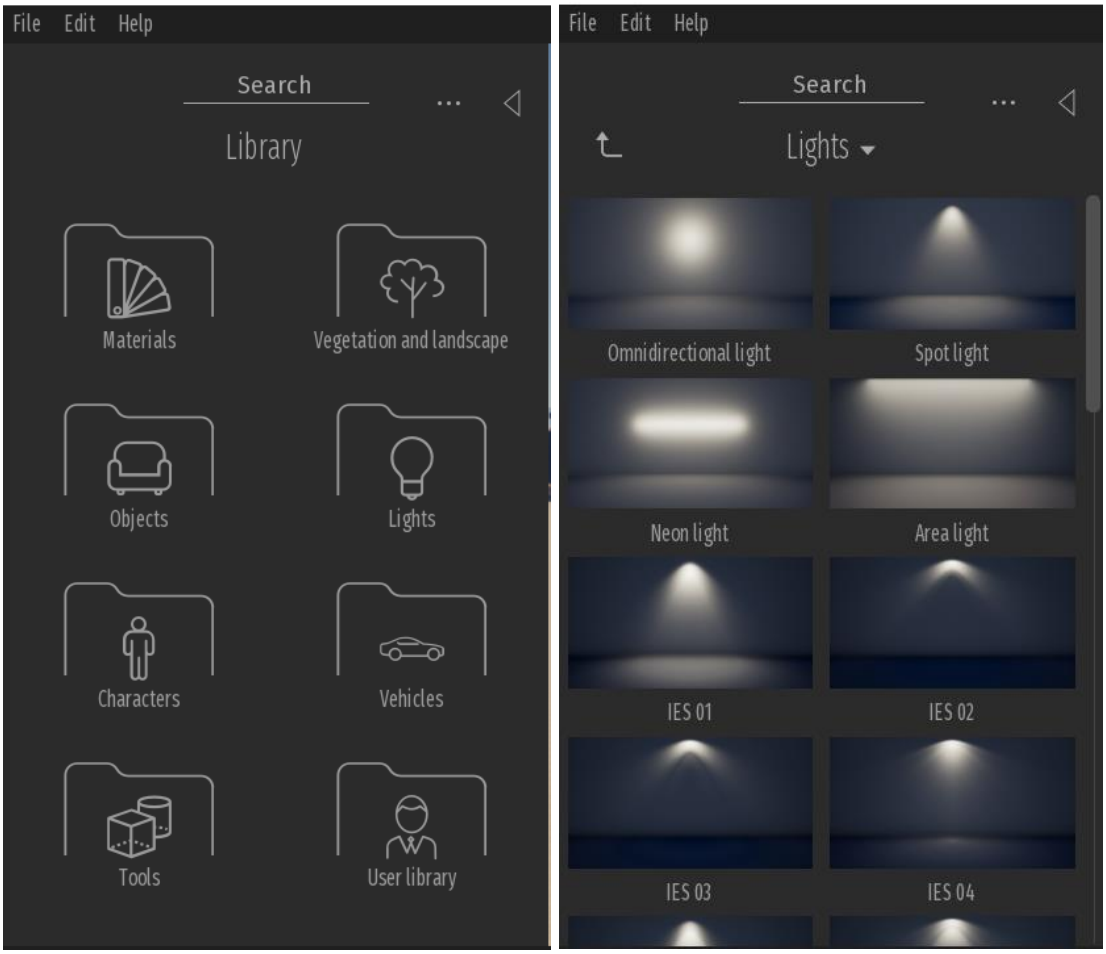


Figure 50 Twinmotion's library

Twinmotion's library includes not only static props like furniture and rocks, but you can also breathe life into your scene with ambient sounds, photo-scanned human characters with motion-captured animation, animal characters, and even high-resolution plants that blow in the wind—all just by dragging and dropping.

Figure 51 Transparent pipeline

The image displays a transparent pipeline in the project which is located under the soil, but in this software the pipeline could be indicated in this way. BIM is mostly involved before installing electromechanical pipelines, so the MEP function is used to solve the problem of pipeline installation. This is also the primary function of the construction unit using BIM. At present, the 3D simulation effect of Twinmotion is currently one of the best. We can switch the perspective according to different needs and present the MEP system in different ways. This is undoubtedly an excellent way for construction units and design units. To each other, but also to show to customers.

Figure 52 “Fabbricato centrale” Revit model transfer into Twinmotion

If we have modeling experience, we must be clear. For example, sometimes we need to model a stone, not to 3d all the irregular edges and corners, but to use simplified polygonal models and special mapping techniques. Similarly, in real-time rendering, many furniture and objects appear to be unrealistic. One of the reasons is the insufficient number of geometric faces of the objects, which is a helpless balance between running speed and quality.

Through BIM technology, after the model is refined and deepened, it can be used with relevant software to perform 3D rendering animation close to reality, giving people a sense of reality and direct visual impact. The model not only adds component information but also allows viewing methods such as 360-degree rotation and detailed enlargement. All parties to the project can have an understanding of the overall structure and details of the building and combined with VR and other technologies, and virtual reality demonstrations can be realized, increasing the real experience of the owner or related personnel. The use of Twinmotion software, with its visual and straightforward operation, dramatically improves the accuracy and efficiency of the 3D rendering effect and provides the owner with a more intuitive promotion and introduction to realize the real "what you see is what you get", which can increase the chance of winning the project.

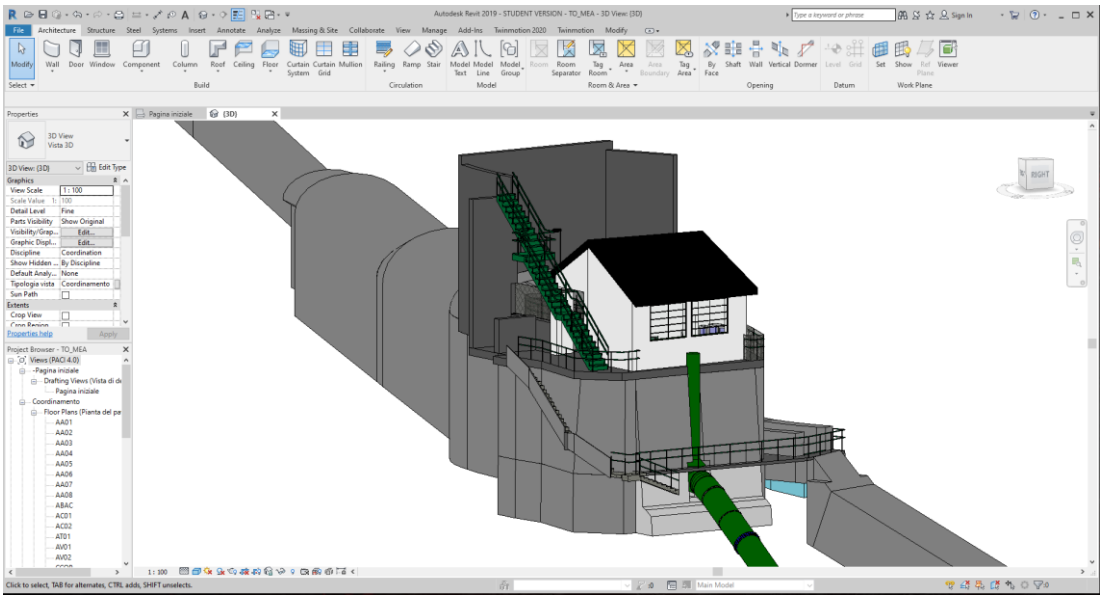


Figure 53 “Vasca di Carico” Revit model transfer into Twinmotion

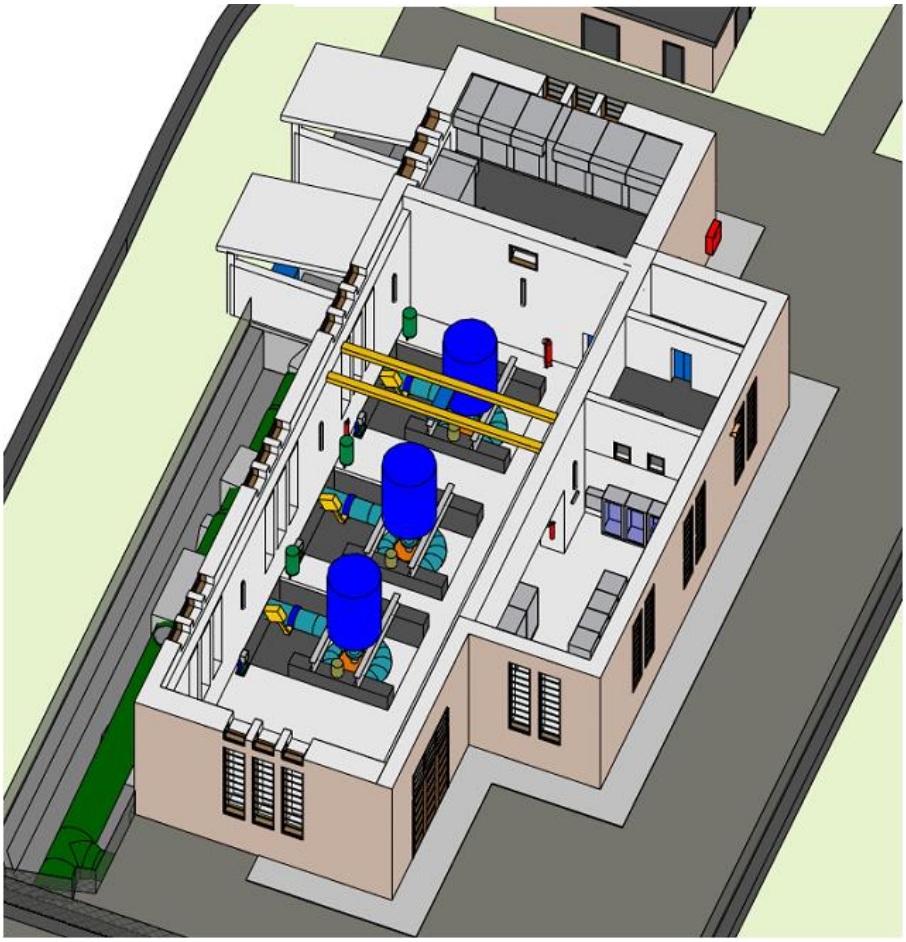


Figure 54 “Fabbricato centrale” Revit model transfer into Twinmotion

4.3.2 Export a Twinmotion application

In this topic, I would like to talk about a feature of Twinmotion that is an exportable stand-along application from that the customer could navigate around the project and different optional scenarios could navigate to several parts of the project, and this is an excellent feature for some laptop that does not have the original Twinmotion software. The laptop of customers could be sent the stand-along application by the producer in which use the feature of Twinmotion but no need to install the original software.

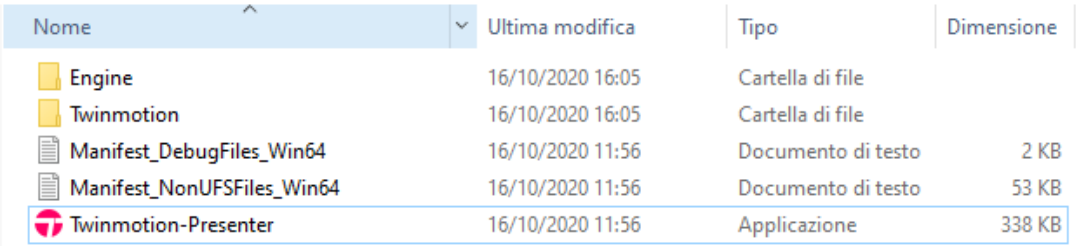


Figure 55 Stand-along application folder

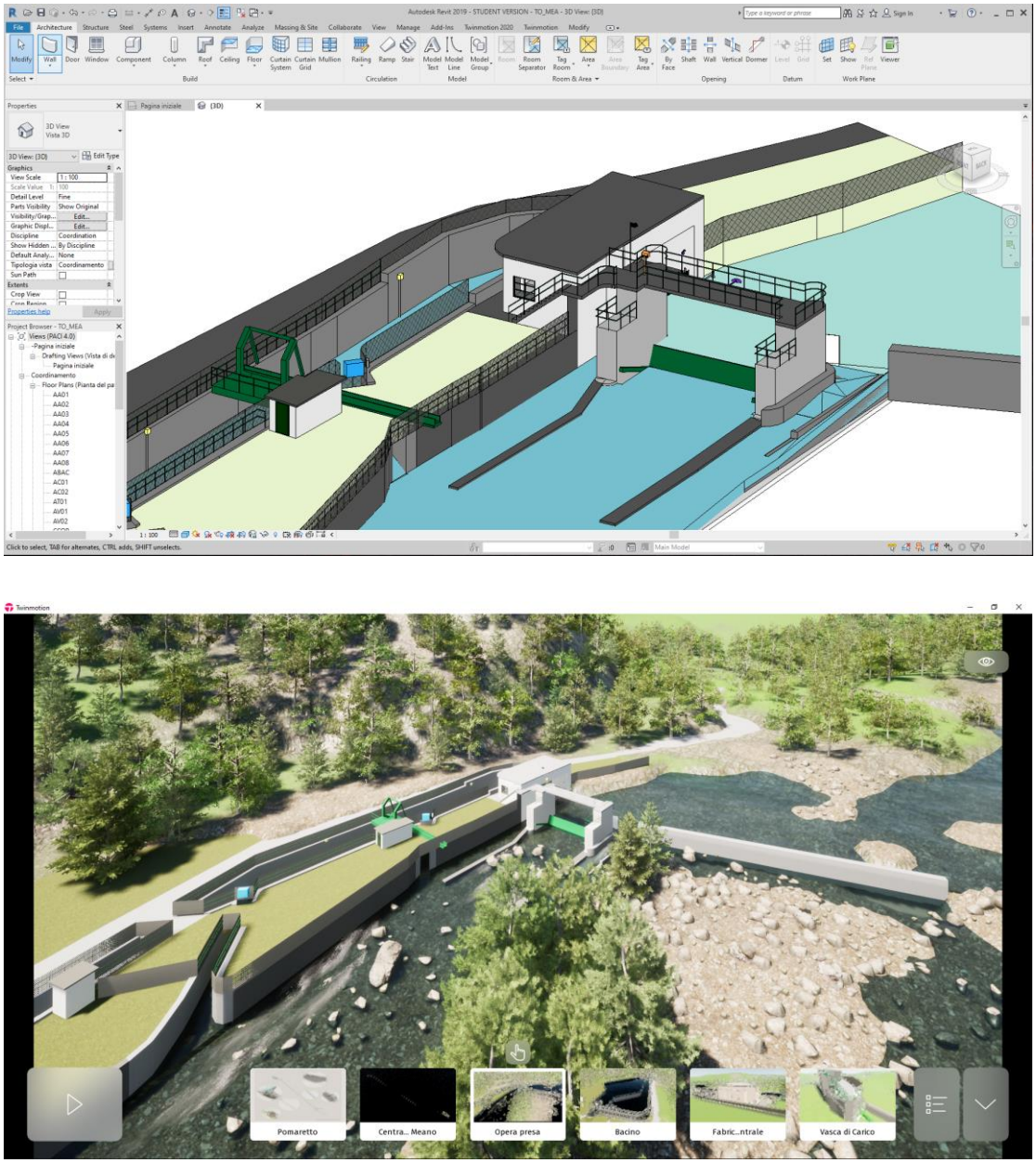


Figure 56 “Opera di presa” Revit model transfer into Twinmotion application

4.4 XR application in Unity engine

4.4.1 Unity connect with Revit

As far as the application is concerned, we almost universally underutilize our valuable 3D models. By bringing a design model into an immersive real-time engine like Unity to bring out XR experience, on the one hand, we have to make the model navigable; on the other hand, we can set some features, such as displaying technical datasheets, highlighting safety information. We want to make sure that Revit already models any geometry that we want to see in the final product. Unity is very good at bringing in models from different sources. The most important part here is to make sure that we take a look at all the details of the building we'll be exporting from Revit to Unity.

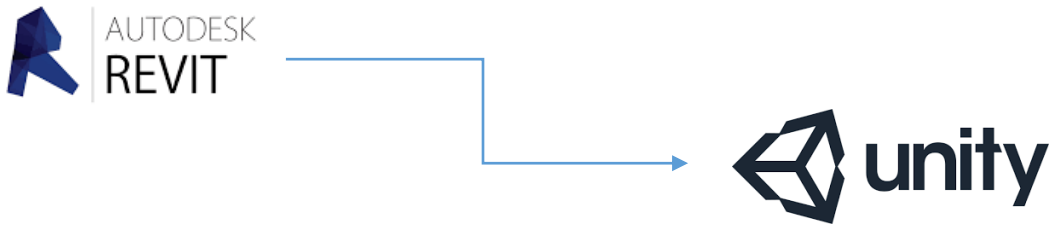


Figure 57 Revit to Unity

There are many ways to transfer from Revit to Unity, such as transfer to IFC file or FBX file then take them into Unity. Still, some object will disappear after transformation, especially export to FBX directly, so that's why I selected to export to IFC firstly.

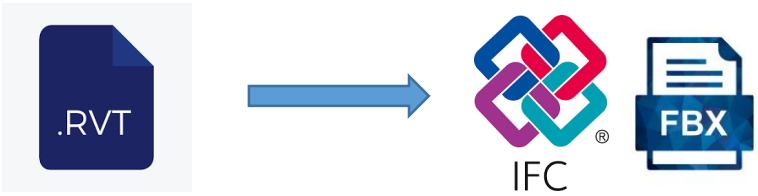


Figure 58 Unit .IFC or .FBX to .RVT

Let's get our Revit project exported into IFC, which is a format that's frequently used for translating between different BIM software. First, we are going to want an additional 3D view here that shows all the geometry that we want to export in one place. So let's go to our static building, right-click and duplicate view. Now go to the visibility graphics. And let's turn on everything that we're going to want for this export. We're going to look at getting this IFC file into Unity.

4.4.2 Essential setting at the beginning of Unity

Firstly, start by making a new project, in order to creat a XR project that should be used the 3D template, the Unity interface since the project is open, firstly needs to choose a Unity version in order to adapt some plugins especially for VR which I have to use in my project.

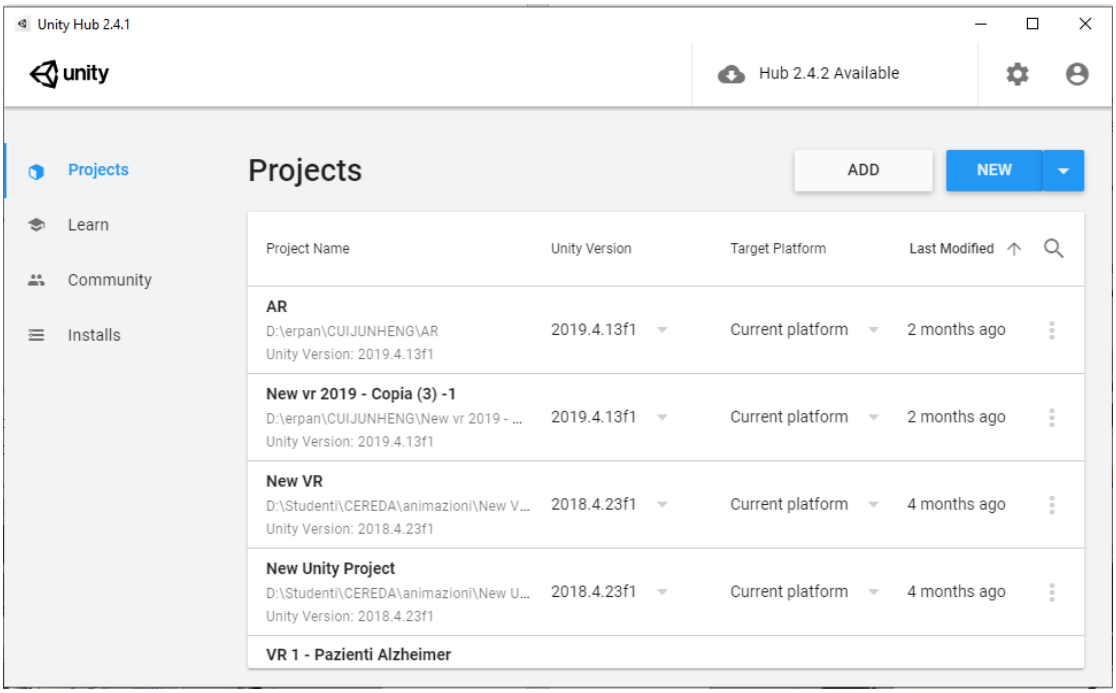


Figure 59 Unity Hub

As shown from this image, we have the Scene tab. The Scene tab shows everything that has been brought into my scene, and I can navigate through it in three dimensions. In order to navigate in the scenario, it can zoom in or zoom out using the scroll wheel on my mouse. Also, hold down the right mouse button and move the mouse around to pivot and look in different directions with my camera in the same place.

Then, the keys WASD can move me forward, back, left and right. Over here on the left, we have the Hierarchy tab. The Hierarchy tab contains a list of all of the elements currently living in the scene that we have open. When we start a new project, we have the main camera, and we have this directional light that represents the sun. Right at the second area here, we are showing the Project tab. The Project tab contains this Assets folder. Any game object that we select will have multiple components, and those components control the different aspects of the game object, so where the last right tab

contains a lot of components of the object that we want to modify their reference, etc.

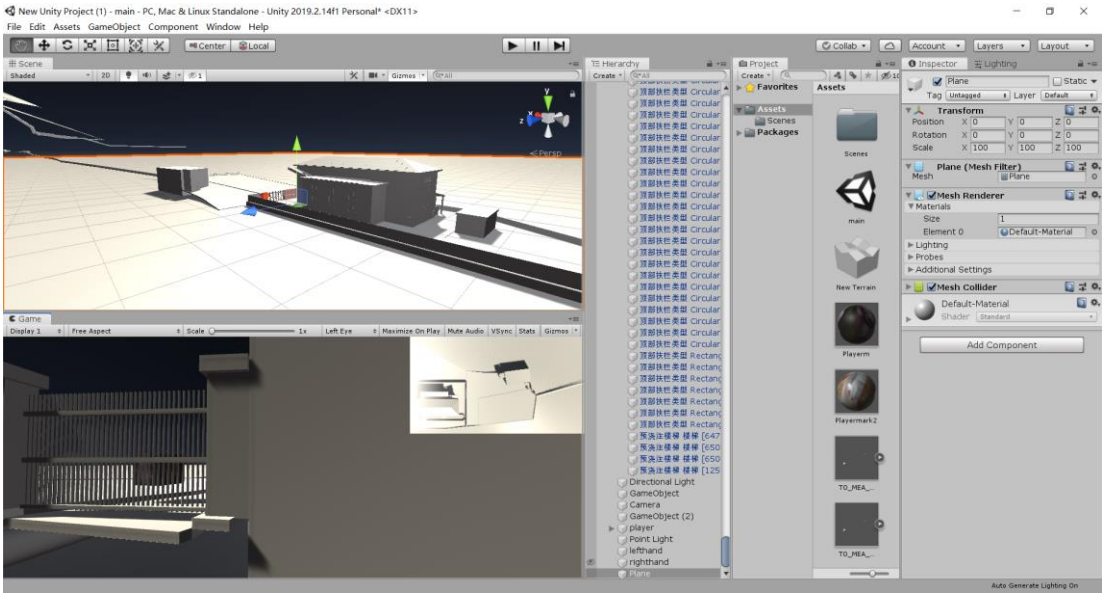


Figure 60 Model inserted in Unity

Now that we have all of our import settings set up, we're ready to place the scene's objects. We can do that in a few different ways. My preference is to grab all the things that I need to bring into the scene and drag them into the Hierarchy tab. By dragging the items into the Hierarchy tab, they start with a (0, 0, 0) position in their transform, which is what we need.

After our scene is set up, we're ready to start interacting with it. But firstly, in order to begin to understand what is materials in Unity is a very important component in Unity, what we see still now are all influenced by materials, we need to create a shade, which is what tells the engine how to render a material, in my case what we can see the imported model is rendered by the shade, these settings, Metallic, Smoothness, sometimes specularity are all about the shininess and reflectivity of the object.

Right now, we have a camera placed in the scene, it's the same camera we've had the entire time, this primary camera, but we just moved it into the building. If we push play, we go into a preview mode where this game window is essentially playing the game or walkthrough or visualization that we've been making this entire time. Unity's camera is used to present the game world to the player. You always have at least one camera in the scene, and you can have more than one. Multiple cameras can give you a two-person split-screen effect or create advanced custom effects. You can make the camera move or control them with physics (components). Almost anything you can think of can be made possible with a camera, and to suit your game style, you can use a typical or unique camera type

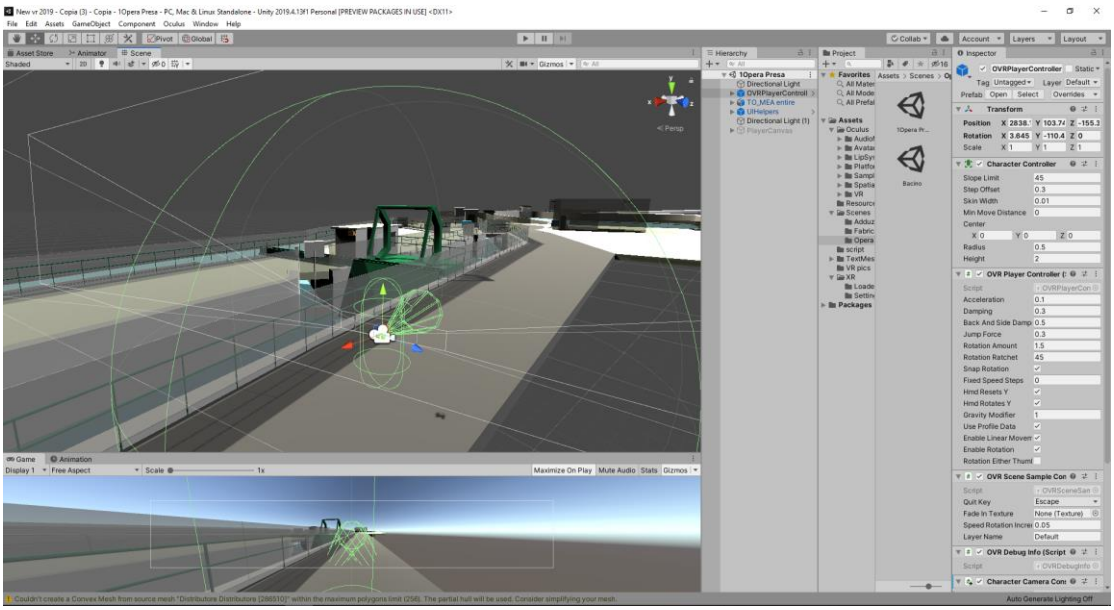


Figure 61 Camera unit

To show the game to the customer, the camera is essential. The camera can be customized, scripted, or controlled to achieve any imaginable effect. We can create multiple cameras and assign each camera to a different depth. The cameras are drawn in order from low depth to high depth. In other words, a camera with a depth of 2 will be drawn on top of a camera with a depth of 1. We can adjust the Normalized View Port Rectangle property's value to adjust the size and position of the camera view on the screen.

Figure 62 Oculus devices

Unity provides built-in VR support for Oculus devices. The Oculus Integration package adds scripts, prefabs, samples, and other resources to supplement Unity's built-in support. The package includes an interface for controlling VR camera behavior, a first-person control prefab, a unified input API for controllers, rendering features, debugging tools, and more. is an all-in-one source for core VR features, components, scripts, and plugins to ease and enhance the Oculus app development process in Unity. It packages several vital SDKs that offer advanced rendering, social and community building, sample framework, audio, and avatar development support for app.

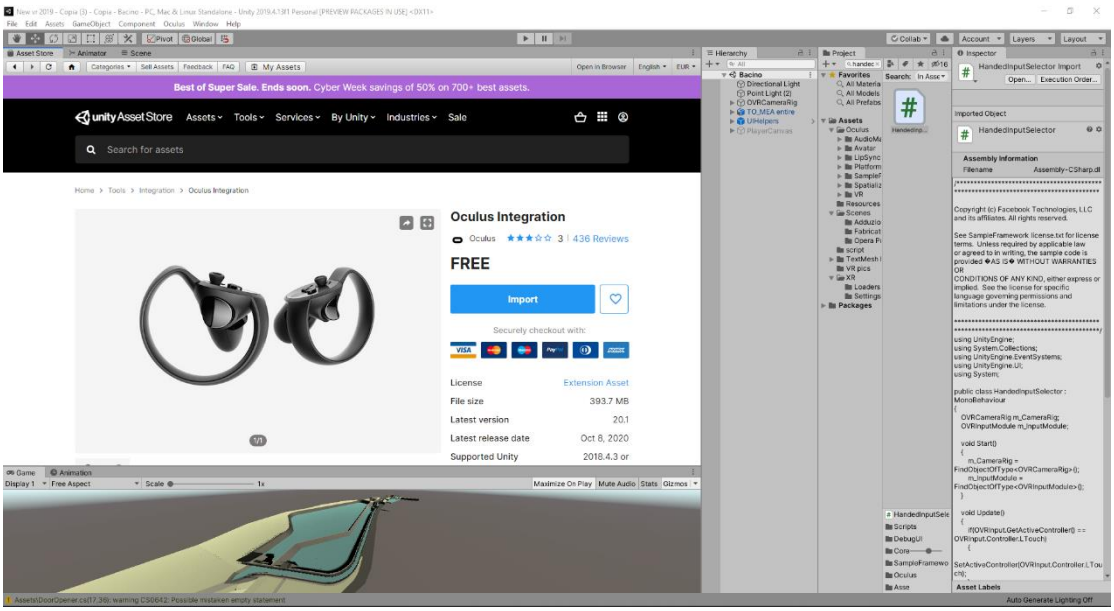


Figure 63 Oculus Integration

After download Oculus Integration Package from Asset store which is home to thousands of free or affordably priced assets that save critical time and effort for Unity creators. In this guide, we'll explain what each asset is, help you navigate the store and show you how to download and install the assets into Unity.

As shown in the hierarchy that we can import "*OVRPlayerController*" allows the player to move around in the virtual environment. It includes components and child objects that are necessary for 3D control. It includes *OVRCameraRig* prefab to serve as the VR camera and is attached to a character controller. The Oculus Integration package contains scripts that assist with the development and a handful of illustrative scenes that implement reusable game components.

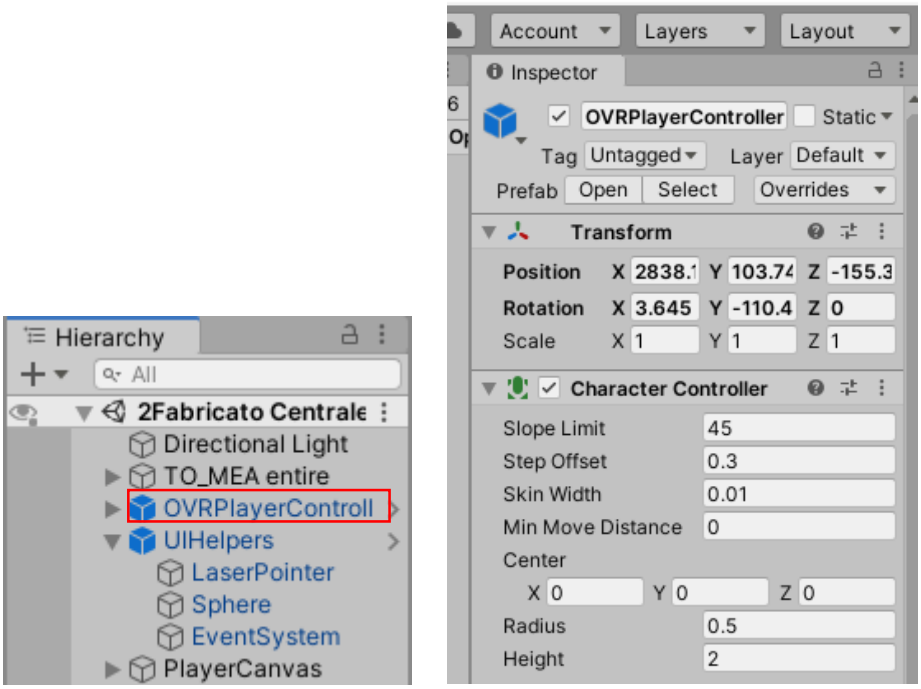


Figure 64 Prefab of Oculus integration

These prefabs are reusable game objects, such as 3D shapes, lights, audio, or camera. The Oculus Integration package contains several prefabs that facilitates you with essential VR features. When import the package, Unity adds it in the Assets folder and maintains the package's original directory structure.

- *OVRCameraRig*: A custom VR camera that optimizes rendering for a stereoscopic display on the Oculus device. It provides access to *OVRManager*, which is an interface to the VR hardware.
- *OVRPlayerController*: Allows the player to move around in the virtual environment. It includes components and child objects that are necessary for 3D control. It includes OVRCameraRig prefab to serve as the VR camera and is attached to a character controller.
- *OVRCubemapCaptureProbe*: Captures a static 360 screenshot of your app from the perspective of your scene camera, while the app is running. Let our capture the screenshot at a specific time after launch, on a specific key press, or with the use of the *OVRCubemapCapture*. Trigger Cube map Capture static function.
- *OVRHandPrefab*: Implements hands as input affordance.

4.4.3 Functional setting related to the scripts

The behavior of GameObjects is controlled by the Components that are attached to them. Although Unity's built-in Components can be very versatile, we will soon find our need to go beyond what they can provide to implement our gameplay features. Unity allows us to create our Components using scripts. These will enable us to trigger game events, modify Component properties over time and respond to user input in any way you like.

The Unity engine is developed with C++ code. The early official packaging of three scripting languages JavaScript, C#, Boo, for developers reduces user development difficulty. And because there are indeed some functions in Unity that are not strong enough to be used in many situations, the Character Controller is one of them. It is enough to meet the needs of small projects or experimental projects, but we have to write our code to achieve a better one once the requirements are involved. Another example is some UI components. If we don't like the built-in progress bar style or are slightly different from our needs, we can create the progress bar. Since Unity has provided various image display methods, it is not difficult to make one yourself.

So in this project, in order to achieve many practical purposes, such as scene conversion, door opening, image following lens, highlighting items, etc. These additional functions need to use C# code to complete the target function more smoothly. The development of C# code requires the use of specific relevant knowledge. First of all, how to compile, here you need to introduce the proper understanding of Visual Studio.

Microsoft Visual Studio (abbreviated as VS) is a series of development kits of Microsoft Corporation in the United States. VS is a complete set of development tools, including most of the tools needed in the entire software life cycle, such as UML tools, code control tools, integrated development environment (IDE), and so on. The target code is written applicable to all platforms supported by Microsoft, including Microsoft Windows, Windows Mobile, Windows CE, .NET Framework, .NET Compact Framework, Microsoft Silverlight and Windows Phone. Visual Studio is currently the most popular integrated development environment for Windows platform applications. The latest version is Visual Studio 2017, based on .NET Framework.

Figure 65 Visual Studio logo

Firstly, an empty C# script is created by from the Unity interface, which are usually created within Unity directly. We can create a new script from the Create menu at the top left of the Project panel or by selecting *Assets* > *Create* > *C# Script* from the main menu. It is a good idea to enter the name of the new script at this point rather than editing it later.

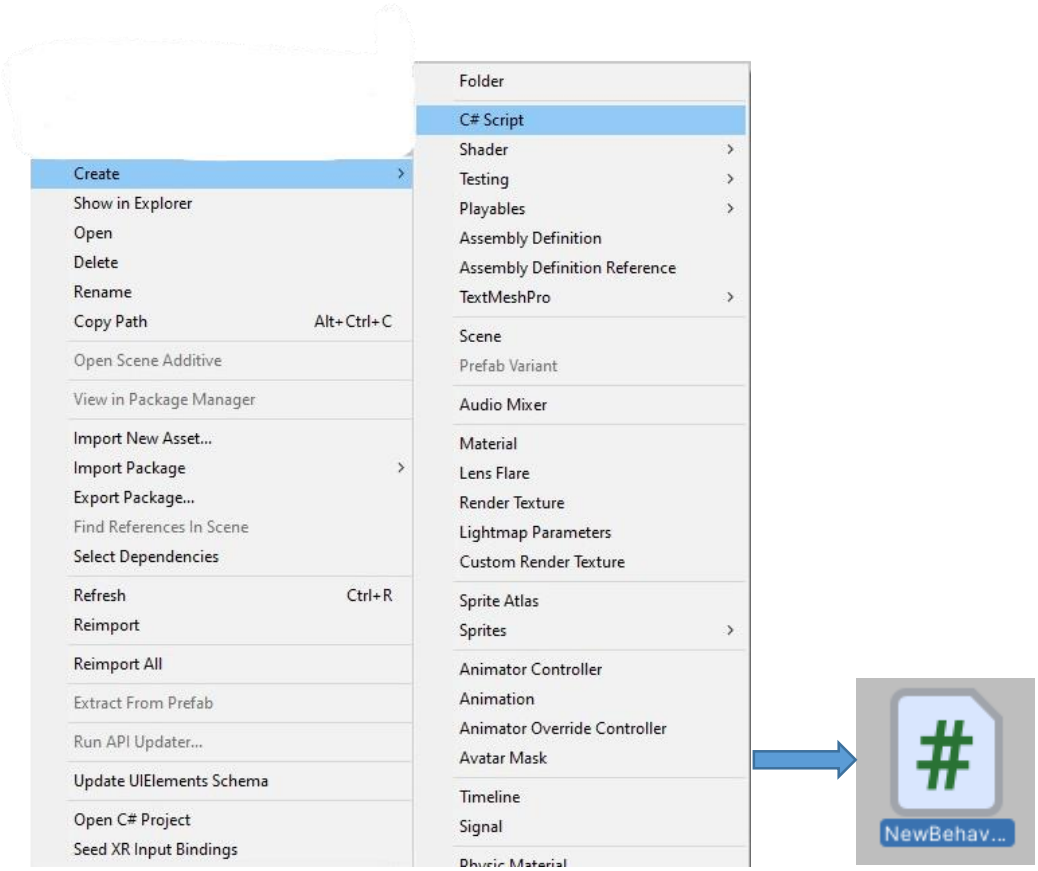


Figure 66 New script creation

A script makes its connection with the internal workings of Unity, each time you attach a script component to a *GameObject*, it creates a new instance of the object defined by the blueprint. The name of the class is taken from the name you supplied when the file was created. The class name and file name must be the same to enable the script component to be attached to a *GameObject*.

- **Button features**

In the project, there are many button needs to be defined in order to archive their features, like image below shown the main page of project when the customer firstly attend into, as a menu from which could navigate to different scenes and introduction, by right click mouth from Hierarchy blanket in Unity interface *UI-Button-Button (Inspector)* to give some feature to selected button, here the feature should be defined by script, after done the script define it from *On Click ()* for giving a function to change to different scenes.

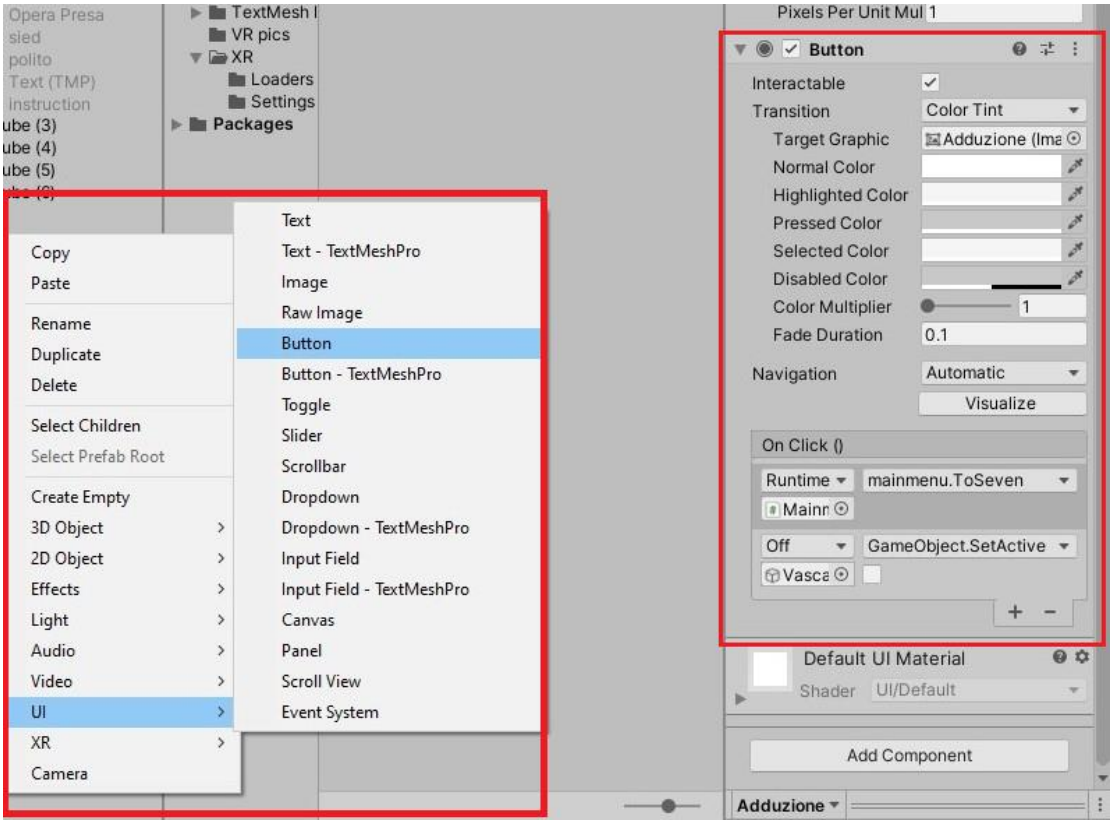


Figure 67 Button features

Follows indicate the *SceneManager* script which could be used to be related with *Scenes In Build* of *Build Settings* in which there existed all the needed scenes for our project, in case each scenes needs to relate to a number start from 0, by using number to represent scene in script to navigate to.

```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;
using UnityEngine.SceneManagement;

public class mainmenu : MonoBehaviour
{
    public void ToZero()
    {
        SceneManager.LoadScene(0);
    }
    public void ToOne ()
    {
        SceneManager.LoadScene(1);
    }
    public void ToTwo()
    {
        SceneManager.LoadScene(2);
    }
```

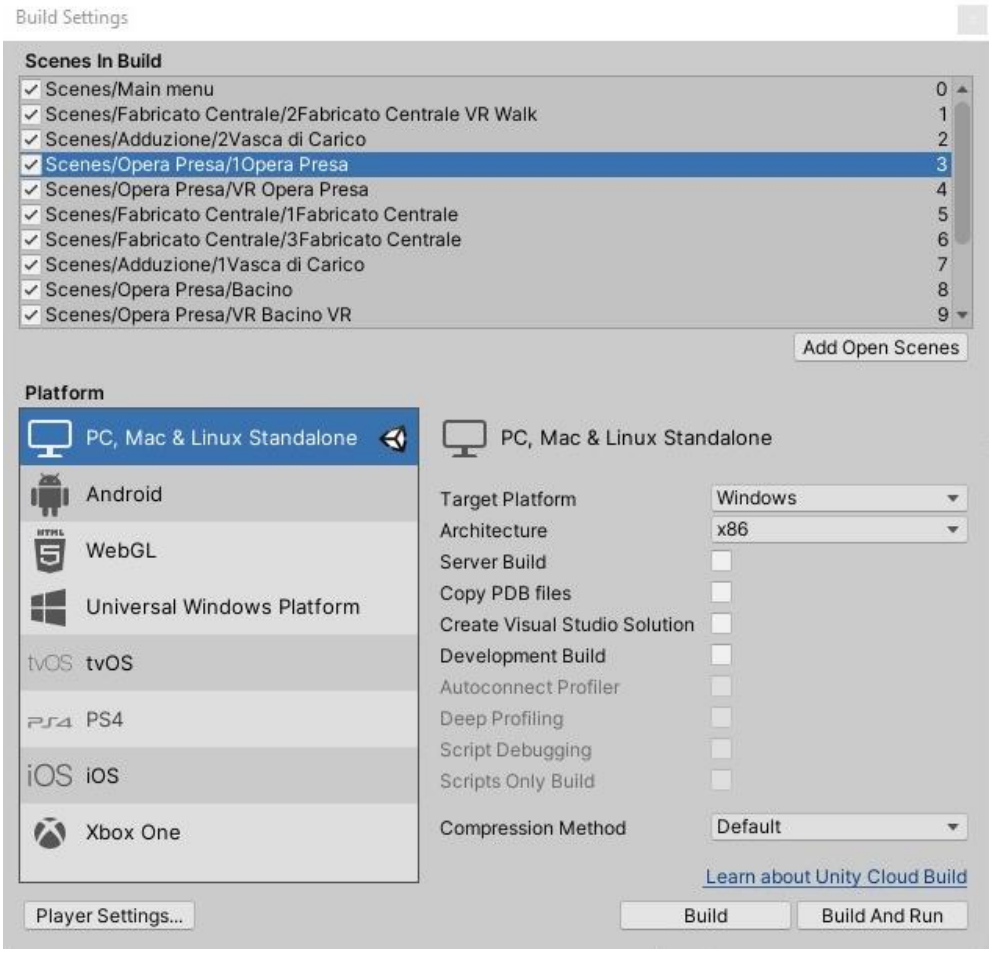


Figure 68 Build Settings

- **High Light Object**

The highlighting of 3D objects in the scene is generally achieved through the *HighlightSystem* plugin. There is no need to modify the code inside the plugin. We only need to know how it should be configured and what methods can be called in the plugin. But in this project, we need to highlight the object and highlight the object while displaying the related information of the object, such as the name, introduction, etc., while highlighting it. In fact, the relevant highlighting plugin can be obtained from Asset store, but we need to pay for it, generally, it is convenient, but if the budget is limited and we don't need to use other functions of the relevant plugin, we can create a new script in order to archive our purposes.

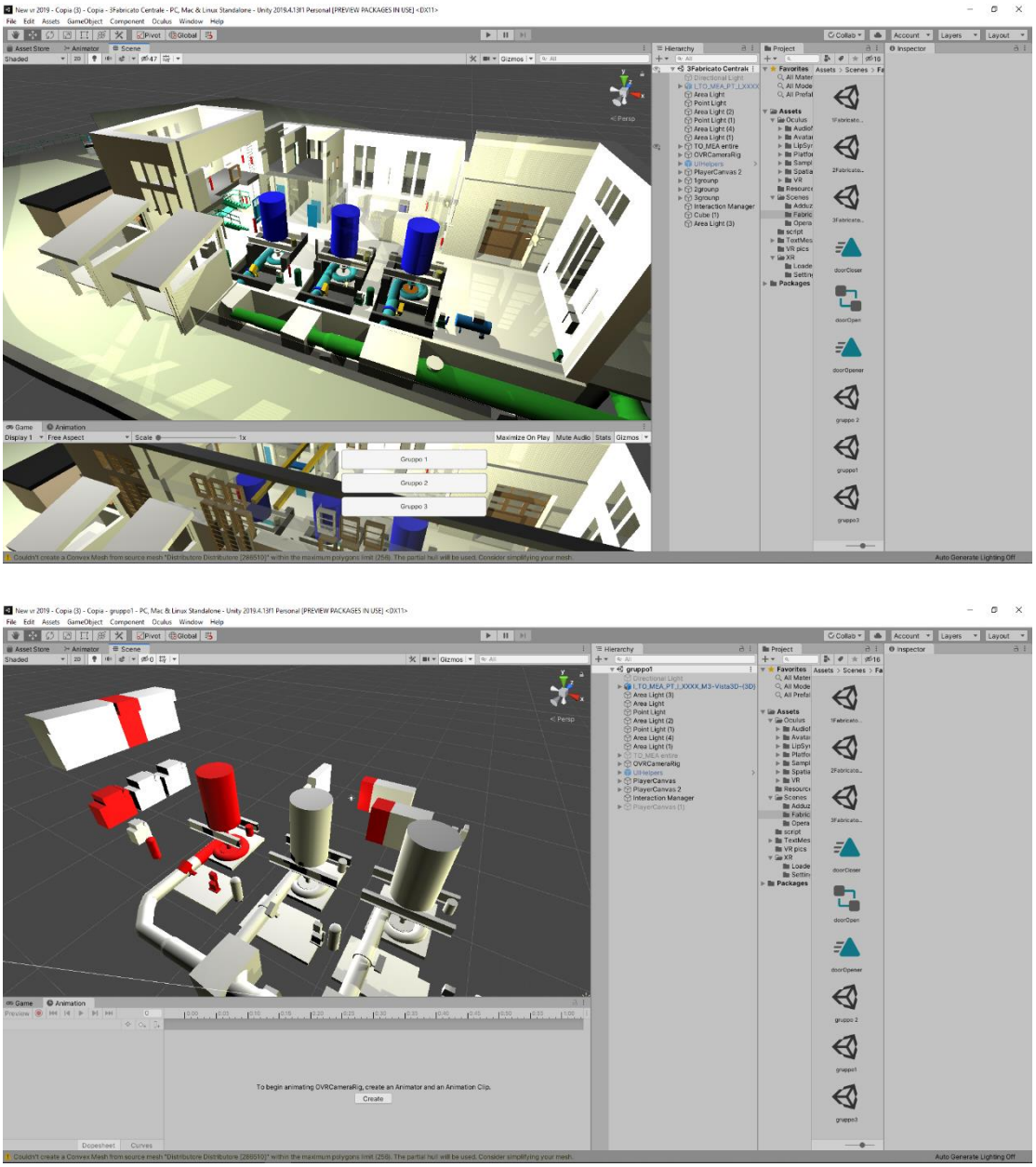


Figure 69 Convert scene from normal to highlighted

```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;

public class HighLightObject : MonoBehaviour
{
    public Material[] materials;
    public Renderer rend1;
    public Renderer rend2; public Renderer rend3; public Renderer rend4; public
Renderer rend5;
    private int index = 1;


    public void buttonPressed(){
    if (materials.Length==0)
        return;

        index +=1;

        if (index == materials.Length + 1)
            index = 1;
        rend1.sharedMaterial = materials[index - 1];
        rend2.sharedMaterial = materials[index - 1];
        rend3.sharedMaterial = materials[index - 1];
        rend4.sharedMaterial = materials[index - 1];
        rend5.sharedMaterial = materials[index - 1];
    }
}
```

In case the script for the project is used to change the color of objects as images are shown, if the mouth is hovering to relevant items, the object will change color from red to blue in order to obtain the highlight effect related to different groups, because there are three cylindrical equipment and relevant which are individually controlled by electrical management device, all red highlighted objects constituted to one group.

- **Manage door open and close--Animation**

Adding dynamic objects to the scene can make the whole scene more vivid and real. Objects in the Unity scene can be animated by making objects. Simple animations such as the movement and rotation of objects (such as rotating fans, flashing light bulbs, etc.), complex animations such as characters' actions in the game, facial expressions, etc. A powerful animation system is built in Unity, which can support animation production in Unity and also supports importing animation from outside.

The *animation* system is based on a resource called Animation Clip, which is stored in the project in the form of files. The data in these files records how objects move, rotate, and scale over time and how the properties of the objects change over time. Each Clip file is an animation.

To make animation in Unity, we need to use the Animation window, which can be opened via the menu bar *Window> Animation*.

Animation in Unity is generally divided into the following steps:

1. Open the Animation window
2. Select the object to be animated
3. Create a new animation Clip
4. Edit, preview, modify the animation

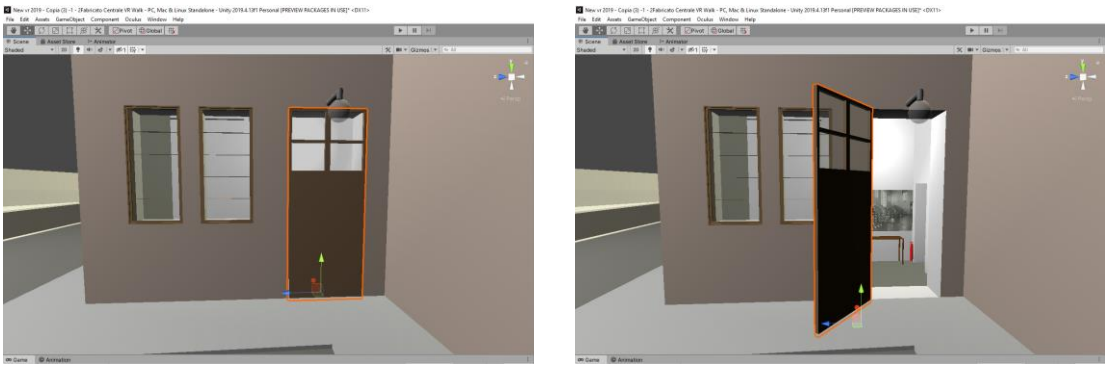


Figure 70 Door animation

Animation Clip is just a piece of animation data. We can compare it to a video file. The Animator component is a player used to control animation's playback, switch between multiple animation clips, etc. The first attribute of the Animator component is Controller. The file corresponding to the project directory is an Animator Controller type file. You can define how to switch between animation clips in this file. Double-clicking this file will open Unity's Animator window and display the contents of the file.

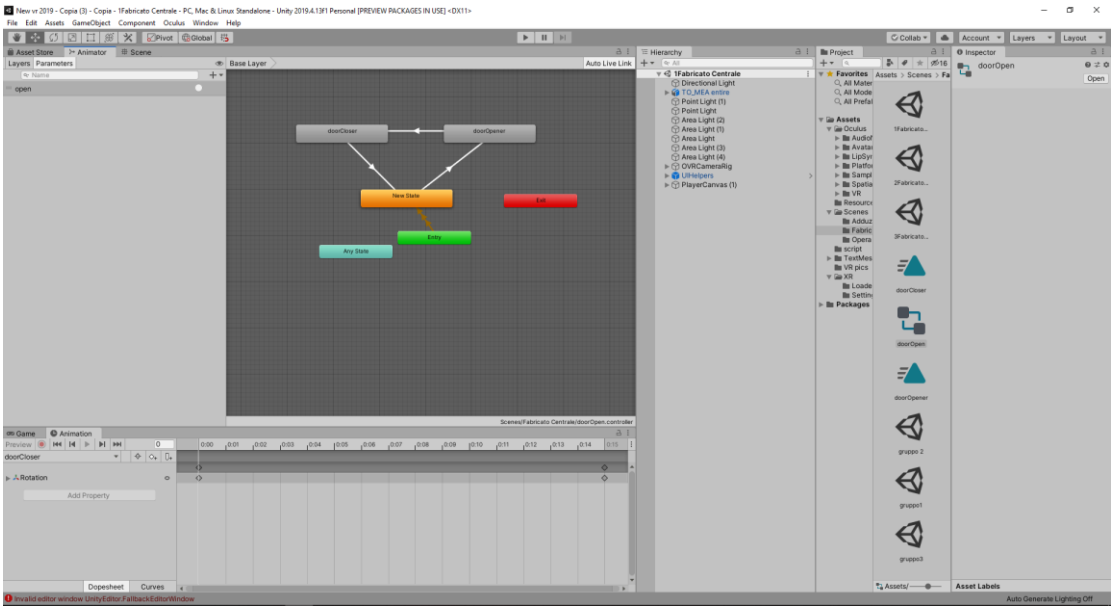


Figure 71 Animation Clip

After creating the animation Clip, we can start making animations.

The Animation window has **two modes**: recording mode and preview mode.

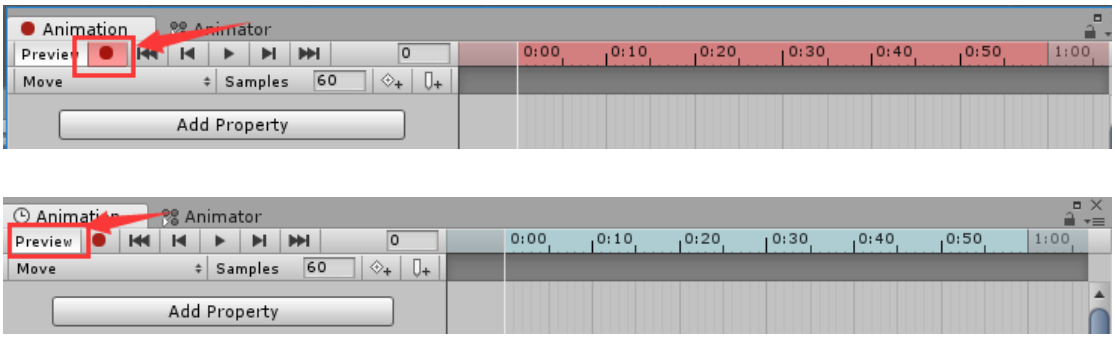


Figure 72 Animation window

In the recording mode, when we make changes to the object (for example, move, rotate, zoom, modify properties, etc.), Unity will automatically generate key frames at the current time position and record the modified properties.

In preview mode, modifying objects will not automatically create/modify key frames. If you need to create/modify key frames, we need to click the add key frame button manually.

In recording mode, whether you move, rotate, or scale objects in the scene, or modify the properties of the object components in the Inspector panel (properties supported by Unity animation), Unity will automatically add key frames to save the current time of the animation Clip. After editing the animation, you can click the record button again to exit the recording mode to avoid subsequent operations on the object being recorded in the animation.

After finishing the animation recording of the door open to close, in most scenes, when approaching the door, the door will be triggered to open or close. Here we need to use the knowledge of the touch body (Trigger)

After adding *Rigidbody* and *Collider* to the door and the player.

- Rigidbody: The basis for the effect of force on an object, including gravity, pulling force (resistance is also a kind of pulling force), angular pulling force (angular resistance is the same).

- Collider: All touches between objects, the basis of collision. The contact collision between any two objects is actually the contact of the collision body. If there is no collision body on either side, the collision will not occur (the penetration effect is produced). The impact of the collision is determined by the shape and size of the collision body.

Among them, we need to check "Is Trigger" to indicate that the collision body is set as the trigger body Trigger. At this time, the object will not collide with other objects, that is：other objects will pass through it and generate a trigger event. (A trigger collides with a normal collider, one of which must have a rigid body attached)

When a rigid body enters or exits the trigger, *OnTriggerEnter*, *OnTriggerExit* and *OnTriggerStay* messages will be sent.

**OnTriggerEnter*, *OnTriggerExit OnTriggerStay*: three status of objects triggered or not indicated in Console.

Follow are shown the script that needs to be added in inspector of “door”, if so the trigger will work, otherwise the door will have no reaction.

```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;
public class DoorOpener : MonoBehaviour
{
    private void OnTriggerEnter(Collider other)
    {
        if (other.tag == "Player");
        {
            Animator anim = other.GetComponentInChildren<Animator>();
            anim.SetTrigger("open");
        }
    }
    private void OnTriggerExit(Collider other)
    {
        if (other.tag == "Player") ;
        {
            Animator anim = other.GetComponentInChildren<Animator>();
            anim.SetTrigger("open");
```

For this case in order to test the player is inside the range of trigger of door, we can add the next script that could give a function of the door to show the player if is inside in the range of trigger, if the player first enter in the range, the console will show a debug that “you enter in the triggered item+ name of player", if now the player is always staying in the trigger range the debug is "you are staying in the triggered item +name of player", and lastly if the player get out from this range the debug is "you leave out the triggered item: + name of player".

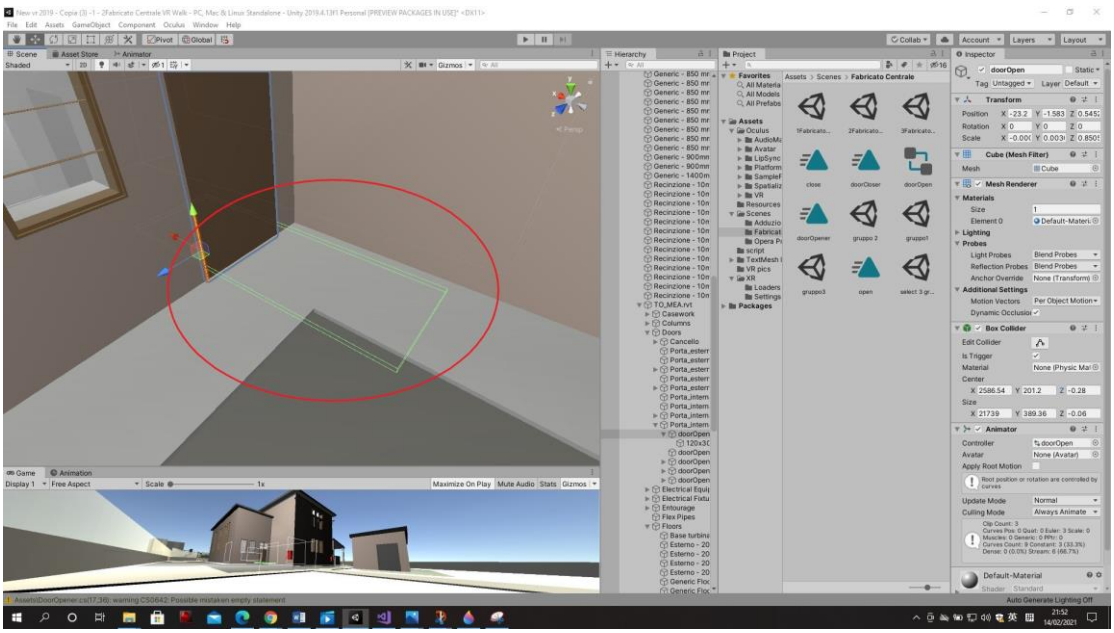


Figure 73 Trigger area

```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;

public class TiggerTest : MonoBehaviour
{
    public GameObject prompt;
    public void Show(GameObject prompt)
    {
        prompt.SetActive(true);
    }
    public void Hide(GameObject prompt)
    {
        prompt.SetActive(false);
    }
    void OnTriggerEnter(Collider other)
    {
        Debug.Log(Time.time + "you enter in the triggered item:" +
other.gameObject.name);
        Show(prompt);
    }
    void OnTriggerStay(Collider other)
    {
        Debug.Log(Time.time + "you are staying in the triggered item:" +
other.gameObject.name);
    }
    void OnTriggerExit(Collider other)
    {
        Debug.Log(Time.time + "you leave out the triggered item:" +
other.gameObject.name);
        Hide(prompt);
    }
    // Start is called before the first frame update
    void Start()
    {
        Hide(prompt);
    }
    // Update is called once per frame
    void Update()
    {

    }
}
```

- **click controller's key to open canvas**

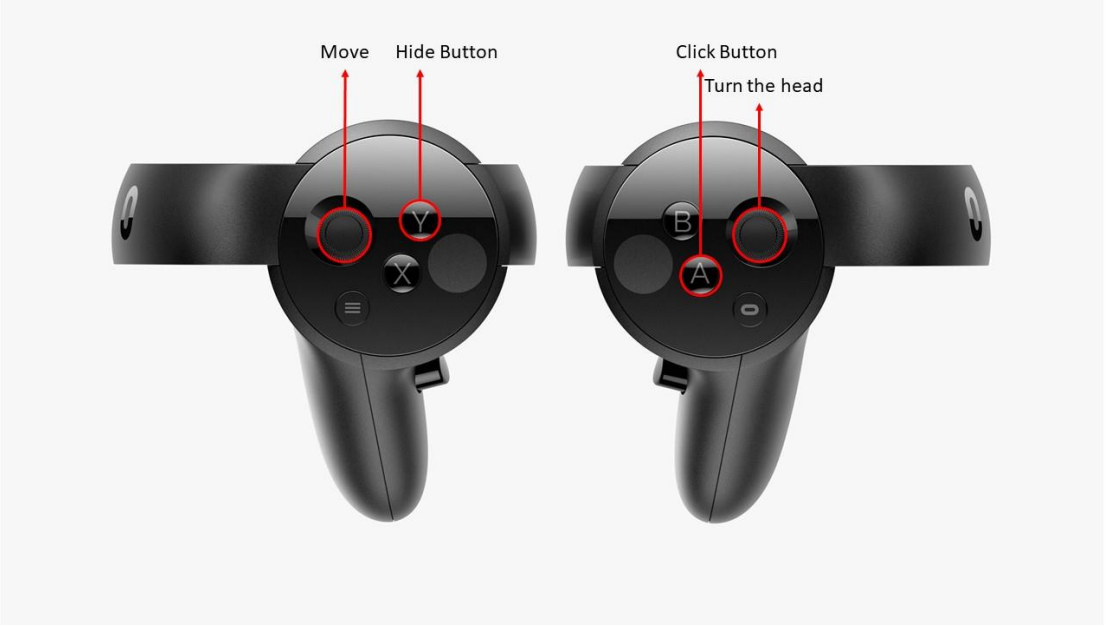


Figure 74 Oculus Controller

Oculus controller is a pair of tracking controllers that can simulate real hands and reproduce the real pointing sense of both hands in the virtual world. The Touch controller uses traditional action buttons, joysticks and analog triggers, which can bring a sense of familiarity to the user's new experience.

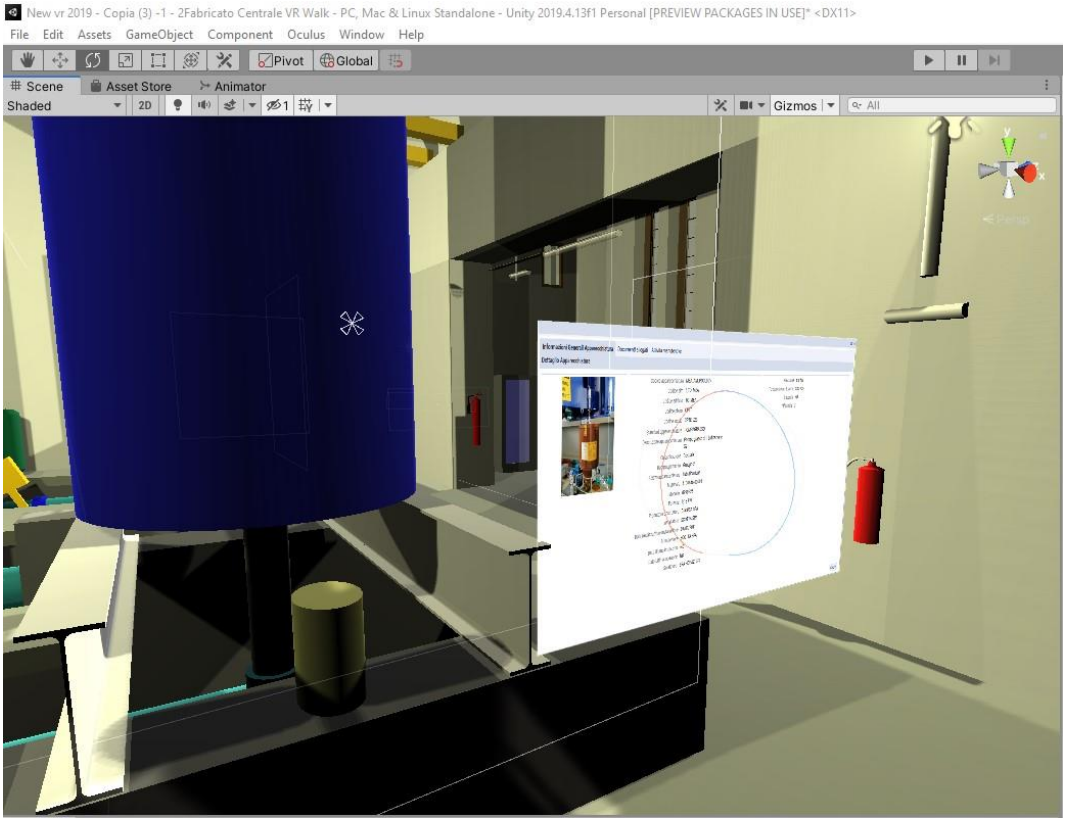
In order to define the function for each keys on the controller, we need to find out the indeed script about the controller, and modify the order to archive our target.

The following script is about to define button "A" to open or hide Canvas:

```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;

public class HideCancas : MonoBehaviour
{
    public GameObject Canvas;
    // Update is called once per frame
    void Update()
    {
        if(OVRInput.GetDown(OVRInput.RawButton.Y))
        Canvas.gameObject.SetActive(true);
       if(OVRInput.GetUp(OVRInput.RawButton.Y))
        Canvas.gameObject.SetActive(false);
    }
}
```

- **Facing to camera**



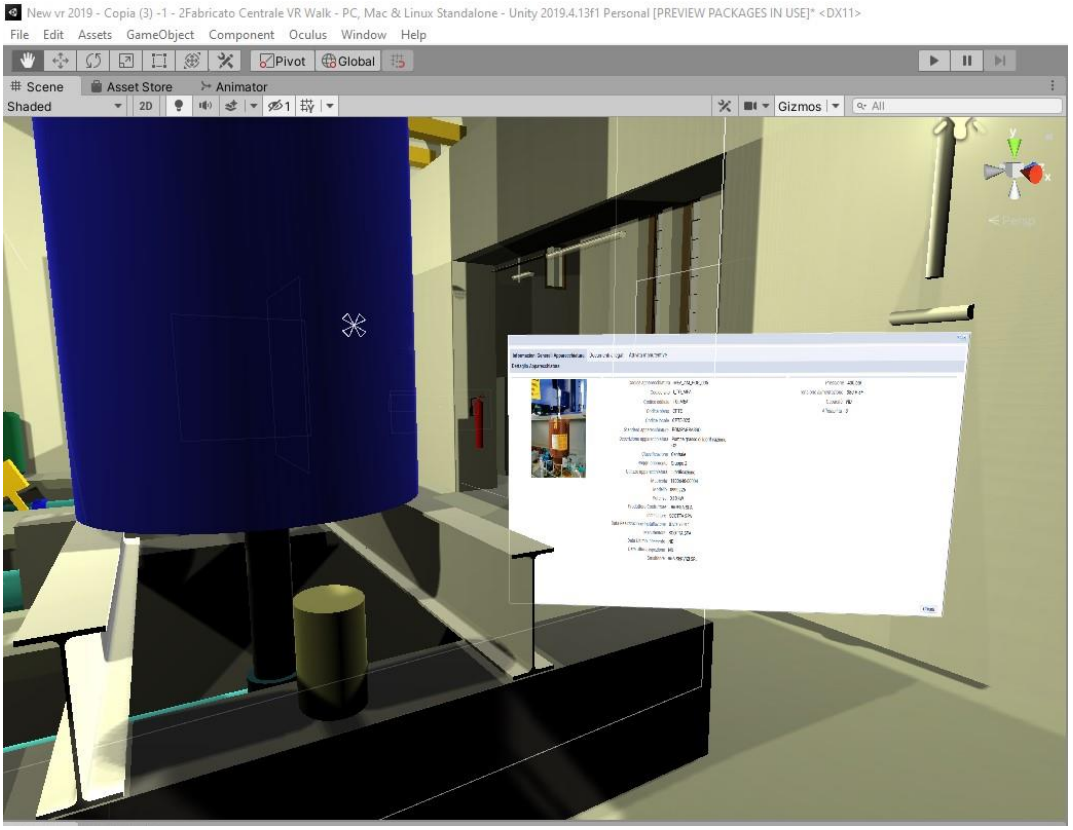


Figure 75 Facing to the camera code

As shown in images, if without the following script, this picture will not focus on the camera but just face to one direction, after using the script, after game start the relevant images will always follow the VR camera whatever change the direction of camera.

```
using UnityEngine;
using System.Collections;

public class NiftyNoteFacingCamera : MonoBehaviour
{
    public Camera cameraToLookAt;
    // Update is called once per frame
    void Update()
    {
        Vector3 v = cameraToLookAt.transform.position - transform.position;
        v.x = v.z = 0.0f;
        transform.LookAt(cameraToLookAt.transform.position - v);
        //transform.Rotate(0,180,0);
        transform.rotation = (cameraToLookAt.transform.rotation);

    }
}
```

Conclusion

Through the actual operation and use of BIM for a project, I realized that BIM is a new way of working. Its final result is a three-dimensional building model with complete information, enabling real-time communication and collaboration between building structures, water, electricity and heating. The model can be transferred to the owner, construction unit, and property company for update and query. In other words, BIM is a container, and information is the water in it, and everyone can share it easily. In line with the design idea, the design that takes time to do, instead of drawing and modifying the drawing over and over again through AUTOCAD most of the time. For the construction party, the BIM concept can generate profits. Every time a problem is discovered on the site, it will cause rework, rectification, and affect the construction progress. However, the use of BIM concept drawing can find the problem and solve the problem as soon as possible. The profit generated lies in the reduced construction period and site rectification. It can also work together and improve efficiency, both architecture and structure model could be managed by Revit and could connect to each other very well; after modeling and transfer to Robot to carry out the structural analysis process is convenient and practical, to bring out the gorgeous visualization for customers, Twinmotion and VR controlled by Unity are practical and carry out incredible effect, by means of .FBX or .IFC unit file transformation more and more operations become useful and straightforward.

Consequently, the concept and philosophy of BIM are beautiful and can run through the entire life cycle of a building, but there is currently no project in China that can achieve this goal. Because of the maturity, localization of the current BIM software, and the inability to perform perfect handover, reuse and other functions in the model's transfer process at different building stages. So BIM is not a panacea, it needs time to improve it, 10 years, 20 years, or even longer is possible; everyone is running in, in fact, no matter when, the bimer is always looking for where the future is. Many predecessors are concerned about BIM. The future direction of the construction industry is still cautious. Also the profit margins of construction companies are generally low. A low profit rate means that employees need to spend more time, which means that the overall income level will not be in the forefront of all industries. To get rid of the dilemma of the construction industry, it is necessary to use digital means to change the original backward production methods and management models, promote the sustainable development of construction enterprises, and realize the transformation and upgrading of the construction industry. At this stage, the profit margins of Chinese construction companies are generally low, and cost control capabilities need to be

further improved. As the core technology of digital transformation, BIM technology and other digital technology integration and application will be the core technical support to promote the digital transformation and upgrading of enterprises. The integrated application of BIM and project management system. It will improve the data integration and sharing between various business units in the project management process, effectively promote the connection and collaboration of the three pipelines of technology, production and business, and better support the optimization of the plan. To ensure the rapid determination of the cost during the implementation process, control design changes, reduce rework, reduce costs, and improve quality. In short, if we want to increase the net profit margin, we must rely on BIM!

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Sitography

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