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Department of Structural, Geotechnical and Building Engineering
Master of Science degree in Civil Engineering

From Point Cloud to BIM to FEM and VAR for data management and visualization

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Abstract

The aim of this study is to investigate the efficiency and application of a conversion from Point Cloud-BIM Model to FEM-software and VAR to safety assessment for existing structure. With this information, the engineer can save time, also optimize the workflow and increase the accuracy of model. because engineers know which conversions can be properly executed and which data losses will occur during each conversion when a BIM-model is being transferred.

The results did point cloud -BIM application is very useful for geometry investigation of existing building and BIM to FEM can be solve difficulty of creation most complex structure in FEM software. not support the expectations that using an IFC file format is the ideal manner to exchange information between BIM-software and FEM-software. If a direct link is available between two programs, this is still recommended. Even an intermediate file, developed to be used between two specific programs, had better results for most of the conversions than using an IFC file format. However, IFC is a file format that can be used as long as the engineer knows which data is imported correctly from the BIM-model.

Key words

Point cloud, Building information modelling (BIM), Finite element analysis (FEM), Interoperability, IFC, Virtual Reality (VR), Augmented Reality (AR)

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1.Introduction

1.1 Description of the Building

1.1.1 PALAZZETTO "LE CUPOLE"

The building "Le Cupole" is located in the southern part of the City of Turin, close to the border with the municipality of Nichelino, precisely at the intersection between Strada Castello di Mirafiori and Via Artom.

The building is part of a parabolic reinforced concrete monolithic structure, consisting of two circular flat domes that intersect along a joint line made of prestressed reinforced concrete structure. The two hemispheres form a shell with the reinforcement concrete structure. Used by the stands for the public and locker rooms. Given the complex geometry of the building, a three-dimensional survey was performed using laser scanner technology, which allows the structure to be create with CAD / BIM, allowing the thicknesses of the architectural and structural elements to be estimated with reasonable accuracy. Following a further on-site inspection and based on the analysis of the crack pattern, the circular dome-shaped roof structure would appear to be "resting" on a perimeter system of reinforced concrete column with a height of about 230 cm from the floor. external trampling that coincides with the internal one; the thickness of the building package is about 60 cm. The dome has a constant or in any case slightly variable section of about 40 cm from the interlocking section at the level of the head of the pillars up to the top where there is a hole for natural lighting with a diameter of 315 cm.

At the intersection between the two domes, they each "unload" their weight and the weight acting on a pair of prestressed reinforced concrete beams with a rectangular cross section of 40x150 cm. These beams are prefabricated and prestressed, and they are shelved. On pillars cast during casting work. The rectangular section is 50x115 cm and is connected by 40 cm thick concrete septa. The space between the beams is filled with reinforced concrete slabs.

Figure 1: Palazzetto le cupole building in google map

1.1.2 Swimming Pool & Gym "Parri"

The building is located in via Tiziano Vecellio 39 in the central district of San Salvario. The complex consists of several rooms consisting of a gym designed to host volleyball, basketball, and the swimming pool area with its changing rooms, area and municipalities and staff offices as well as the rooms used as a machine room in the basement. The structures date back to the 70s and are made of ordinary reinforced concrete cast on site for the floors, beams and columns of most of the complex, while the roofs of the swimming pool and gym environments were used prefabricated elements in prestressed reinforced concrete respectively with beams box section.

Given the complex geometry of the building made up of different buildings connected together, a three-dimensional survey was performed using laser scanner technology, which allows to have a return in CAD / BIM environment of the georeferenced structure in space, allowing to estimate with reasonable accuracy of the thicknesses of the visible architectural and structural elements. The image at the beginning of the paragraph shows the approach used for creating the 3D model or by importing the point cloud into the BIM environment (the point cloud is the output of the survey with laser scanner instrumentation) the geometry of the structure with centimeter precision. From the BIM model it was therefore possible to export the model in IFC interchange format and import it into the FEM software to create the calculation model with which the structural analyzes and verifications were carried out. The complex looks like three buildings connected together which are the building of the swimming pool with the grandstand, the gym and the building at the entrance that houses the changing rooms, staff offices and common areas. Below these rooms there is a basement used as a warehouse and technical rooms.

Figure 2: Parri building in google map

2. Definition of the Reference Structural Model

2.1 Existing Structure and Assessment

An existing construction is defined as the one having the structure completely built at the date of the safety assessment and/or the retrofitting intervention. The process of assessment and structure management is a decision process which aims to remove any doubts regarding its current condition and future structural performance and to identify the most effective intervention required to fulfill the basic requirements. it is important that this process is optimized considering the total service life costs of the structure.

The purpose of the structural analysis is to verify the structural safety and serviceability of a structure with respect to its specified remaining working life where necessary to suggest interventions. The structural analysis and verifications should take place on the basis of the updating of actions, construction material and structural models and geometrical properties, damage and deterioration mechanisms, all of which in turn are used for the establishment of updated values for the action's effects. ultimate resistance and deformability capacity.

2.2 Italian Reference Technical Code: Existing Buildings - Chapter 8

In this thesis considered Italian Reference Technical Code-NTC for safety assessment and verification. This chapter establishes the general criteria for the safety assessment and for the design, execution and testing of interventions on existing building.

The safety assessment and the planning of the interventions must take into account the following aspects of the construction:

- It reflects the state of knowledge at the time of its realization;
- There may defects in design and construction;

- It may have been subject to actions; even exceptional whose effects are not completely manifest;
- Its structure may present degradation and significant changes, compared to the original situation.

In the chapter 8.3 of Italian Reference Technical Code, safety assessment of an existing structure is a quantitative procedure, aimed at determining the extent of the actions that the structure is able to support with the minimum safety level required this regulation. Safety assessment allows to know if the use of the structure can continue without interventions, the use of the structure must be changed, it is necessary to increase structural safety through retrofitting intervention.
Safety assessment outputs:

$$\xi_E = \frac{\boldsymbol{maximum\ sutainable\ seismic\ capacity}}{\boldsymbol{design\ seismic\ demand\ to\ NTC18}}$$

$$\xi_V = \frac{\boldsymbol{maximum\ sutainable\ Live\ load\ capacity}}{\boldsymbol{design\ seismic\ demand\ to\ NTC18}}$$

In NTC chapter 8.5 , the analysis starts finding the documents available on the origin of the building such as , for example ,design and reports at the first construction and at any subsequent intervention , further survey and drawing made during the time , eventual test reports , in detail ,the historical /critical analysis will report:

- The era of construction;
- The techniques, construction rules, the technical standards at the time of the construction;
- The original form and subsequent modifications;
- Alterations of the boundary conditions;

- Deformations, failures and crack patterns with indications, where possible of their evolution over time;
- Previous restoration interventions;
- The urban and historical aspects that governed the development of the building aggregate of which the building is a part.

2.3 Definition of Mechanical Properties of Materials

In the "LE CUPOLE" building there is no information regarding the diameters of the reinforcement bars also no information of the type of steel, however in the test certification performed by technical staff are indicated of the estimated resistance obtained through a sclerometer investigation and reported below:

Sono state effettuate alcune battute sclerometriche, in particolare: su di un tratto del muro di appoggio della paretina monolitica di formazione pneumatica (punto 1), sul setto di unione dei due pilastri tra le due cupole rivolto a est (punto 2), su pilastro lato sud dell'elemento precedente (punto 3), su pilastro ingresso lato est (punto 4), sulla veletta di coronamento gronda lato nord (punto 5), riscontrando una resistenza media di 500 kgf/cm^2 per i punti 1,2,3, e 4, mentre per il punto 5 si è riscontrata una resistenza media di 290 kgf/cm^2.

PROVE	PUNTO 1	PUNTO 2	PUNTO 3	PUNTO 4	PUNTO 5
1° Quadrante	*46/38/37*	*40/42/46*	*49/50/47*	*50/50/42*	*35/36/35*
2° Quadrante	*41/46/40*	*50/42/43*	*45/45/45*	*45/48/48*	*40/35/35*
3° Quadrante	*45/46/46*	*45/43/50*	*52/52/48*	*50/45/48*	*30/32/30*
4° Quadrante	*40/48/42*	*50/52/50*	*48/49/46*	*46/45/42*	*32/30/30*
Media battute	*42,875*	*46,05*	*47,95*	*46,55*	*33,275*

[Sclerometro SCHMIDT - BASEL - N.26 - 66665]

Figure 3: Original Material Tests

According to the sclerometer test result, the average resistance about 50Mpa. Although the strength value of the concrete is excellent during the test, a conservative method is still considered to be suitable for the Rck value of 30 Mpa. According to Chapter 8 of Italian technical code, for existing structures, it is necessary to indicate the level of knowledge achieved and the corresponding confidence safety factor. In this case, due to the lack of information and the use of simulation project methods, the level of knowledge reached is LC1 and the corresponding FC value is 1.35: this is the value that determines the calculated resistance of existing materials.

For the "PARRI" building , there is no information on strength of the material used , but according to the Italian technical code and construction rule of time of the construction , it can be take average strength of material is equivalent to Rck 30Mpa of concrete, and for the reinforcement steel bars ,AQ50 or equivalent FeB38K can be considered . due to lack of information and the use of simulation project method, the level of knowledge reached is LC1 and corresponding safety factor value is 1.35, this is the value that determines the calculated resistance of existing material.

3. Geometry Survey by Using Laser scanner

3.1 Laser Scanner Technique and Point Cloud

Three-dimensional laser scanning technology is an advanced fully automatic high-precision three-dimensional scanning technology. It is a fully automatic measurement technology that uses a three-dimensional laser scanner to obtain the spatial coordinates of various points on the surface of the target, and then constructs a three-dimensional model of the target from the obtained measurement data. Three-dimensional laser scanning technology is another new surveying and mapping technology after GPS and has become an important technical means for spatial data acquisition.

Figure 4: Faro Laser Scanner Device

3D laser scanning technology is a new way to obtain spatial data of objects. Compared with traditional measurement methods, 3D laser scanning technology can continuously, automatically and quickly collect a large amount of 3D point data on the surface of the target, that is, point cloud, so It has many unique advantages, such as:

- fast data acquisition speed and strong real-time performance;
- large data volume and high accuracy;
- strong initiative and can work around the clock;
- full digital features, easy information transmission, processing and expression.

Its working process is actually a continuous data collection and processing process, which expresses the sampling results of the system on the surface of the target object through a point cloud image composed of spatial points with a certain resolution. The traditional measurement method is to collect data at a single point and obtain single-point data. The three-dimensional laser scanning technology does not require a cooperative target, so it can automatically, continuously and quickly obtain the data of dense sampling points on the surface of the target, thereby improving the efficiency of measurement. Broadening the application field of surveying and mapping technology.

Compared with the traditional photogrammetry modeling, the three-dimensional model established by using the point cloud data obtained by the three-dimensional laser scanner has faster data acquisition speed and more accurate three-dimensional model. , Terrain survey, digital city, existing structure , virtual reality ,urban planning, intelligent transportation and other fields have broad application prospects and value, but also an important direction for the development of 3D laser scanning technology.

3.2 Maintenance of Existing Building

The use of 3D laser scanning technology can go deep into the complex field environment and space for scanning operations, and can directly realize the complete collection of various large-scale, complex, irregular, standard or non-standard solid or real 3D data, and then quickly Construct a three-dimensional model of solid objects and various drawing data such as lines, areas, volumes, and spaces. Therefore, this technology has been widely used in the maintenance of existing buildings and monitoring of building deformation. And with the continuous development of 3D laser scanning technology, the application field will become wider and wider.

3.3 Site Mapping

Scanning a building generally requires multi-site scanning to obtain complete data, and the multi-site scan data establishes a spatial correlation relationship to achieve a complete expression of the surface shape of the building. The more complex the appearance of the building, the smaller the space available around it, and the more sites it scans, so site design is particularly important. Field scanning requires site layout. The scanning angle of the scanner itself is 270 ° × 360 °, which is generally "what you see is what you get." The principle of complementarity is to collect as complete data as possible within the conditions allowed for observation. Site design generally follows the following principles:

- Scanned data can fully cover the surface of the building to minimize scanning loopholes.
- There is overlap of scanned data between stations.
- Minimize redundant data while ensuring data connection to improve the efficiency of later data processing.

For complex buildings, the 10-20mm setting should be used when scanning, and the point cloud interval that can fully reflect the smallest details of the building should be guaranteed. At the same time, under appropriate point cloud interval settings, 3 to 4 scans should be used to achieve the effect of point cloud encryption, so that high-quality scan results can be obtained to meet the requirements of modeling accuracy of complex buildings.

Figure 5: Site Mapping of Parri Building

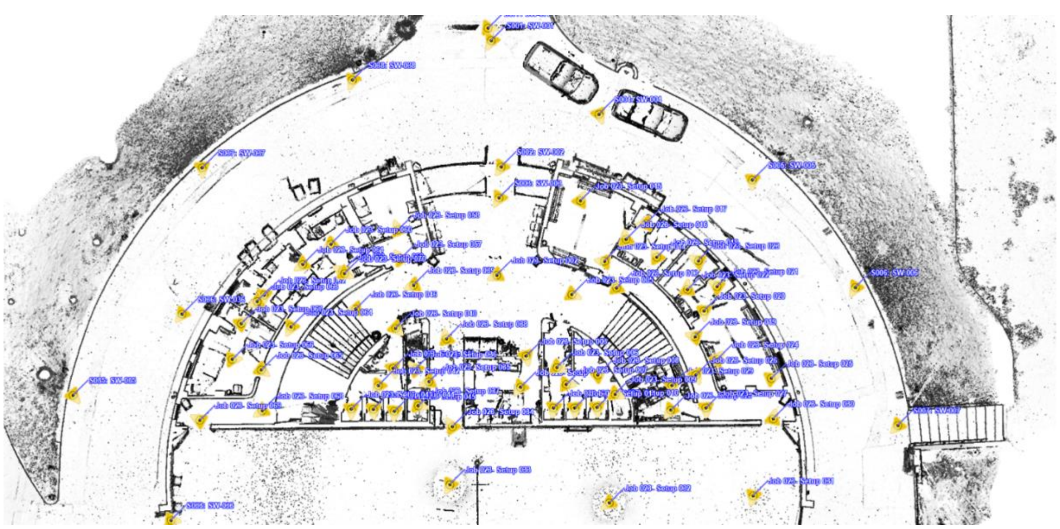

Figure 6: Site Mapping of Le Cupole Building

3.4 Point Cloud in BIM

For building managers with older structures, many buildings and older facilities have difficulty collecting information. Documents about structures, machines, pipes, electrical equipment and past renovations are usually stored on misplaced paper. The point cloud survey allows you to start over, detail everything, and build a BIM-style schematic of an existing structure to help with building / facility maintenance.

Fundamentally, the point cloud keeps BIM (and other forms of computer models) connected to the physical space. Point cloud can not only simply retain the guide or theoretical representation, but also effectively import 3D physical space into digital format and inform / expand your existing digital model.

Autodesk ReCap software is an important connection for the application of point cloud in BIM technology. It can create a point cloud projection file (RCP) by referencing multiple index scan files (RCS). Using Autodesk ReCap to convert the scanned file data to a point cloud format so that it can be viewed and edited in other products. Autodesk ReCap handles large-scale data sets and can aggregate scanned files and clean up, classify, spatially sort, compress, measure, and visualize them. The resulting high-speed format can be used by AutoCAD and other Autodesk applications, such as Autodesk Revit and Autodesk Inventor software. In Autodesk ReCap, can create a new project by selecting the scan file to import. It supports scan data in many popular formats, including Faro, Leica, Lidar, etc. After selecting the scan file to import, adjust the input settings that affect the size and appearance of the point cloud. At this time, the imported file will be displayed on the projection screen, using various tools to operate the scanned file.

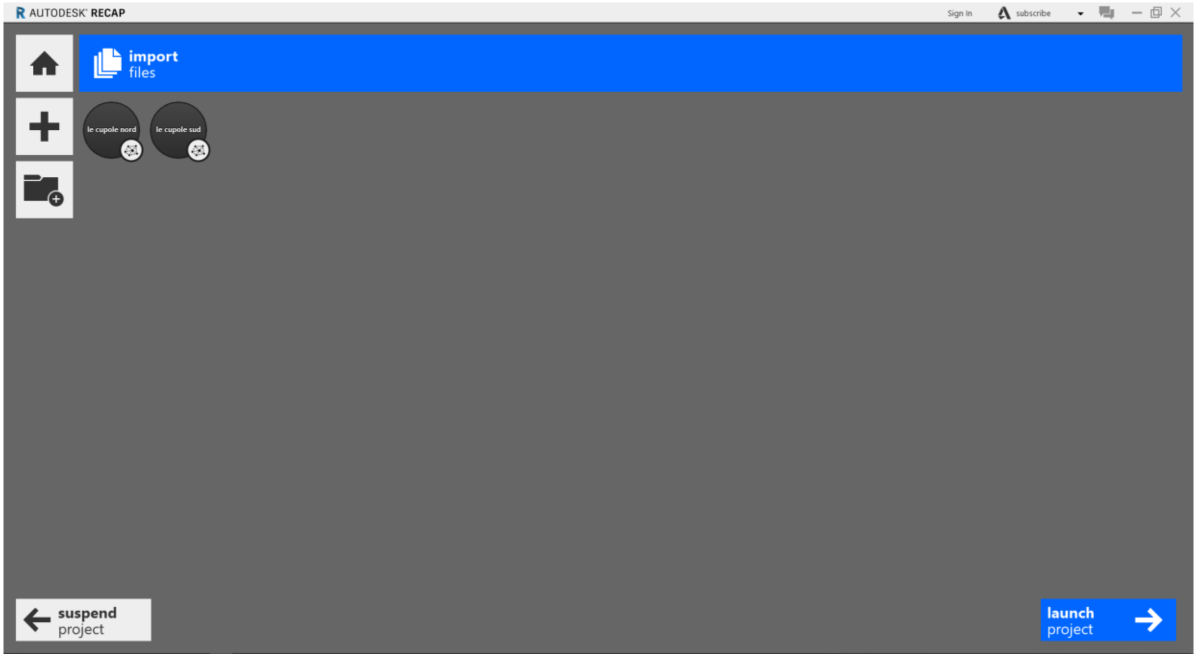

Figure 7: Importing Scan File in Recap Pro

Importing point clouds into Revit requires specific file formats, such as .rcp or .rcs .the file .rcp format are project files grouped with multiple .rcs scan files. The result of indexing the original format file is a .rcp file and one or more .rcs files. Use AUTODESK RECAP to merge part of the point cloud, because the point cloud contains geographic coordinates, AUTODESK RECAP will recognize the geographic coordinates of each point, and then merge each scanned point cloud to form a whole model, because AUTODESK REVIT will not Identify the geographic coordinates of the point cloud. Autodesk Recap also has different display modes. In some point clouds without RGB, different display modes can better distinguish objects, such as the direction of the slab etc.

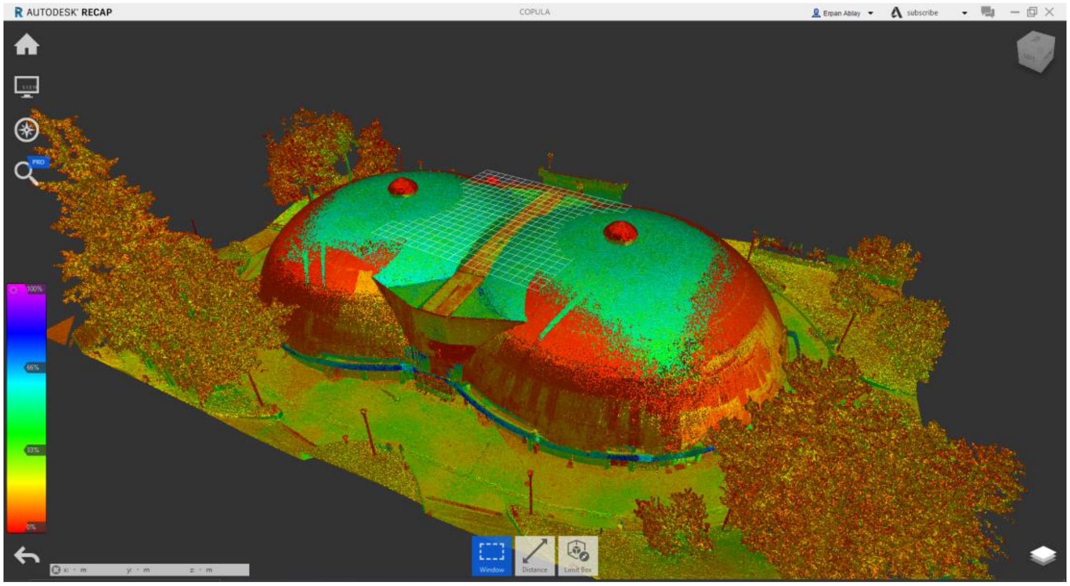

Figure 8: Cupole Building Point Cloud in Recap Pro

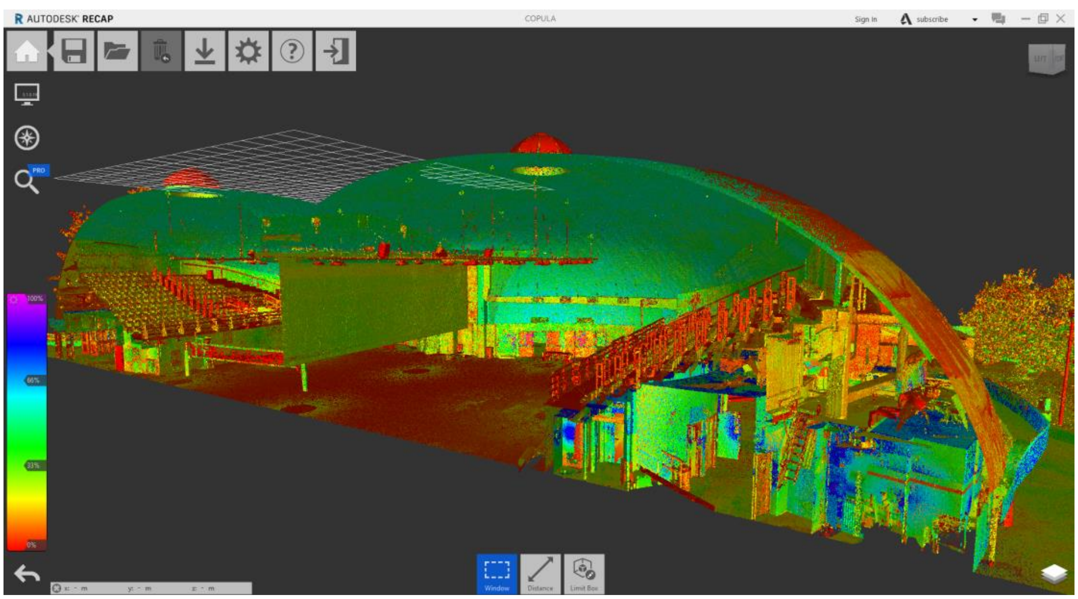

Figure 9: Section of Cupole Building Point cloud in Recap Pro

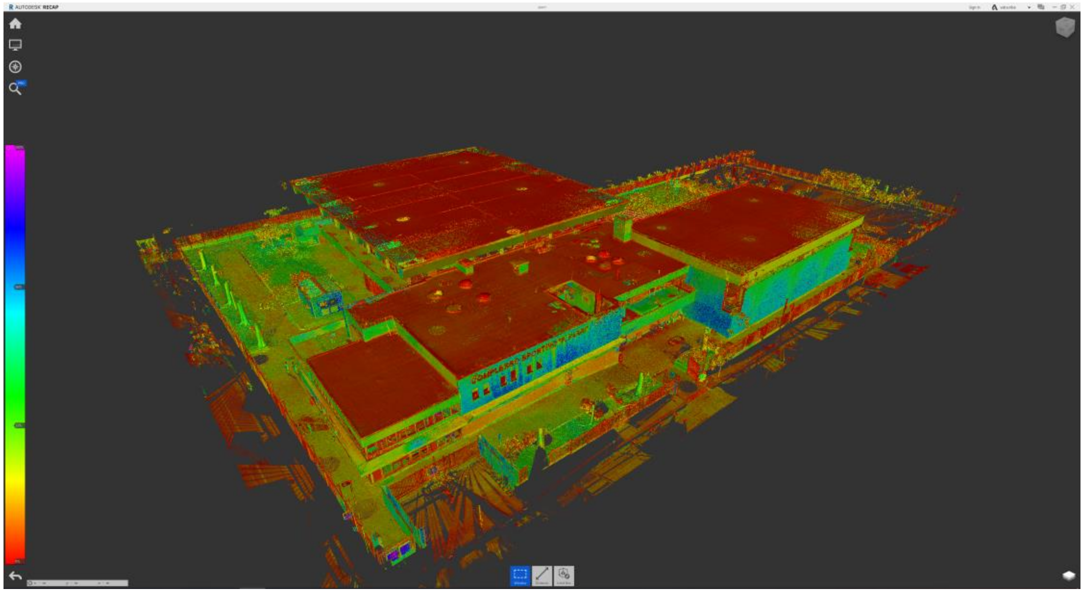

Figure 10: Parri Building Point Cloud in Recap Pro

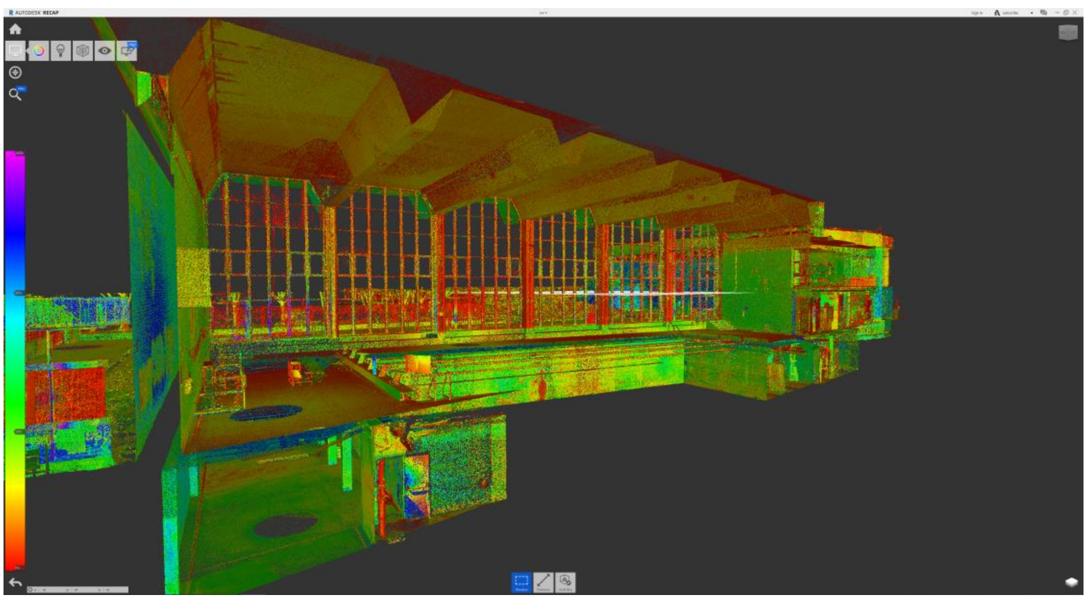

Figure 11: Section of Parri Building Point Cloud in Recap Pro

4. From Point Cloud to BIM

4.1 Introduction

One of the earliest recorded examples of the BIM concept is the Building description system, which was published in 1975 by BIM master Chuck Eastman. In 1999, Chuck Eastman developed the Building description system as the Building Product model and believed that the architectural Product model provided rich and integrated information in the concept, design and construction process. In 2002, Autodesk acquired Revit for the first time using the first letter of Building information modeling. It became known as BIM today.

BIM is a digital expression of the physical and functional characteristics of a building facility. It is a complete description of the physical and functional characteristics of the project facilities. It is based on the 3d geometric data model and integrates other related physical information, functional requirements and performance requirements of the building facilities. BIM is a sharing of knowledge and other resources to realize the information sharing of building life cycle. Based on the digital model of this function, the planning, design and construction of the project can obtain the information they need. These data are continuous, immediate and reliable.

BIM is a digital management method and coordination process applied to design, construction and operation. It is also an information technology, its application needs information software support. In the different stages of the project, the different stakeholders through extracting BIM software in BIM model, application, update relevant information, and gives the modified information to BIM model, support collaborative work, improve the design, construction and operation of the efficiency and level.

Autodesk Revit Structure software is a building information model (BIM) solution designed for structural engineering companies, with powerful tools for structural design and analysis. Revit Structure integrates multi-material physical models and editable analytical models to achieve efficient structural modeling and provides bi-directional links for common structural analysis software. It can help users visualize the building structure more accurately before construction, thus making the relevant personnel make more informed decisions early in the design phase. Revit Structure that provides users with BIM have advantage, can help users to improve Structure design document more professional skill and minimize errors, and to strengthen the cooperation between the engineering team and construction team.

Revit Structure in the construction project, the biggest advantage is able to coordinate various professional work, all the model information is stored in a database together, realize the effects of a modified, updated everywhere, so as to minimize the repeatability of the modeling and mapping work, reduce the error in the project design changes, improve the efficiency of the work of an engineer.

Building Information Modelling (BIM) methodology is increasingly penetrating into building design. It will also lead to an inevitable increase in the demand for BIM modelling in the existing building stock. That raises the question, what is the most effective method of surveying existing buildings, Laser scanning appears to be the ideal solution. It allows the quick and precise high definition capture of 3D data. Various pilot projects and user reports tell of the effectiveness of the procedure as the basis for creating a 3D BIM model. But, thereby, is the procedure ‘Scan-to-BIM’ by no means trivial. The challenge here is to create a parametric 3D BIM model from the precise depiction of the real world, in the form of a point cloud.

4.2 BIM Modelling with Point Cloud

First it is necessary to transfer the original survey data into the required BIM system. Currently there are only a few BIM systems, such as, for example, Autodesk Revit, that are capable of importing and displaying large point clouds. There, it is then possible to use the point cloud as a modelling reference, whereby sections from and planar views of the point cloud can be extracted. Point snapping allows the precise remodeling of the point cloud regions with 3D BIM elements

Insert an indexed point cloud file into a Revit project or convert a raw format point cloud file to the .rcp and .rcs indexed formats. First, it needs to open the Revit project with structural template, then click insert tab adding point cloud. The rcp format is already done using Autodesk recap software, it will be faster than insert original rcs file. After inserting point cloud file its need to move the level 0 in order to create correct level for modelling.

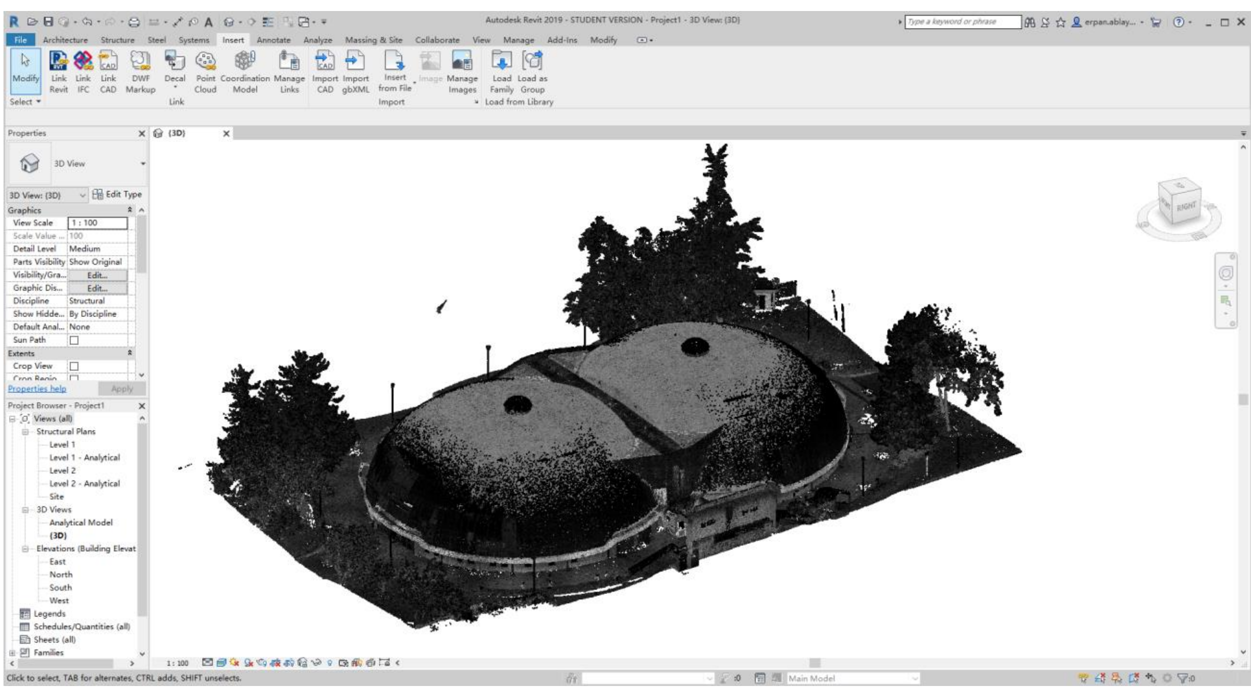

Figure 12: Cupole Building Point Cloud in Revit

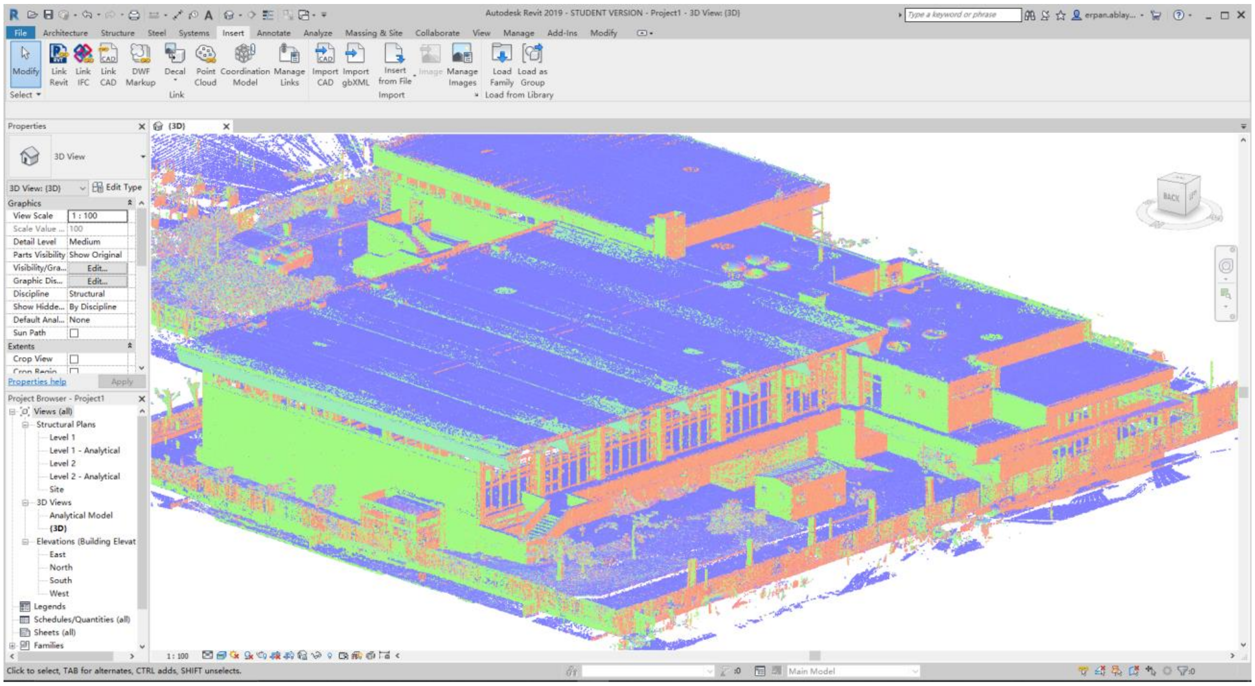

Figure 13: Parri Building Point Cloud in Revit

After inserting the point cloud its need to create levels and grid system, Grid tools first place the grid lines on the floor plan. it can quickly locate structural columns and structural beams and improve the regularity of structural dimensions.

For creating the level, it can reference top surface of the slab, but in elevation plan it’s difficult to see slab surface, because point cloud scanned entire building, so using elevation plan it can see only the surface of the façade. For solve this problem it needs to create section plan in order to get correct position of the slab surface. after obtained slab position it’s easy to insert different levels of the building using Revit. for each level Revit automatically show the section plan of point clouds , it’s convenient to obtain information of each floor , for example dimension of column , width of beam etc. but in some cases the floor plan not clearly show the information , the reason is view range of floor plan is in between the slab , so its need to adjust the position of the view range using properties panel of Revit until all the information are clear.

After adjusting of view range, it can be obtaining the correct position of the structural element and dimension of the column and width of the wall. than it can be create grid system using reference of column position. The creation of grid system is very essential in modeling with point cloud, because using grid system its easily obtain and distinguish the structural column system. The laser scans all the actual information of the building, so in some cases, some MEP system or architectural element will affect distinguish of the column position. So, for this reason the creation of grid system is very important.

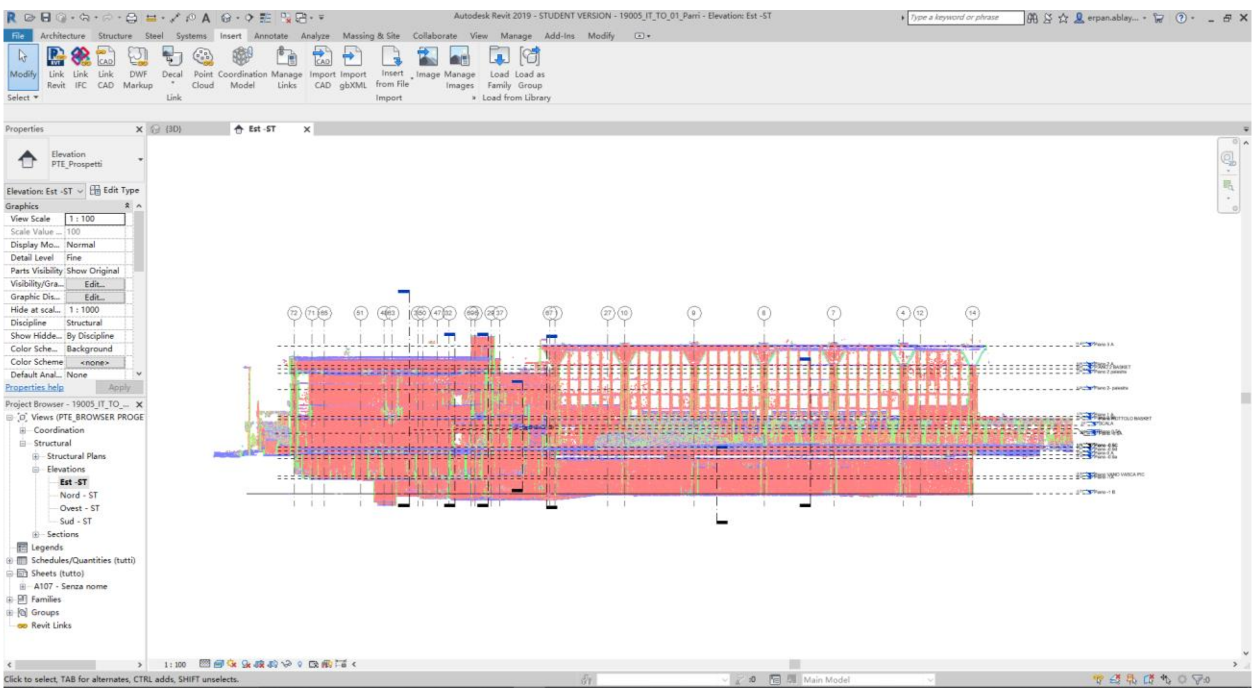

Figure 14: Create Structural Elevation System in Revit

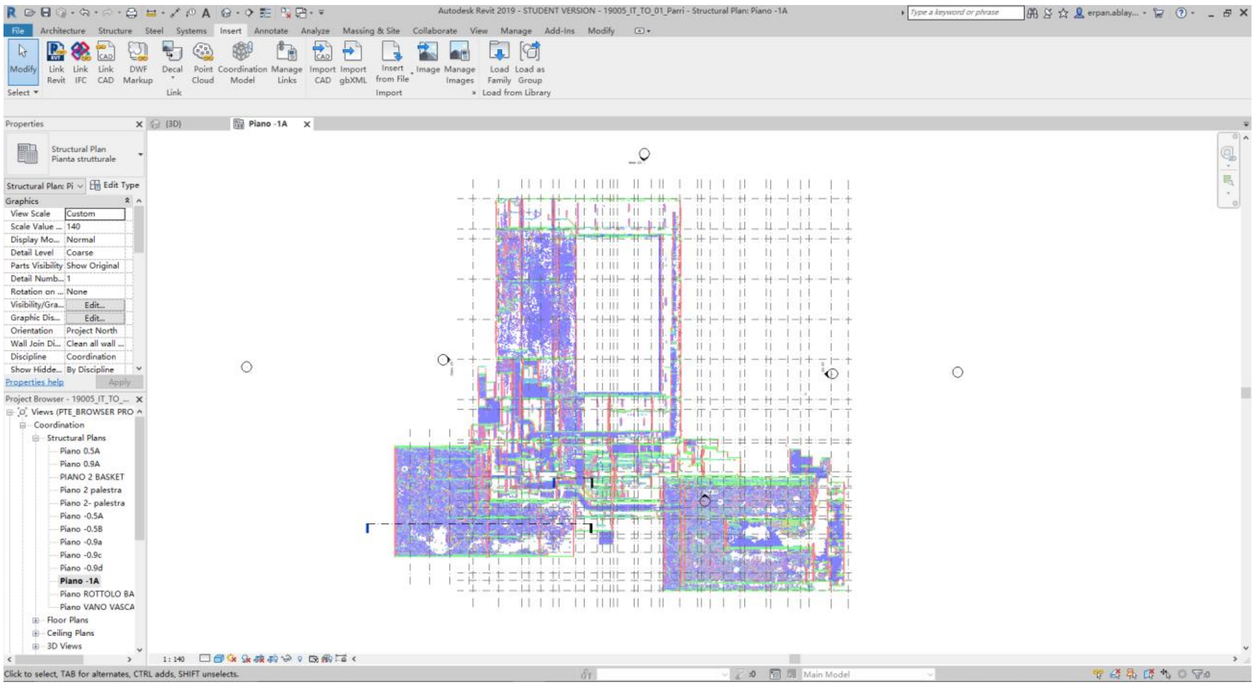

Figure 15: Create Structural Grid System in Revit

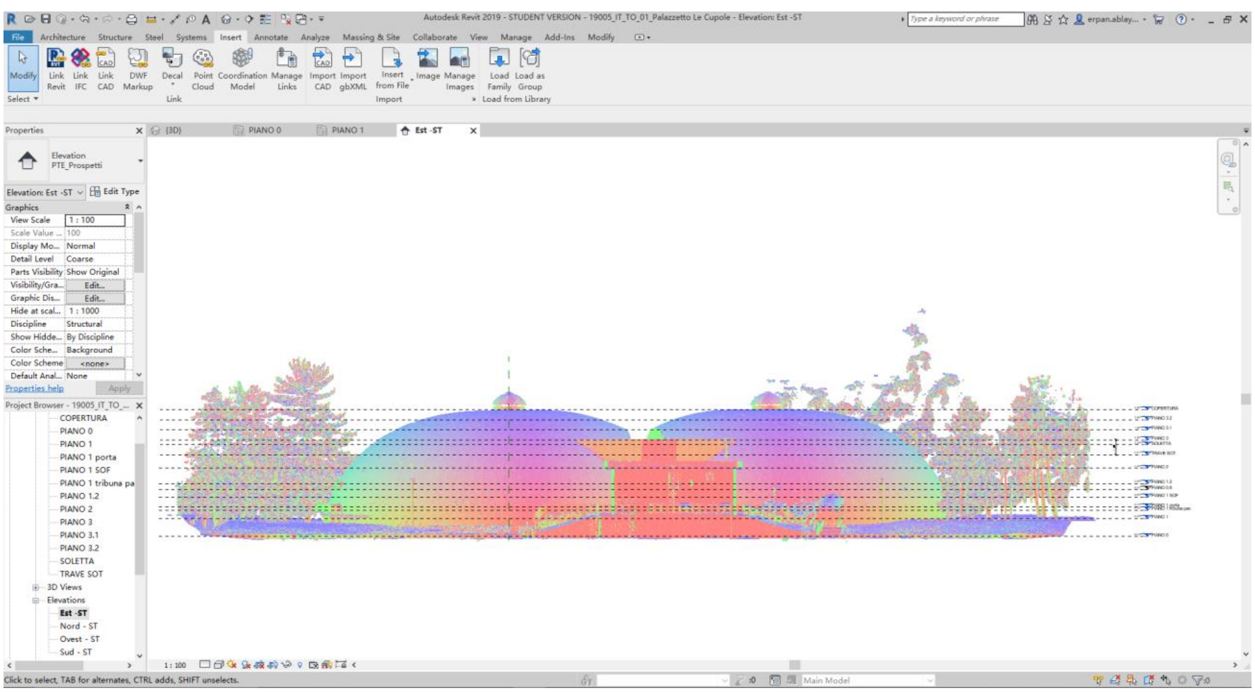

Figure 16: Create Structural Elevation System in Revit

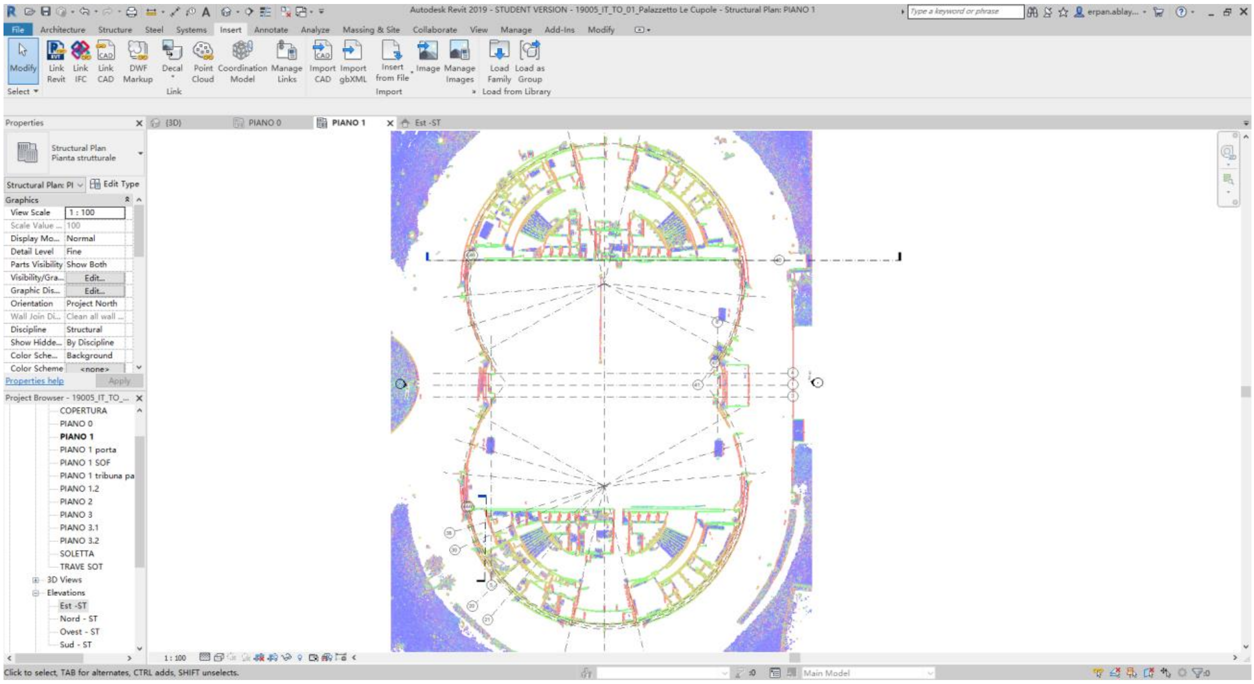

Figure 17: Create Structural Grid System in Revit

4.3 Modelling of "LE CUPOLE" Building

The building consists of two dome-shaped roofs. After further on-site inspections and analysis of crack patterns, the dome-shaped roof structure appears to be “laid on” the surrounding system of reinforced concrete columns approximately 230 cm from the ground. External trample coincident with the interior; the thickness of the building packaging is about 60 cm. The dome runs from the interlocking part to the top of the pillar to the top. There is a natural lighting hole with a diameter of 315 cm at the top. There is a constant part in this area, or in any case it changes slightly, about 40 cm. Since the structure is completely symmetrical, the description of the dome next to it is similar.

The two mirror blocks of the stands are housed inside the structure. From a static structural point of view, the tribune-stairs block of access is independent of the roofing system; in particular, the grandstands are made using 15 cm thick reinforced concrete slabs which unload on inclined beams called "ribs" of 40x50 cm section and on walls of 25 cm section always in reinforced concrete. with a curved pattern which also support the grandstand access staircase. Frontally, close to the playing fields, the stands are supported on a wall always in c. To. about 35 cm thick. Finally, the ribs are supported on pillars which have variable dimensions with typical sections of 40x55 cm, 40x40 cm and 30x50 cm. On the back of the tribune there is a space reserved for the systems and accessible through a trap door in the corridor, made with a full slab of about 15 cm left unfinished。

With respect to the point of view of FEM and BIM modelling, creation of non-linear dome shell structure is very difficult, because the difference with other dome, the section is not circular, its ellipse, the thickness of concrete shell is not constant. It’s not a continues dome, the middle of two domes, they unloaded on the beam, so the best solution is generic model family, to do this, first its need to create section boundary reference with point cloud section and using Revolve command to create entire shape. thanks for the symmetric of two domes, its easily create another dome using mirror command. after creation of the dome shape geometry, its need to add material parameter with concrete.

The middle of two domes has flat roof and structural beam and column system to support load of two domes , to model this , thanks for the Boolean command its need to cut middle part of two domes and create columns and beams using structural beam and column family reference with point cloud in the plan view.

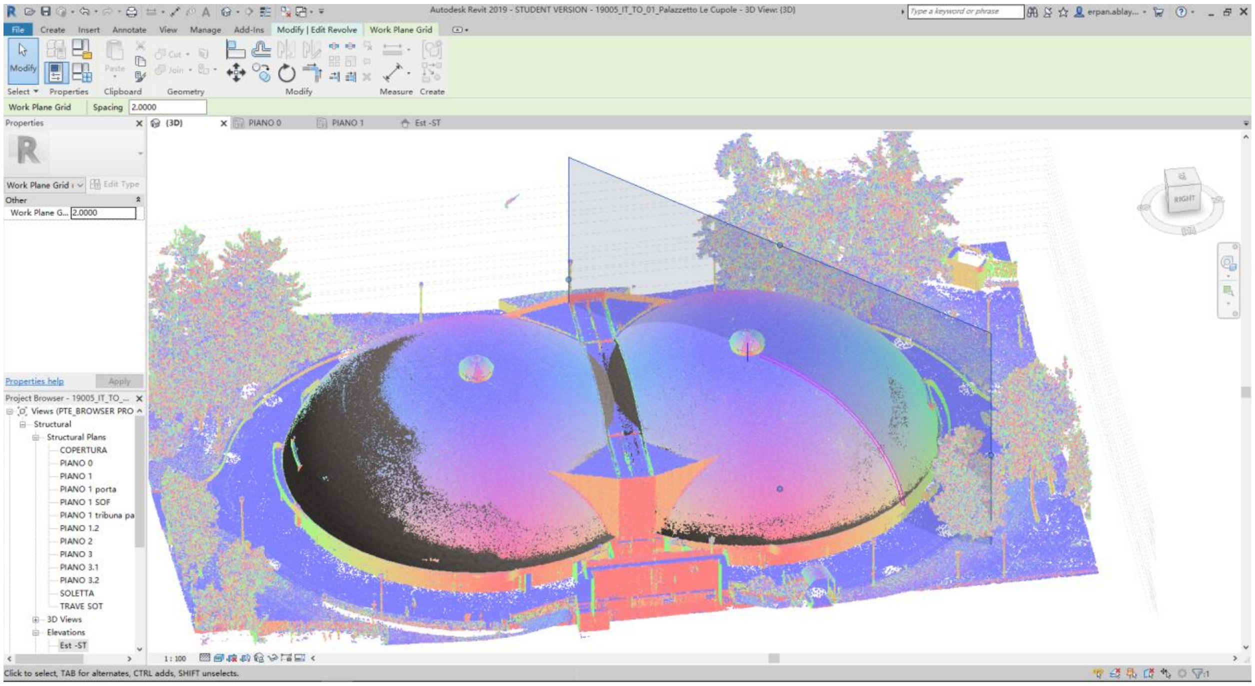

Figure 18: Create Family in Revit

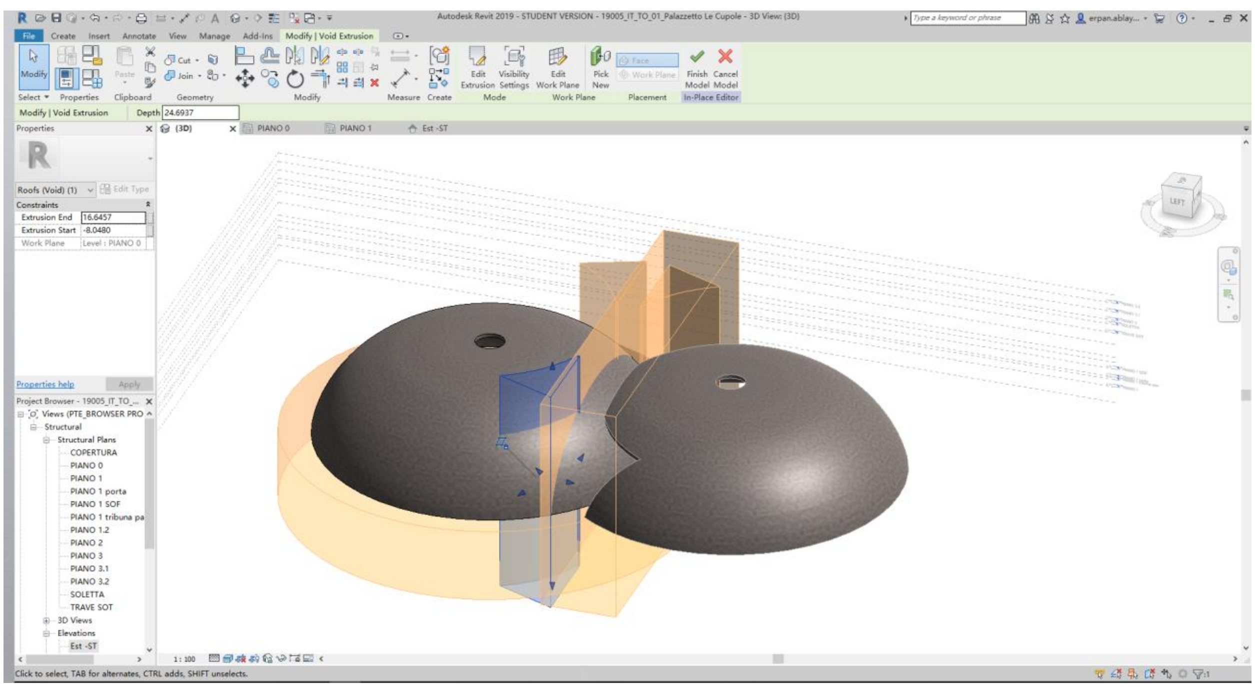

Figure 19: Boolean in Revit

After modelling of domes its need to model external wall element using structural wall family using circular boundary. The external wall created using two material, where structural support part used reinforced concrete wall and fining part used with brick material. Columns and beams need to be arranged in the opening part of the external wall doors and windows. In the plan view, the size of the beam and column can be obtained by referring to the point cloud, and in the inside view, the position and size of the opening can be obtained by referring to the point cloud.

Once the external structure is modeled, the internal grandstand can be modeled. The stand's two mirrors are located inside the building. From the static point of view, the stands structure access has nothing to do with the external dooms system. The stand is supported by concrete columns and inclined beams. It is difficult to get the position and elevation of the inclined beams in the Revit plan, so it is necessary to determine the position of the inclined beams from a 3D perspective and then draw a section plan, through which the inclined beams can be modeled. After the girder frame is modeled, the stands can be created with structural panels. There are interior walls at the bottom of the stands, which are not structural function and are supported only by frame beams system.

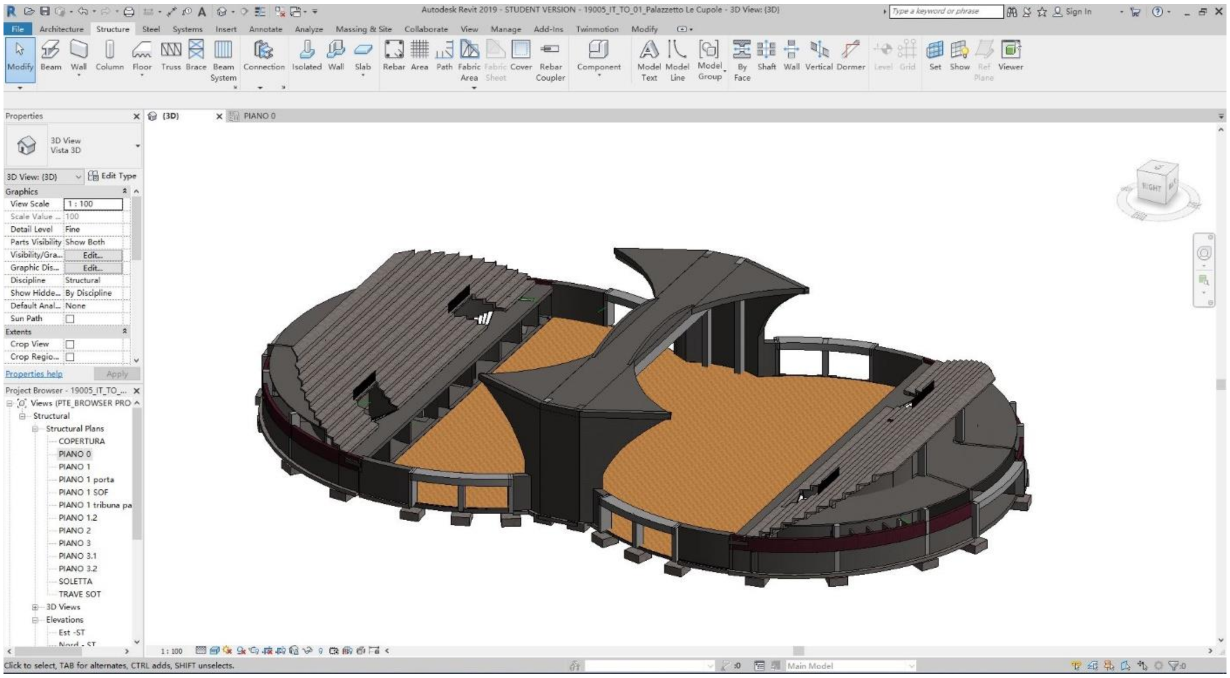

Figure 20: BIM Model of Cupole Building

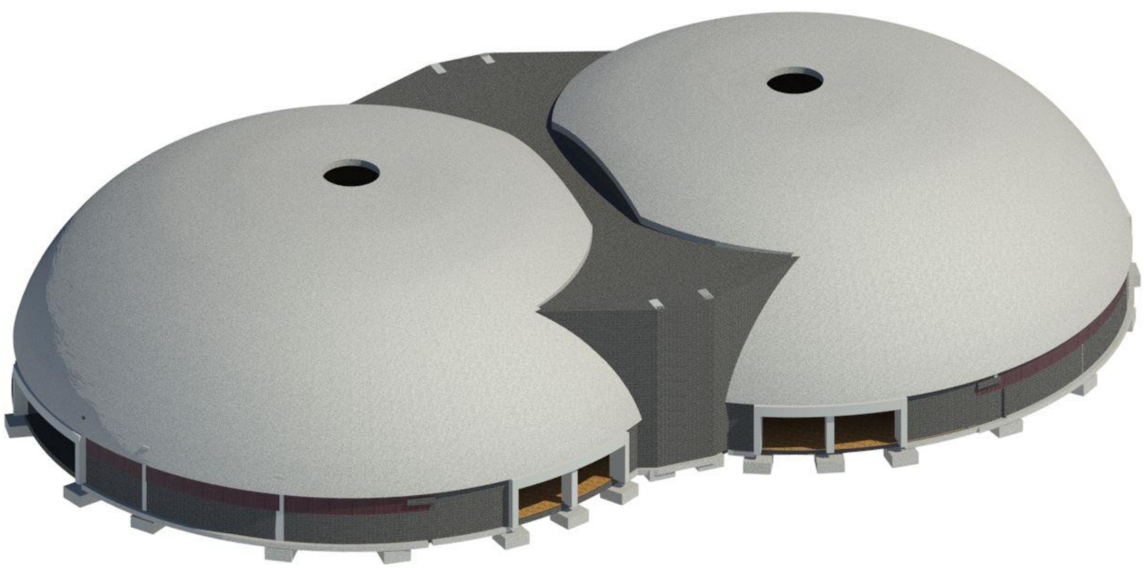

Figure 21: BIM Model of Cupole Building

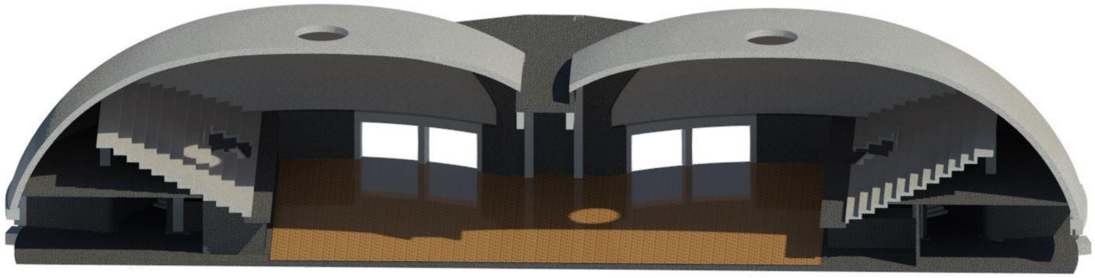

Figure 22: Section view of BIM model of Cupole building

4.4 Modelling of " PARRI " Building

The building consists of a complex geometry of buildings made up of different buildings connected together. The building looks like three buildings connected, with the swimming pool, the grandstand, the gym and the dressing room at the entrance, the dressing room, the staff office and the public area. Below these rooms is a basement used as a warehouse and technical room.

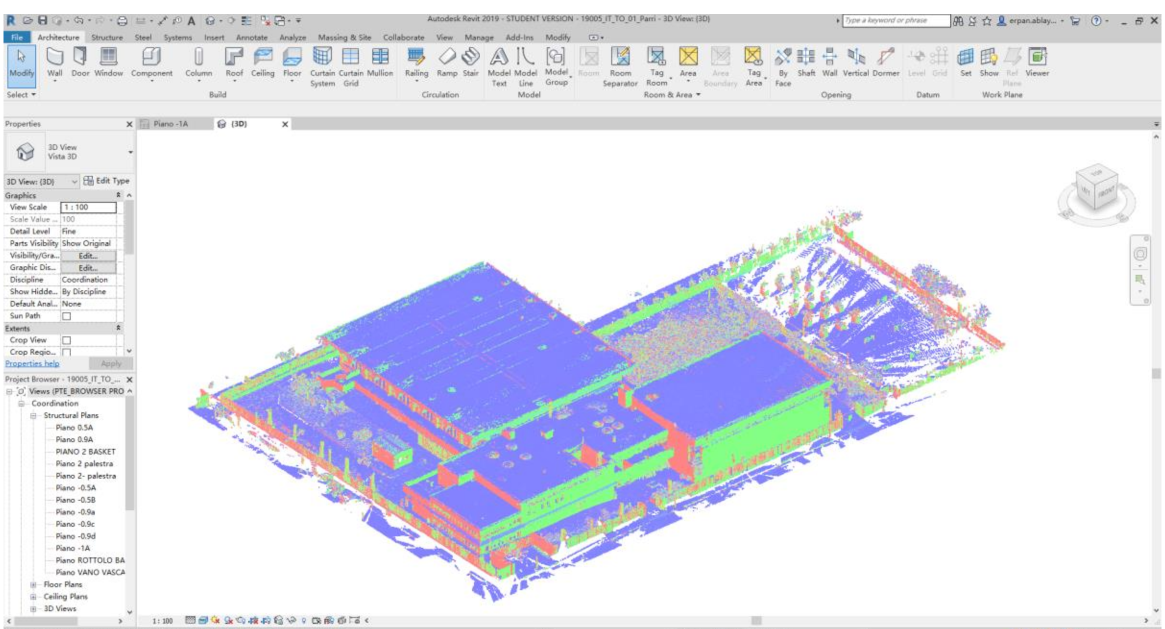

Figure 23: Point Cloud in Revit

4.4.1 Swimming Pool Part

The rectangular shape of the building portion of the pool is about 30m x 40m, and the height from the bottom of the pool to the inside of the roof beam is about 9m. The roof system consists of a main frame consisting of seven precast and prestressed beams.

The opening part is similar to VR, with an opening height of 1.6m and a total upper base of 2.5m. Revit structural beam family can be used for modeling.

The presence of an asphalt overlay on the roof does not allow assessment of the possible presence of an inclined ironing board, but its presence is expected.

The load of the v-shaped beam is applied to the column. The rectangular section of the column is 60x110 with grooves on the short side, it can be modelled using Revit structural column family.

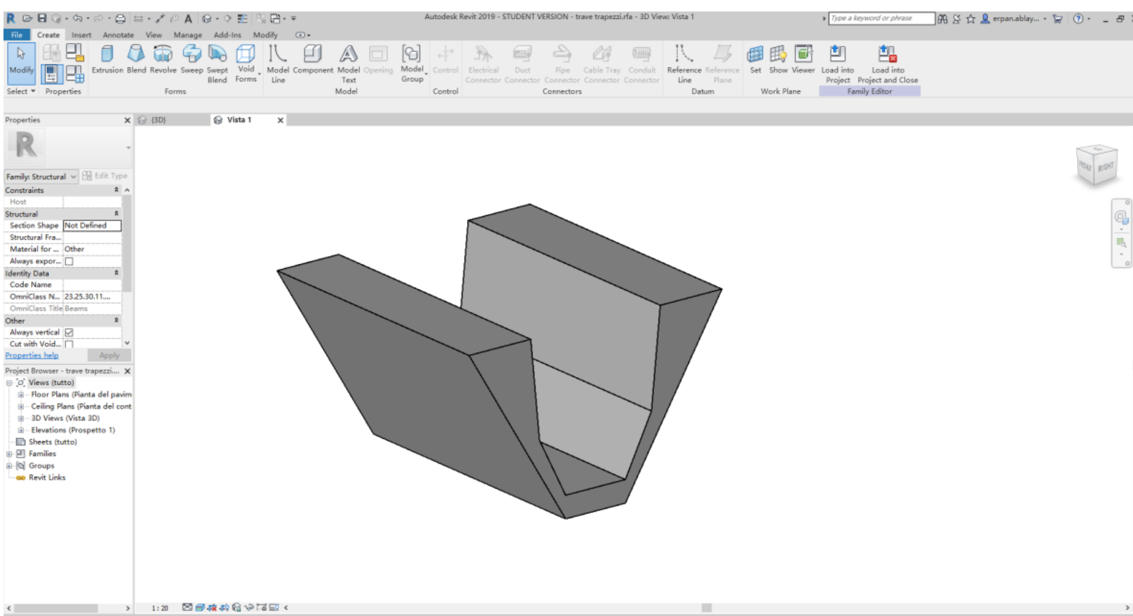

Figure 24: Structural Beam family

The latter is made of reinforced concrete poured on site, but the underlying system is unclear. There is a retaining wall between one pillar and another. The bottom of the barrel is unidirectional brick cement poured on site with a total thickness of 30 cm. Predictably, the thickness of the members ranges from 20cm to 24cm, while the barrel walls are made up of 40cm of reinforced concrete poured on site. The brackets are made of plain reinforced concrete, supported on reinforced concrete beams by sloping concrete brick floors.

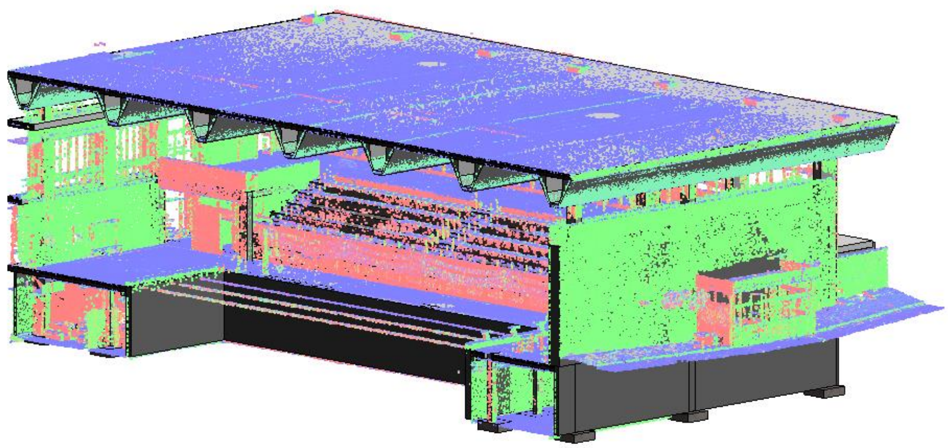

Figure 25: Point Cloud with BIM Model in Revit

4.4.2 GYM Building Part

The GYM has plan dimensions of approximately 30m in length and 20m in width; the roof is flat and made using 253 cm wide and 25 cm thick ribbed tiles, while the cores have variable thicknesses along the height from a minimum of 10 cm to the support up to about 19 cm at the graft with the insole, while their center distance of about 120 cm. These elements are prefabricated and pre-compressed with pretended cables positioned probably in correspondence with the lower edge of the cores and at the top always in correspondence with the same. a circle of the pillars; the vertical elements have section of section 55x45 cm. In fact, the structure consists of 6 frames connected to each other by the beams. The presence of the balcony for the public is presumably made by a slab in full casting which is connected to the frames mentioned above by means of a beam that has been assumed to be similar to that which acts as a support for the tiles. The floor of the game rectangle is made with a brick-cement floor with a total thickness of 34 cm, of which structural was considered equal to 24 cm; this attic acts as a covering of the basement, which is used as a warehouse and technical room, which is supported by a central beam supported by 30x30 pillars whose foundations, however, are unknown because they are covered by the concrete slab of the technical room. The basement room is surrounded by a box made with reinforced concrete walls. of an unknown thickness as it cannot be detected, which however was hypothesized by 40 cm.

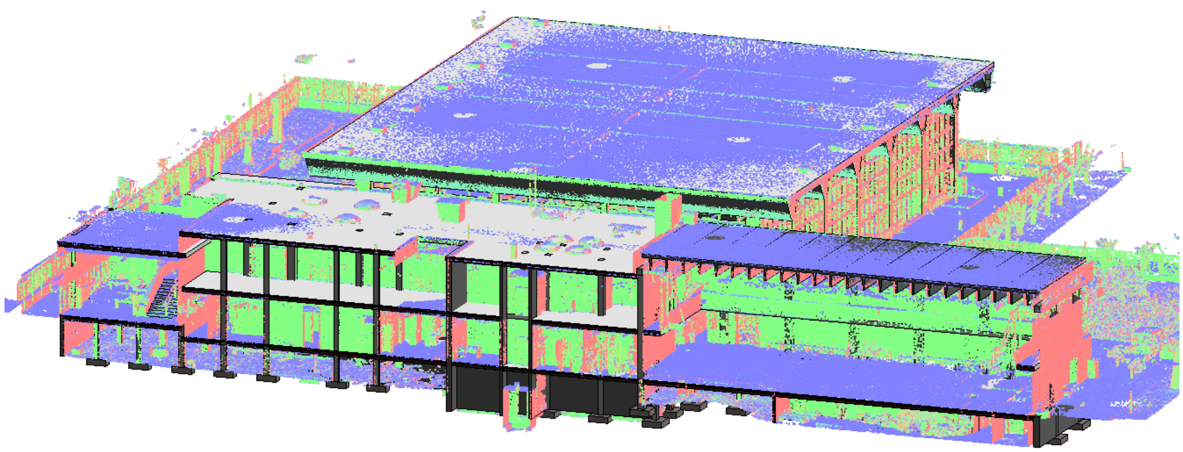

Figure 26: Point Cloud with BIM Model in Revit

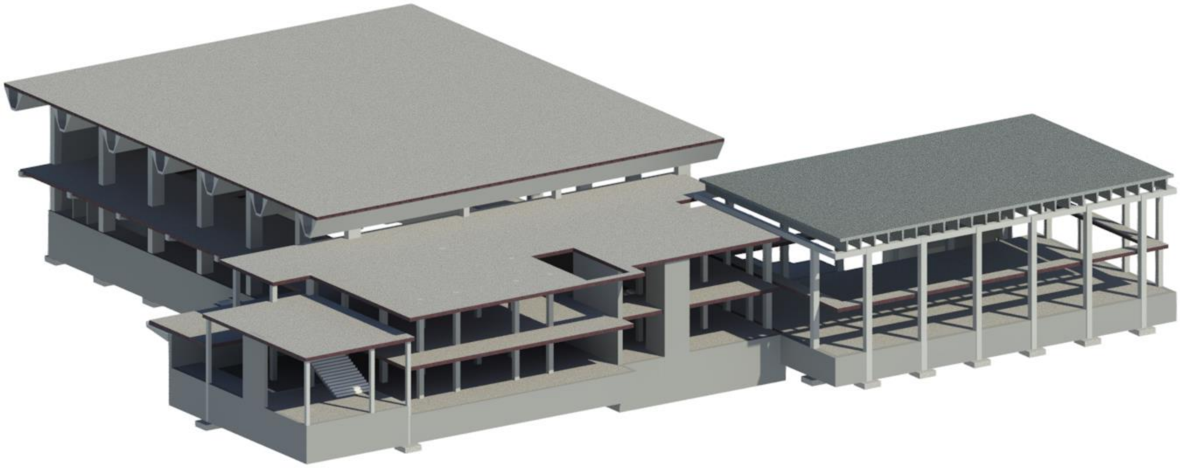

Figure 27: BIM Model of Parri Building

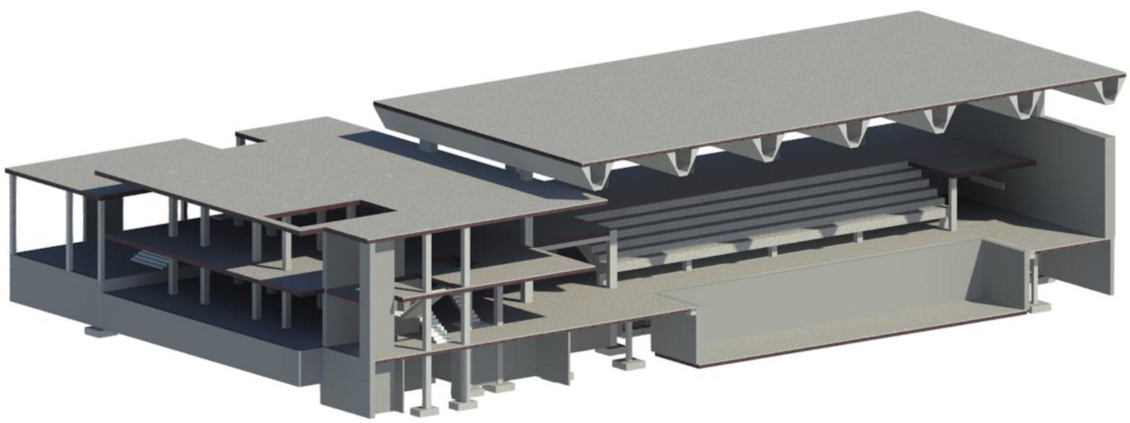

Figure 28: Section of BIM Model - Parri Building

4.5 Fully-Automated Recognition using Edgewise

The paramount wish on the software developer is doubtlessly for fully-automatic and flawless pattern recognition. The software should analyze the whole point cloud, locate all of the fittings, recognize their type and fit the position and parameters optimally onto the observed data. An appealing notion, but unfortunately rather unrealistic.

Such a fully-automated system requires the acceptance of the closed world assumption, that means that everything that is to be found in the point cloud, must also be able to be modelled in the BIM system, but, In large point clouds there are always interference objects such as furniture, paneling or house plants. These would be either incorrectly interpreted (they would not be able to be modelled in the BIM system) or they would hinder recognition of the object (e.g. a plant pot on the windowsill)

Real objects always have more characteristics than those that are relevant or capable of being modelled. For example, for the model of a window only the parameters width, height and sill to floor height should be recognized and modelled. A fully-automated system must, however, recognize all of the characteristics of the window, that is to say, the frame, sashes, glazing bars, ironmongery, etc. to be able to safely recognize the window.

Edgewise is an software developed by CLEAREDGE company, it can be automatically extracted grid structural members to Correct Specifications and fit precisely to the Point Cloud, also it can recognize pipe elements in MEP modelling ,and good interoperability with Revit, but disadvantage of this software is it can only import 10 scanner point, in the large point cloud file it need to be divide for several .rcs file in order to get less than 10 scan point . in the architectural and MEP modelling it has good accuracy, but for modelling existing structure like PARRI and CUPOLA Building, it has less accuracy because the model combined with other architectural and MEP elements, so the software less powerful for recognize structural element.

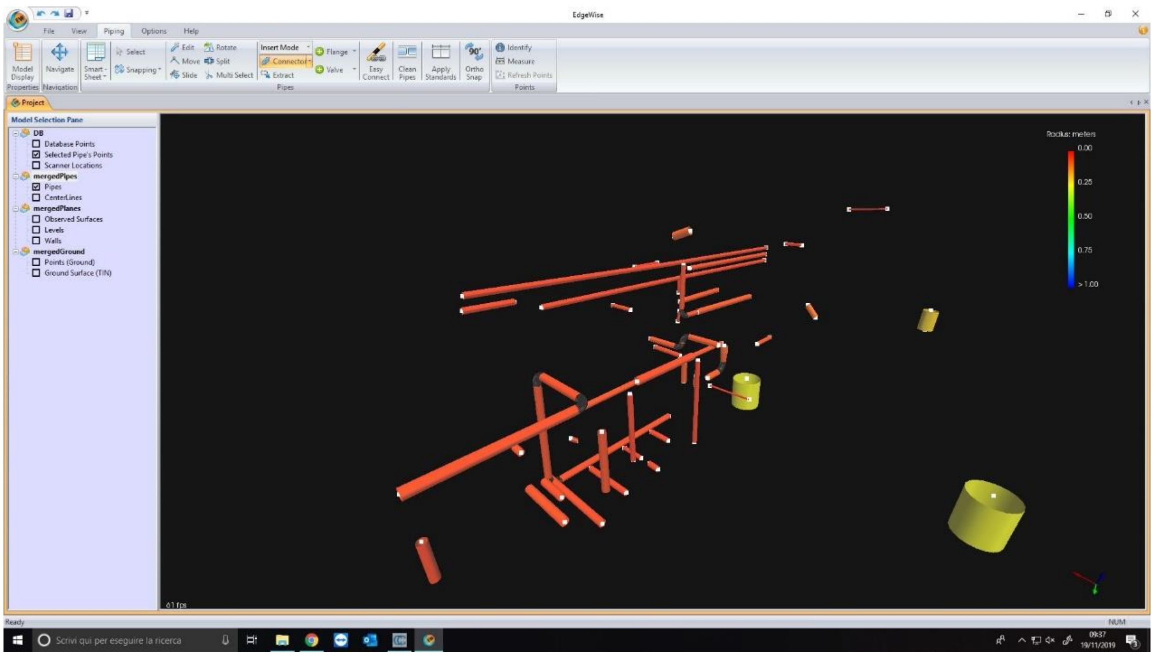

Figure 29: Edgewise Software Interface

5. From BIM Model to FEM

5.1 Interoperability

When a structural analysis is performed with FEM-software, some basic steps should be followed. FEM and exists of a pre-processing, processing and post-processing phase.

The pre-processing phase exists of modelling the geometry of the construction from scratch and making some important assumptions. The modelling is a time-consuming process that can be optimized thanks to the technology available today.

If a solid connection can be realized between the BIM- and FEM-model, the BIM-model can provide the geometrical structure and additional data (for example boundary conditions) for the FEM-model. This would save time during the pre-processing phase. In order to achieve this connection, interoperability is inevitable which means that program B should be able to handle the information provided by program A, even if the interface and the programming language are different.

This can be done by translating the model into a file format, readable by the other software-packages. However, retaining information from the original file is quite a challenge due to the available software-packages handling information in a different way. A large number of software companies provide BIM- and FEM-software. Their software packages come with modelling and construction-related software tools to make sure their programs are compatible. Most of the time, the link between the programs is satisfactory. Issues arise when a connection between the software from two different vendors has to be made. There was a need to create standards to ensure the interoperability, especially when 3D-parametric objects are downloaded from the internet or e-platforms are used. These standards were provided by the International Alliance of Interoperability, better known as Building SMART.

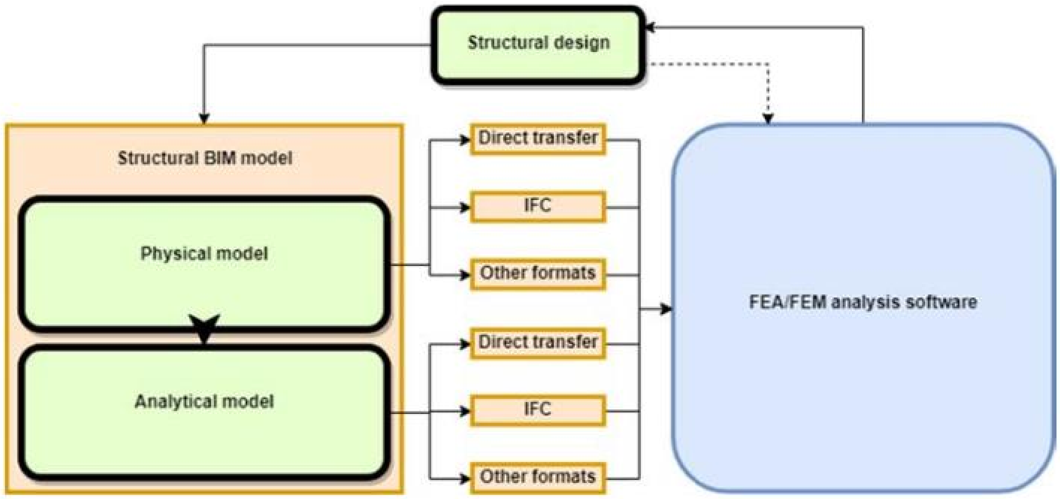

Figure 30: Interoperability Workflow

The IFC standards are their biggest accomplishment, they are also published by the International Organization for Standardization and ought to be followed by the entire AEC industry.

The greatest benefit of interoperability is that it speeds up the design process because information from one model can be reused. Another advantage of the interoperability between programs is that it improves the quality by:

• Automating the tasks, like the conversion of the model or the addition of new information so human mistakes are less likely to happen.

• Implementing the model correctly, the geometry is completely the same and mistakes due to different dimensions are avoided.

• Providing tools in the software such as partial models and special filters. These make it easier to navigate in the model and find certain information.

5.2 What Is the IFC?

The Industry Foundation Class (IFC) as an information exchange standard format, contains many architectural drawings and engineering data information of the process, and these information and project information management needs, the emerging development of AEC management software has a lot of related concepts, such as, the material, the life cycle cost, data model, the IFC data management is based on an information model, all of the information set is produced by the predefined categories, and these predefined criteria also play a role of the management, as well as the associated information according to the tired bai.

In BIM concept prevailing at present, many of the AEC began with CAD application software company development is given priority to with BIM software, such as Revit, ArchiCAD, Bentley, and so on, but there are many advantages of BIM after construction is not make full use of, in view of this, after construction attach BIM for operations management related concept, as well as the related software also begins to be concerned.

BIM software in the transformation model for the IFC formats have different geometrical description of the selection, although various BIM software by IFC standard certification, but using the IFC geometry description of differences, lead to import or export BIM software is the IFC model, for the differences of reading the IFC geometry, and BIM into geometric distortion or lost after the IFC, if the loss or distortion of the model is applied to operations management stage, will cause new problems to the reliability of data.

5.3 Direct Links

It was mentioned in the BIM handbook Using the Application Programming Interface of one system to extract data from that application and write the data using the receiving application API. Some may write a temporary fi le in the exchange between two independent applications, others may rely on real-time exchanges calling one application from the other.

Some applications provide proprietary interfaces, such as ArchiCAD, Tekla, Revit Open API, or Bentley's MDL. Direct links are implemented as programming level interfaces.

5.4 FEM

In the design process, the architect is responsible for designing the construction together with the project team. One of the members of this team is the structural engineer, his job is to make sure that the construction will not collapse when a certain load is applied. For example, the strength and the fire resistance of every building element can be calculated by using the methods described in the codes.

The calculations can be done by hand; however, this process would be too time-consuming, so computers are taking over most of the work, they are efficient and fast. Nevertheless, an engineer should not follow the results of the software blindly. By making some manual checks, serious mistakes can be avoided and more trust in the software will be gained. The goal of the software is to solve numerically physical equations, which is also called 'finite element analysis' (FEA) and can be achieved by using the finite element method (FEM). FEM exists since the introduction of the computer in the late 50's. Back in those days, the direct stiffness method was generalized and improved by M. Jonathan (Jon) Turner. He worked for Boeing, which means that the roots of FEM can be found in the aerospace industry.

Nowadays, several industries make use of FEM, such as the mechanical and AEC industry.

Thanks to FEM, a whole range of problems can be solved by using Ordinary Differential Equations (ODE) and Partial Differential Equation (PDE) in combination with the boundary conditions. The method splits a geometrical model with boundary condition into finite elements, in other words: a mesh is created, and performs a simulation on the model. Thanks to this simulation, the engineer can see where the weak/ critical points in the design are located and if adjustments should be made. It is possible to make simulations of stress, strain, heat transfer, etc.

5.5 Conversion of Geometry

The goal of FEM-software is to make a structural analysis based on an analysis model. The geometrical model of this analysis is different from the model in the design tools, especially from the architectural tools where the main goal is to create a physical model.

The physical model exists of 3D parametric objects and cannot contain any clashes. As said before, BIM-programs are made to avoid clashes in the model, they detect and provide the location of the clashes quickly and make it easy to eliminate them. All the 3D objects together will create a representation model that provides a visualization of the project and is used to create drawings in a later stage of the design process.

The analysis software does not need 3D objects but needs a continuous analytical model which is created by representations of the parametric objects in 1D and 2D. The software can visualize the model in 3D by generating a 3D extent of the representations, for example a beam will be represented by a single line. This will cause clashes in the representation model, for example the cross-sections may clash, but these are irrelevant for the analysis.

Before the conversion of the models between different tools was possible, the structural engineer translated the physical model into an analysis model and built the analysis model from scratch. Sometimes it was possible to speed up this process by importing a DWG-file, which is a manual conversion. To make a correct analysis model, the structural engineer has some specific knowledge at his disposal which is difficult to put into algorithms for the software.

For example, only the structural parts of the architectural model are necessary for the analysis model. This means that the boundaries of the elements in the different models will not match and will cause apparent incompatibility. When guidelines for the modelling activity are provided, it is possible to make an automatic conversion in some cases.

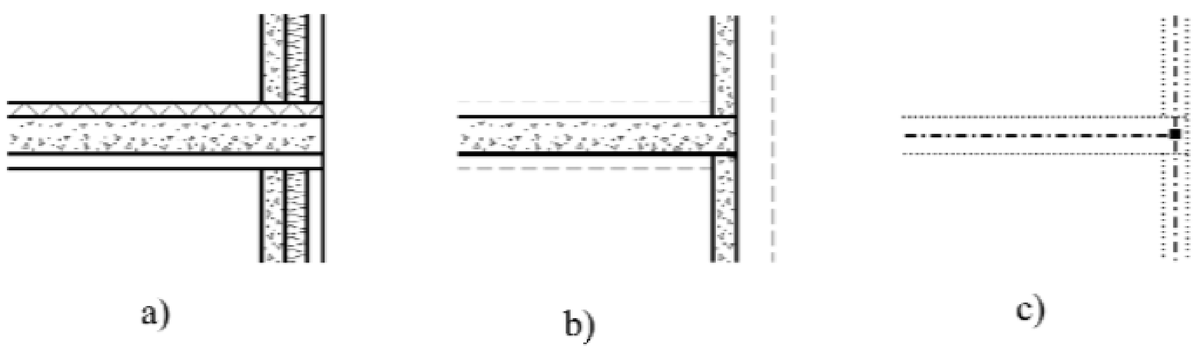

Figure 31: Conversion of Geometry

Ideally, there would exist a general method to convert every occurring 3D architectural situation into an analytical model. A general method is still not achieved, but some steps in the right direction are already made. For instance, to keep the conversion process simple, the modelling tools have limitations but by providing some special purpose connections, the most common situations can be handled. However, not every situation can be managed with this approach because it is too difficult and expensive to implement this while the wished results are not achieved.

Some programs contain a structural and an analytical model, for example Revit, which makes it easier to export information to FEM-software. The exchange will happen based on the analytical model. However, the main goal of the modelling software is to create a visual appealing model, which will be used for further purposes. Even an excellent architectural model does not ensure a good underlying analytical model.

The representation model gives the impression that the columns and beam are connected. However, this is not the case for the analytical model. The analytical model should be checked before the exchange, or tools to fix these issues should be provided by the software.

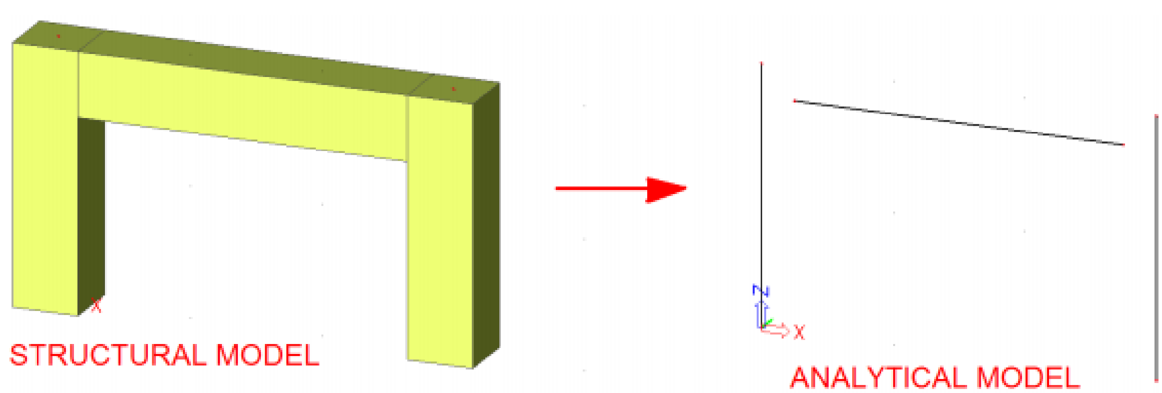

Figure 32: Analytical Model Problem in IFC

5.6 FEM Modelling of CUPOLA building

The roof of Cupola building created by nonlinear organic shell structure , FEM structural software like SAP2000,PROSAP cannot recognize spline and curve geometry , it can only recognize 2node line and rectangular 4 node shell element, because of this reason roof of Cupola building cannot directly import in to FEM software, so before exporting the Revit BIM model into FEM , it need to be meshing the dome in order to get 4node shell element .

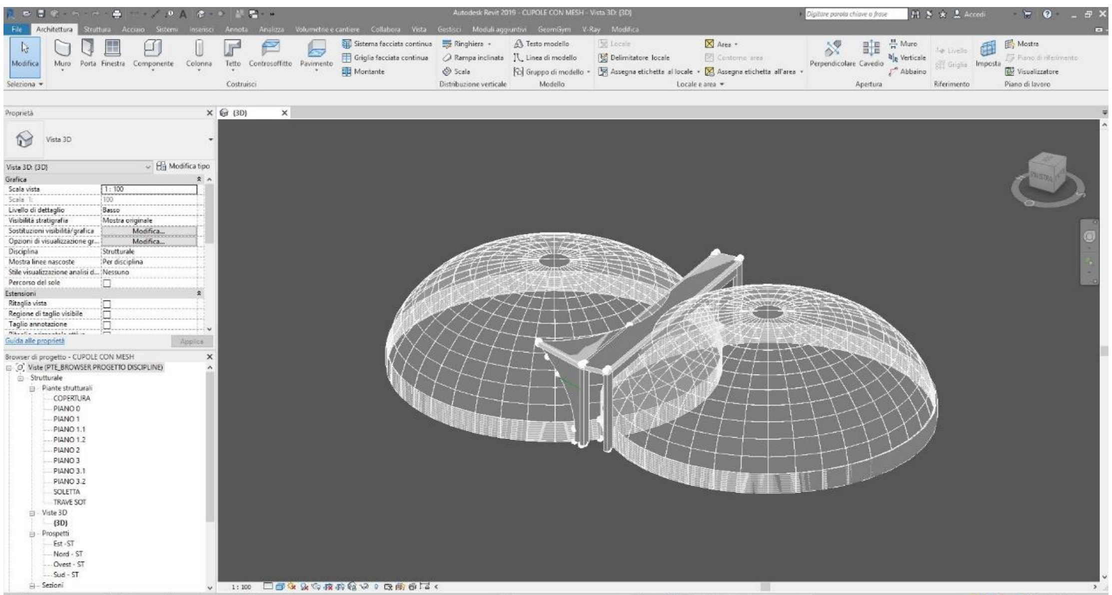

Figure 33: Meshing in Revit

And for beam column and floor element, Revit can automatically create structural analytical model .it can be easily export to FEM model using IFC. The FEM model created with shell elements for the domes, D2 elements (beam) for modeling beams and pillars and D3 elements (shell) for the slabs and walls. For the shells of the domes it assumed to be 40 cm thick.

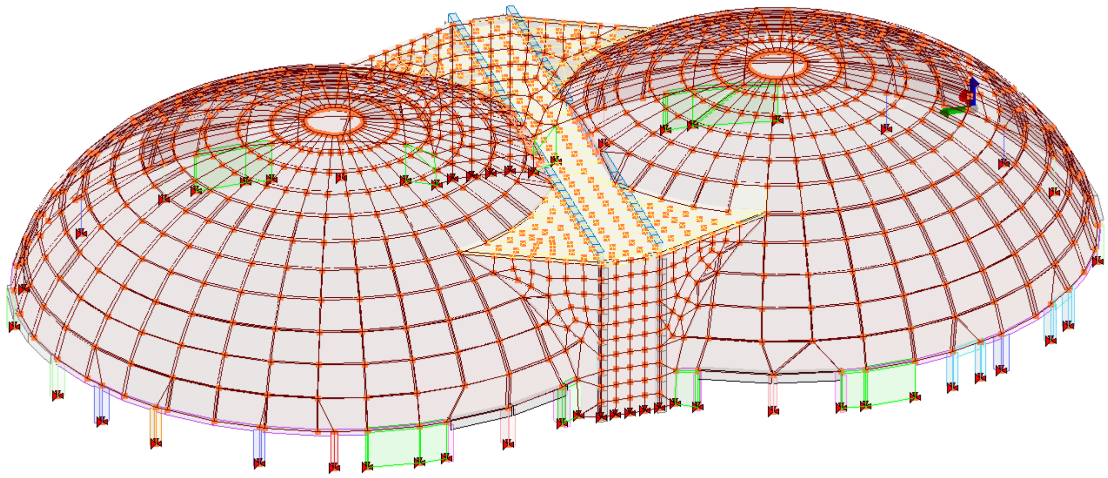

Figure 34: FEM Model

Given the knowledge available and in accordance with the provisions of the current NTC'18 standards, a simulated project was carried out to evaluate the safety of the building. Adopting a conservative approach, despite the excellent value of the strength of the concrete at the time of the sclerometer tests, it was considered appropriate to adopt a Rck value of 30 Mpa. In accordance with what is indicated in chapter 8 of the current legislation NTC'18, and Circular dated 02/2019 attached, for existing structures it is necessary to indicate the level of knowledge LC reached and the corresponding FC confidence factor. In this case, given the scarcity of information and adopting the simulated project method, the level of knowledge reached is LC1 and the corresponding FC value is 1.35: this is the value with which the calculation values of the resistances of the existing materials have been determined.

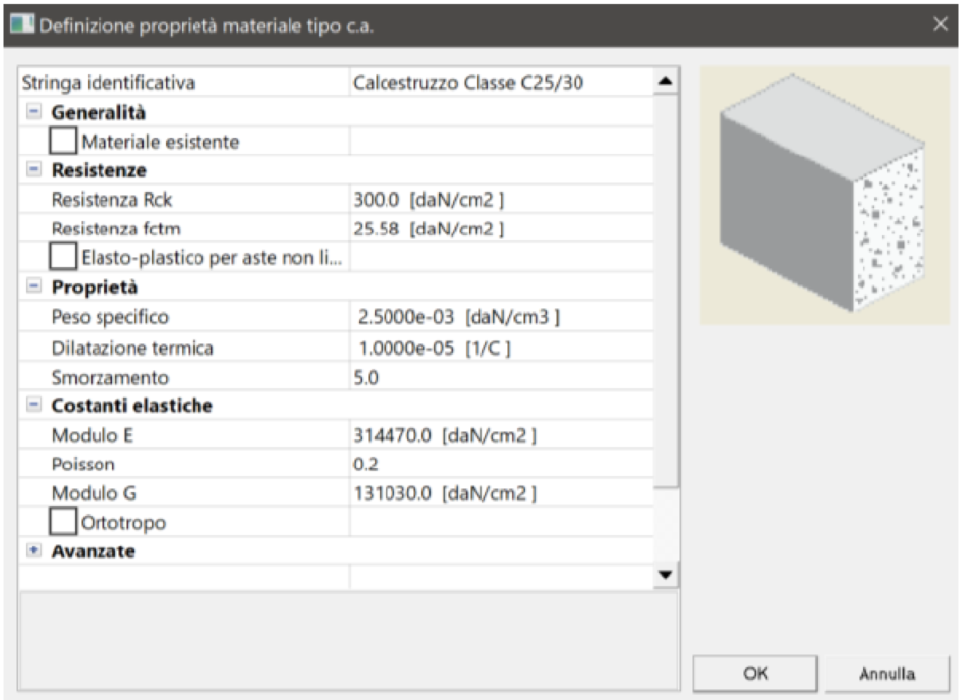

Figure 35: Material Parameter

Parameters adopted in the simulated project obviously refer to the allowable voltage method, the calculation criterion used at the time in the early 1970s. The parameters used are below:

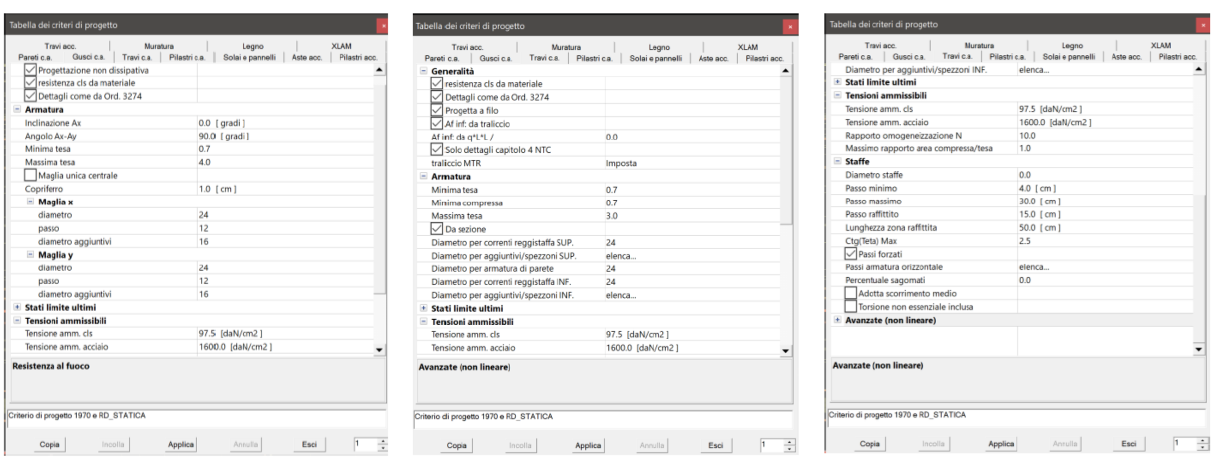

Figure 36: Structural Analysis Parameter

For shell structural elements:

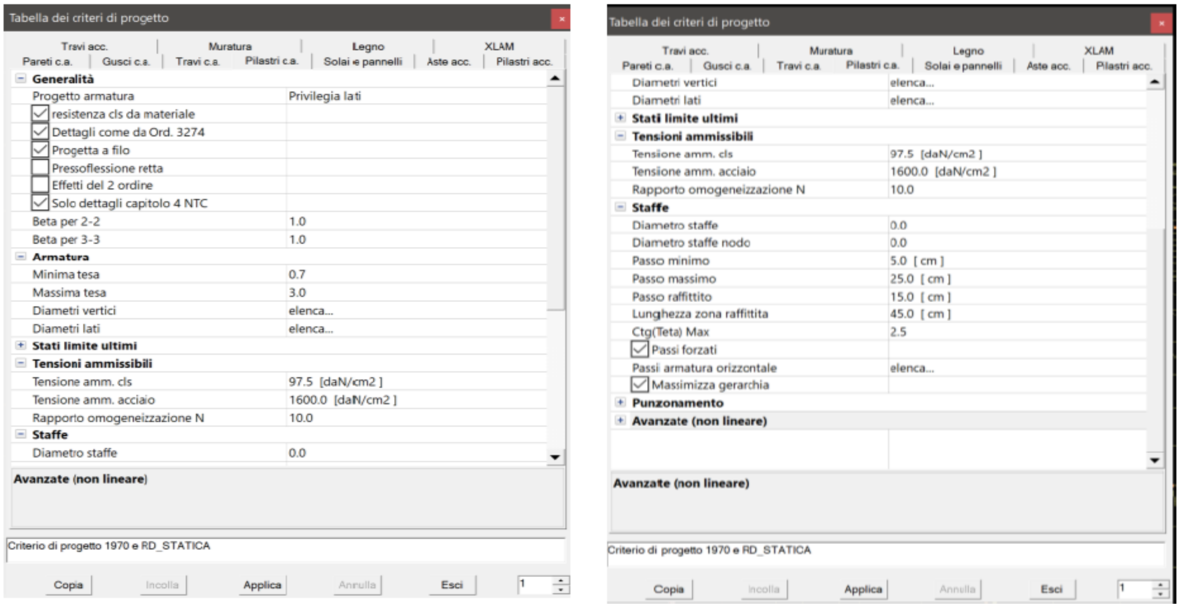

Figure 37: Structural Analysis Parameter

The objective of the simulated project is to obtain the hypothetical reinforcements that have been designed and used, so following this operation a model with identical geometry was prepared, but set with the regulations currently in force and in which they were imported the reinforcements previously determined in order to check the structure with the current loads.

A clarification must be made as previously stated, the beams that support the domes along their axis of symmetry are prefabricated and pre-compressed and there is no information about the manufacturing company, much less the number, size and position of the prestressing cables. One hypothesis that can actually be affirmed is the type of prestressing which in large-scale produced elements is of the "pretensioned cables" type. It should also be remembered that prestressing, within certain limits, brings numerous advantages including minor arrows and greater bearing capacities both in bending moment and in shear moment. During the modeling phase, the contribution of the prestressing was not taken into account, as already said, there is not enough data to calculate the effort, in favor of safety; however, the effect is that of obtaining a greater quantity of brackets inside the beam. As will be discussed later, the beams are those elements that will need to be kept under control through periodic visual inspections.

5.7 Structural Analysis of Cupola Building

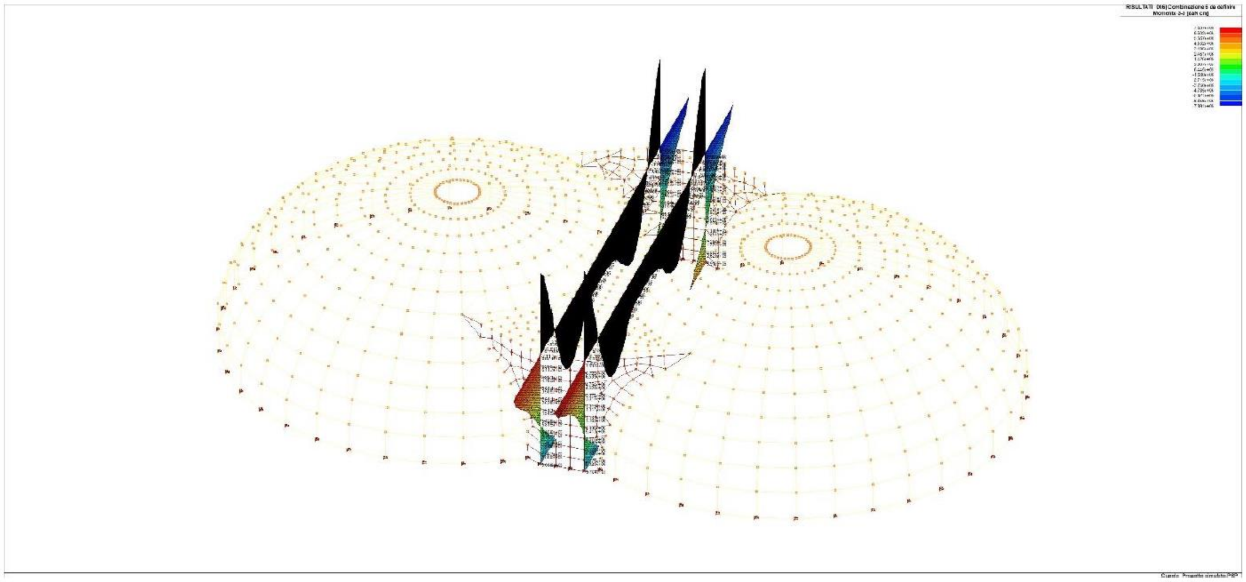

Figure 38: The Bending moment of Beam Element

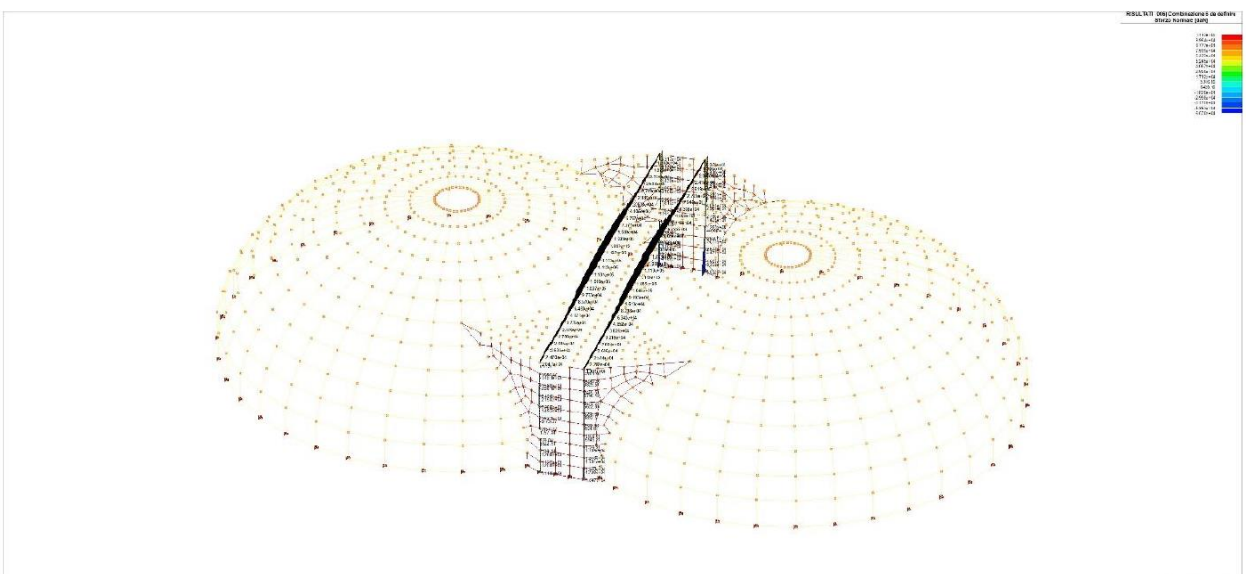

Figure 39: The Axial Force of Beam Element

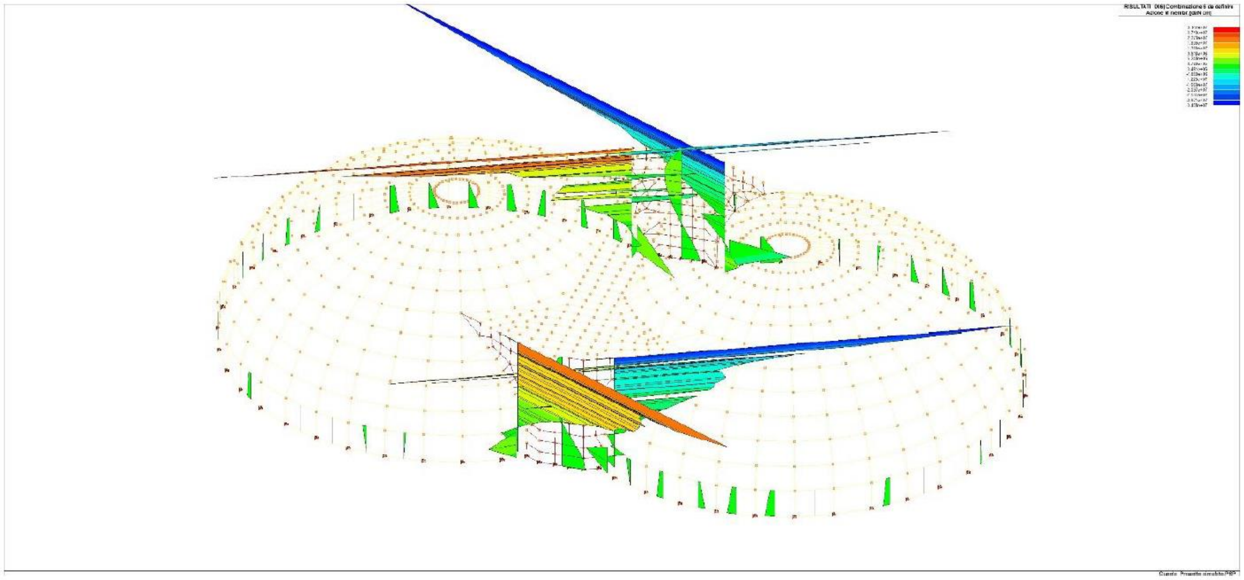

Figure 40: The Bending Moment of Shell Element

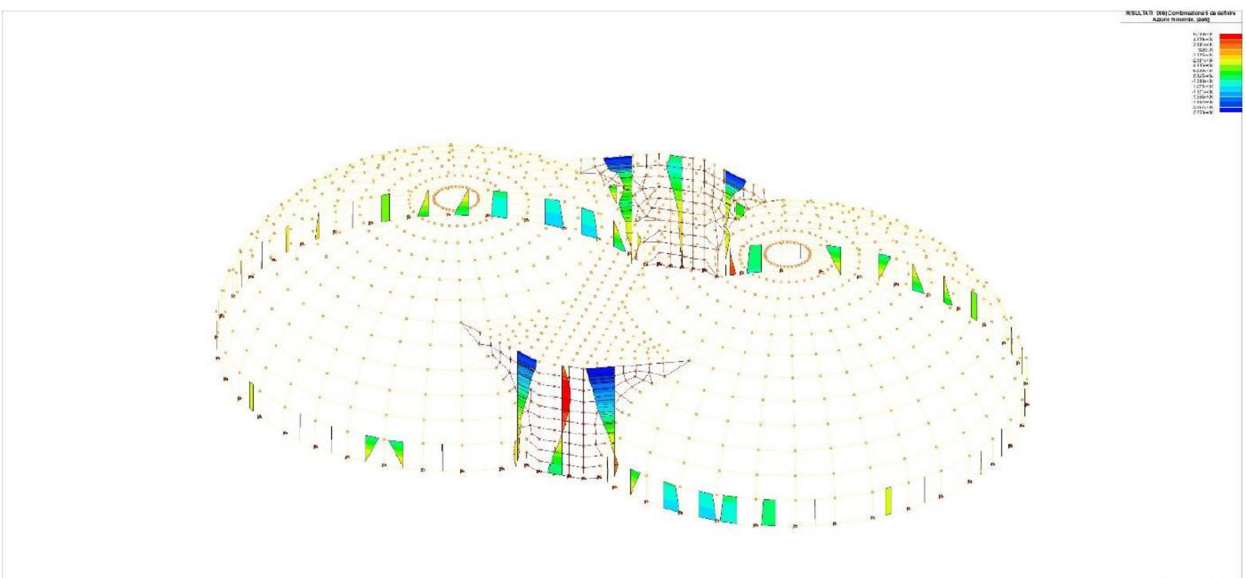

Figure 41: The Axial Force of Shell Element

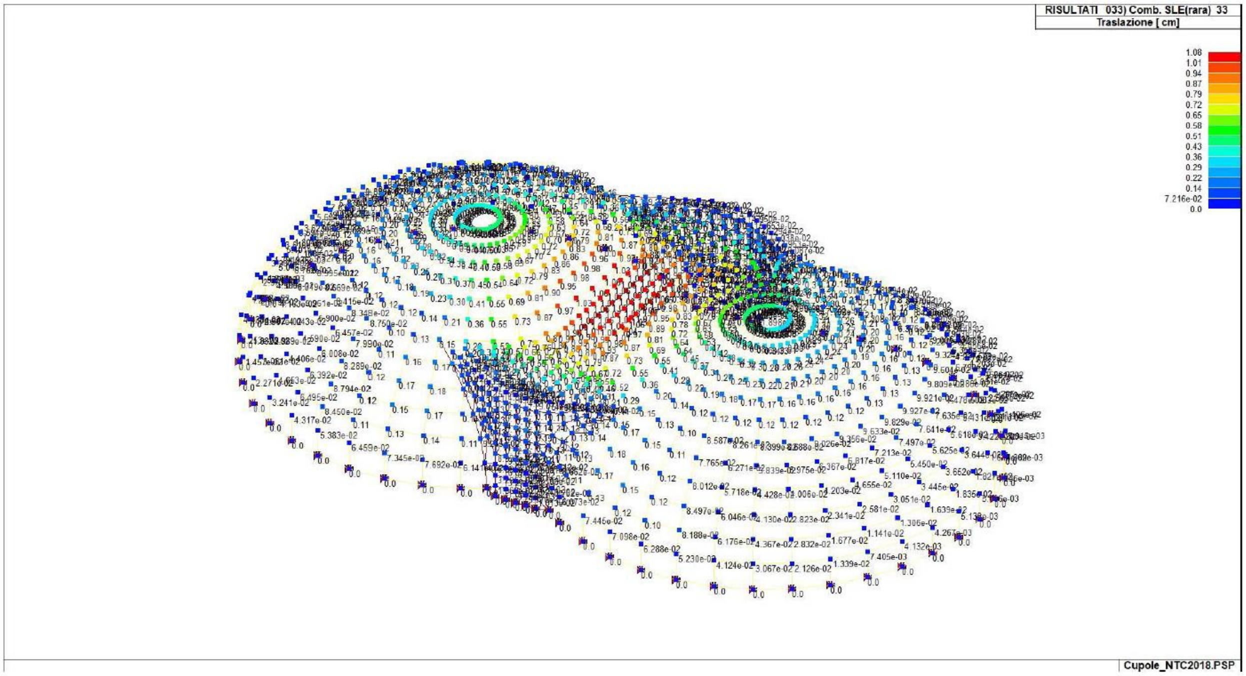

Figure 42: The Nodal Displacement of Dome

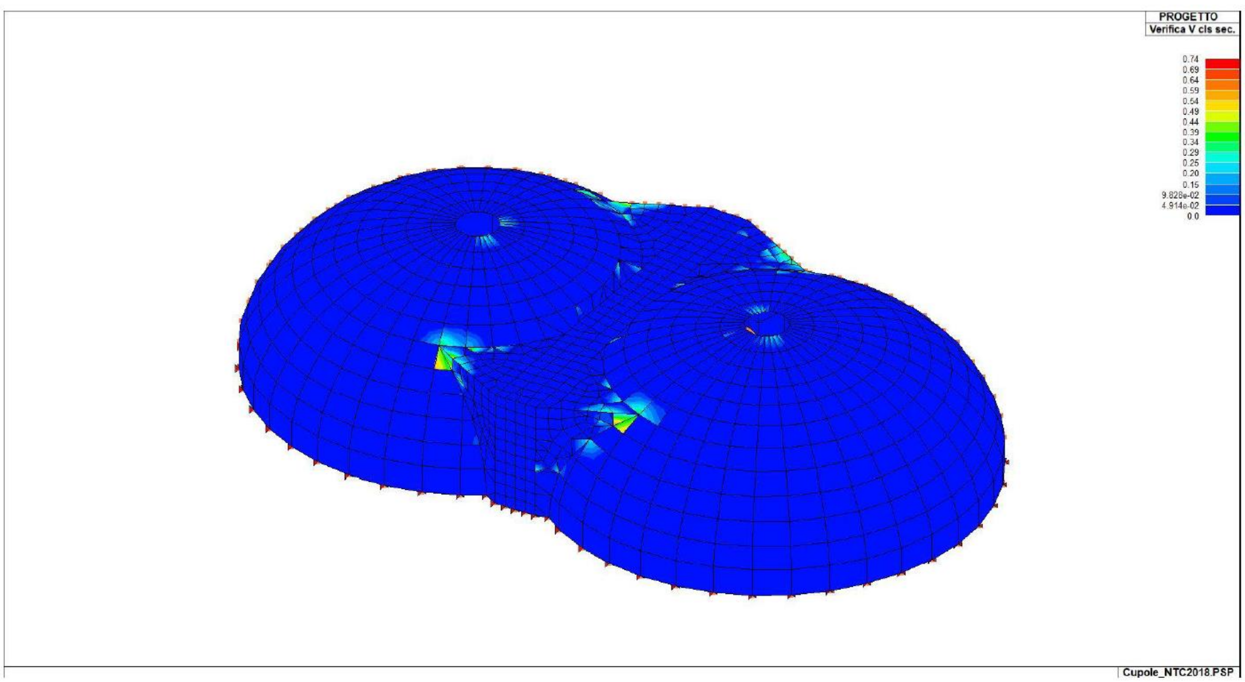

Figure 43: The Verification of Sheer Force of Dome

5.7.1 Structural Analysis of Internal Stand of Copula Building

The two mirror blocks of the stands are inside the structure. From a static structural point of view, the stand-stairs block of access is independent of the roofing system; in particular, the stands are made using reinforced concrete slabs 15 cm thick which unload on inclined beams called "ribs" of section 40x50 cm and on walls of section 25 cm always in reinforced concrete. with a curved pattern which also support the grandstand access staircase. Frontally, close to the playing fields, the stands are supported on a wall always in c. To. about 35 cm thick. Finally, the ribs are supported on pillars which have variable dimensions with typical sections of 40x55 cm, 40x40 cm and 30x50 cm. On the back of the grandstand there is a space reserved for the systems and accessible through a trap door in the corridor, made with a slab full of about 15 cm left unfinished.

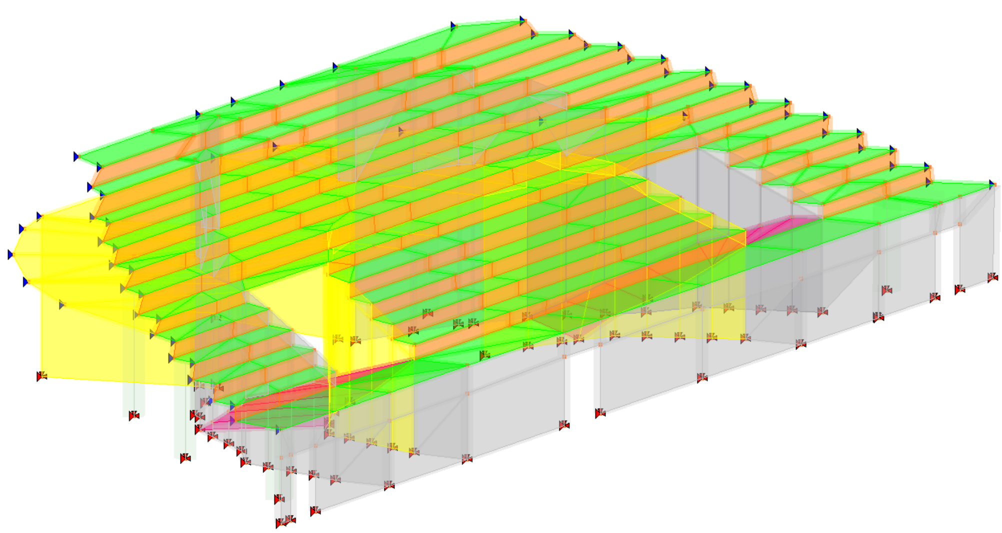

Figure 44: FEM Model of Internal Stands

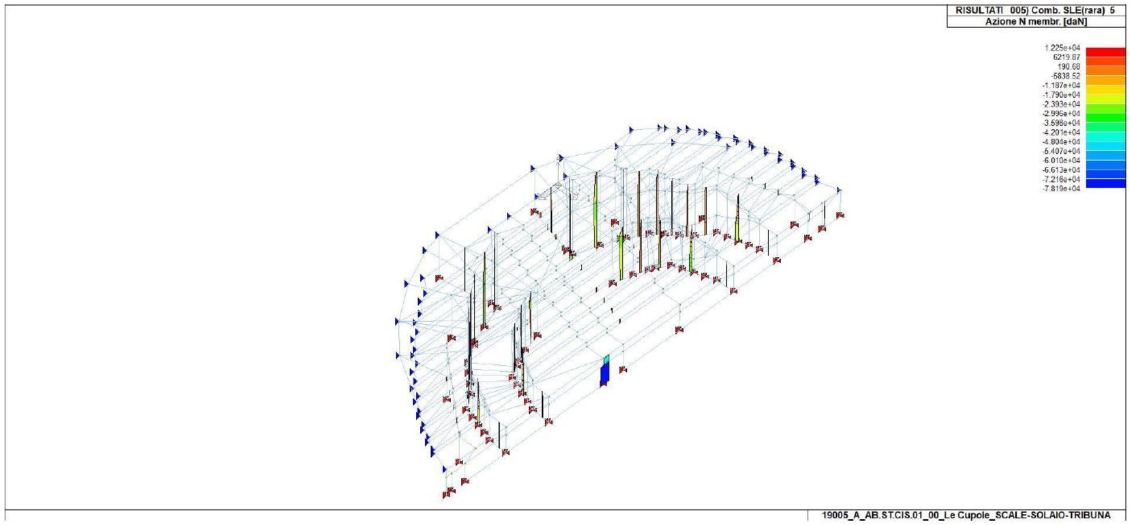

Figure 45: The Axial Force of Internal Stands

5.8 FEM Modelling of Parri Building

From the BIM model it was therefore possible to export the model in IFC format and import it into the FEM software to create the calculation model with which the structural analyzes and verifications were carried out. thanks for PROSAP provide “HELP BIM” command, using this command the conversion of geometry problem can be solved during the interoperability.

Given the knowledge available and in accordance with the provisions of the current NTC'18 standards, a simulated project was carried out to evaluate the safety of the building. By adopting a conservative approach, it was considered appropriate to adopt a value for concrete of Rck equal to 30 Mpa. In accordance with what is indicated in chapter 8 of the current legislation NTC'18, and Circular dated 02/2019 attached, for existing structures it is necessary to indicate the level of knowledge LC reached and the corresponding FC confidence factor. In this case, given the scarcity of information and adopting the simulated project method, the level of knowledge reached is LC1 and the corresponding FC value is 1.35: this is the value with which the calculation values of the resistances of the existing materials have been determined.

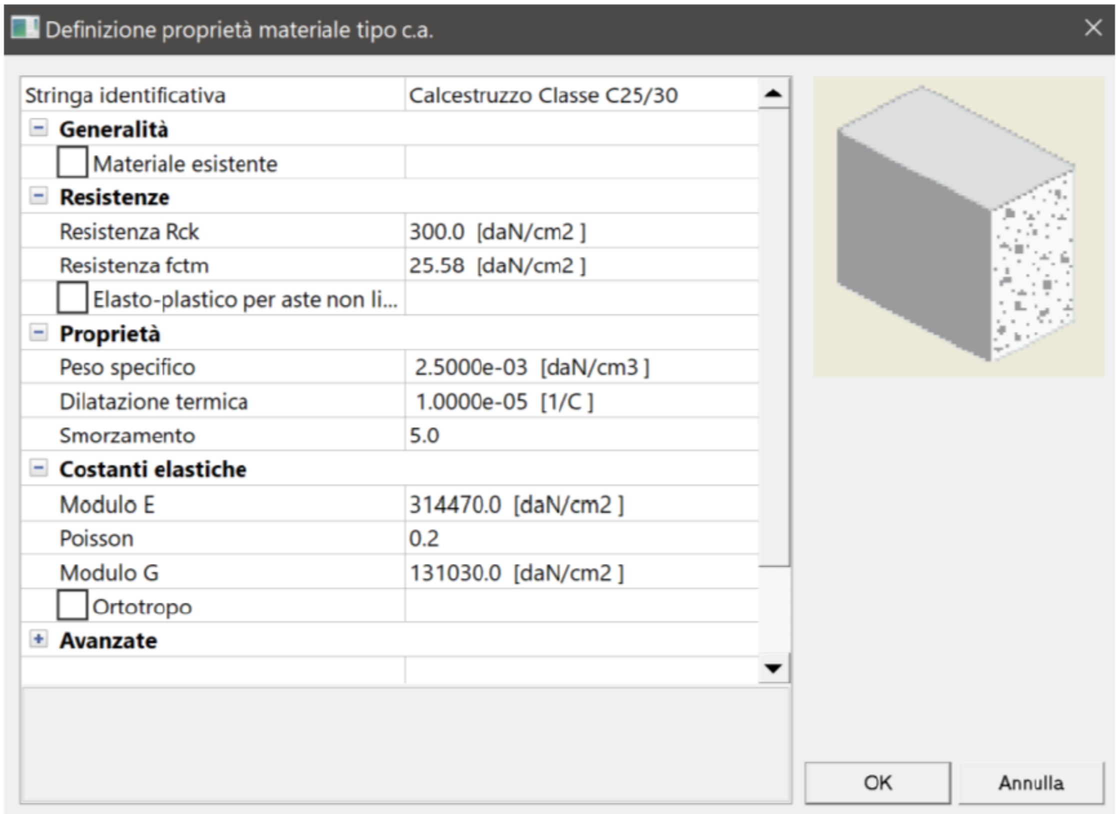

Figure 46: Material Parameter

The calculation model was created with elements D2 (beam) to model beams and pillars and elements D3 (shell) for the slabs and walls. The parameters adopted in the simulated project obviously refer to the allowable voltage method, the calculation criterion used at the time in the early 1970s.

The aim of the simulated project is to obtain the hypothetical reinforcements that have been designed and used, so following this operation a model with identical geometry was prepared, but set with the regulations currently in force and in which they were imported the reinforcements previously determined to be able to check the structure with the current loads.

A clarification must be made as previously stated, the pre-compressed V-beams of the swimming pool and the bent roofs of the gym do not have any information about the manufacturer, much less the number, size and position of the prestressing cables are known. One hypothesis that can actually be affirmed is the type of prestressing which in large-scale produced elements is of the "pretensioned cables" type. It should also be remembered that prestressing, within certain limits, brings numerous advantages including minor arrows and greater bearing capacities both in bending moment and in shear moment. During the modeling phase, the contribution of the prestressing was not taken into account, as as already said, there is not enough data to calculate the effort, in favor of safety; however, the effect is that of obtaining a greater quantity of longitudinal bars and brackets inside the beam. As will be discussed later, the beams are those elements that will need to be kept under control through periodic visual inspections.

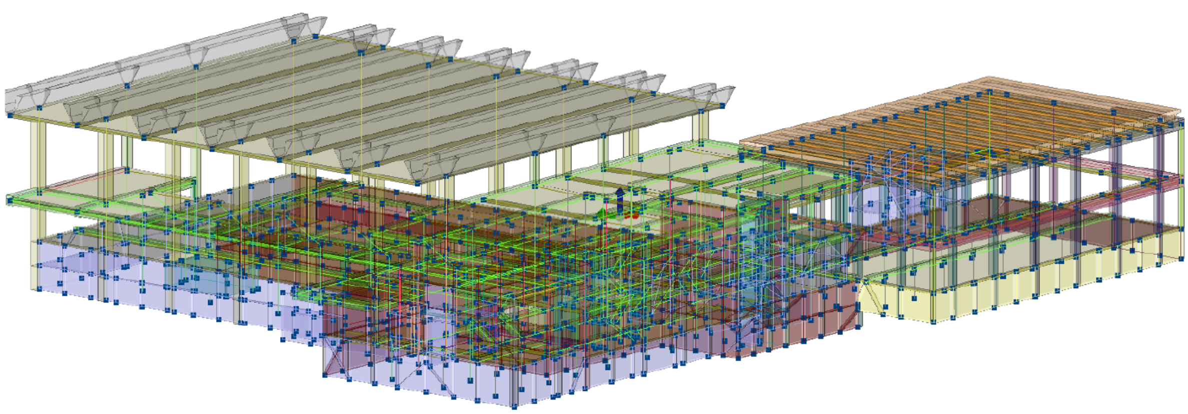

Figure 47: FEM Model

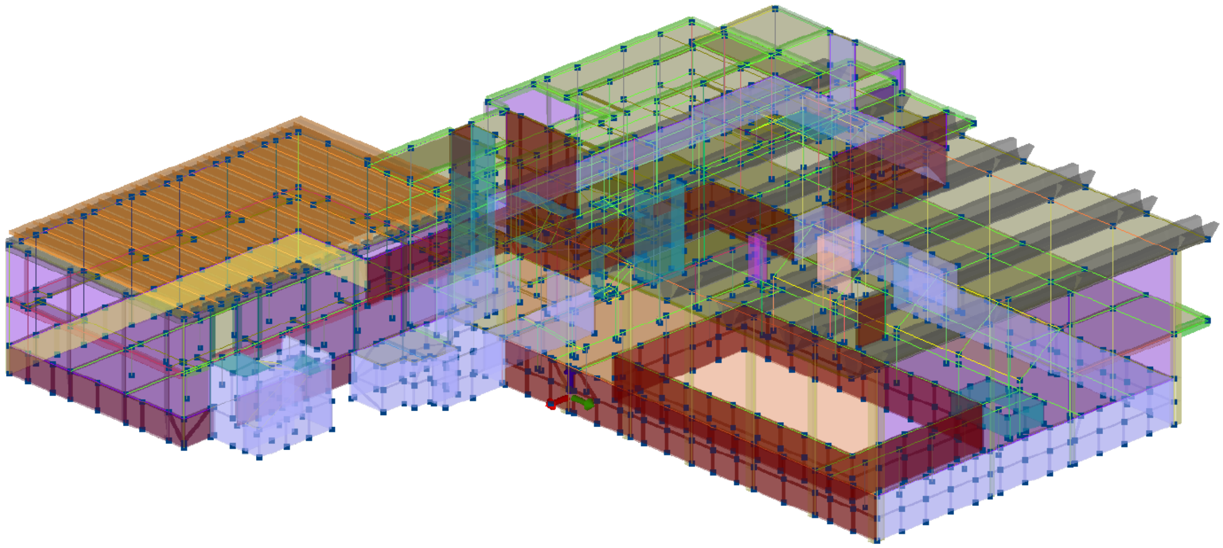

Figure 48: FEM Model

5.9 Structural Analysis of Parri Building

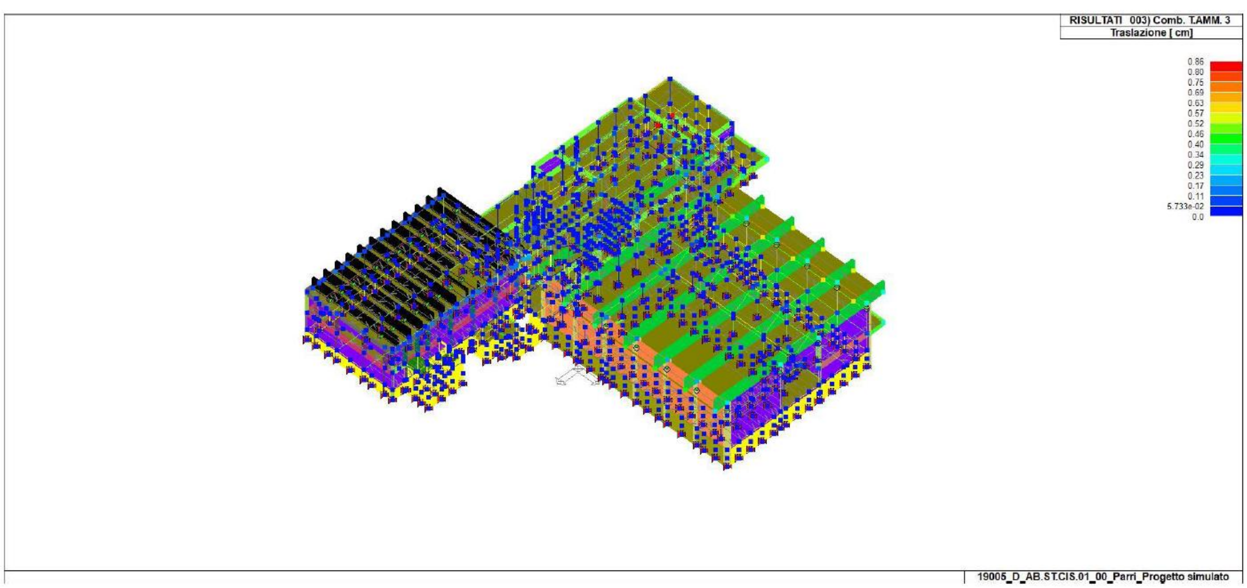

Figure 49: The Nodal Displacement

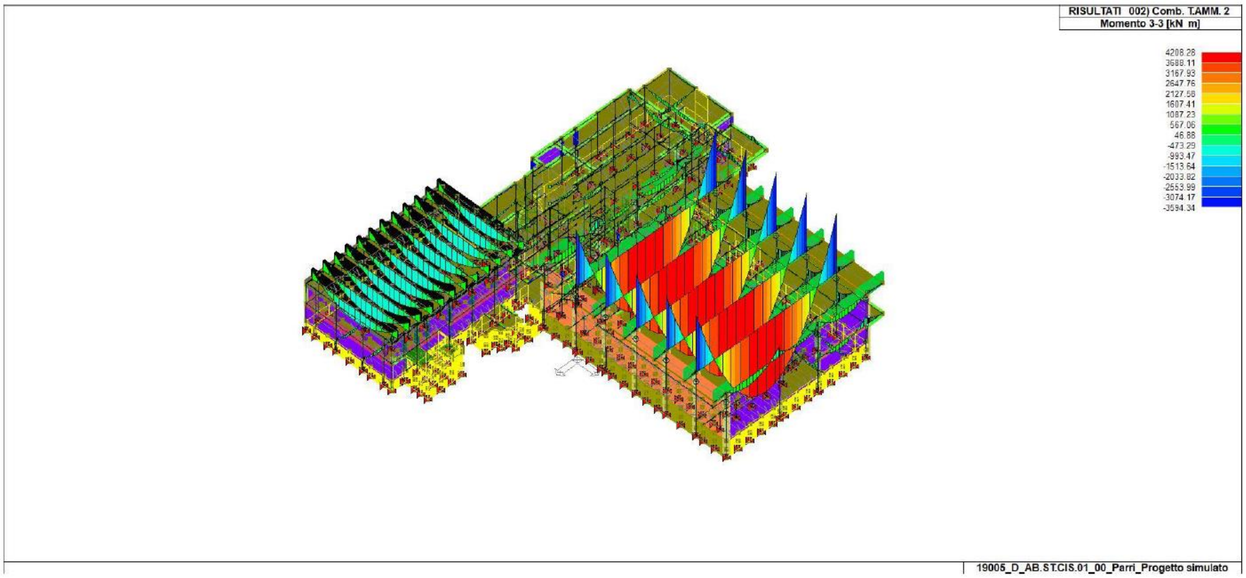

Figure 50: The Bending Moment in the D2 Beam Element

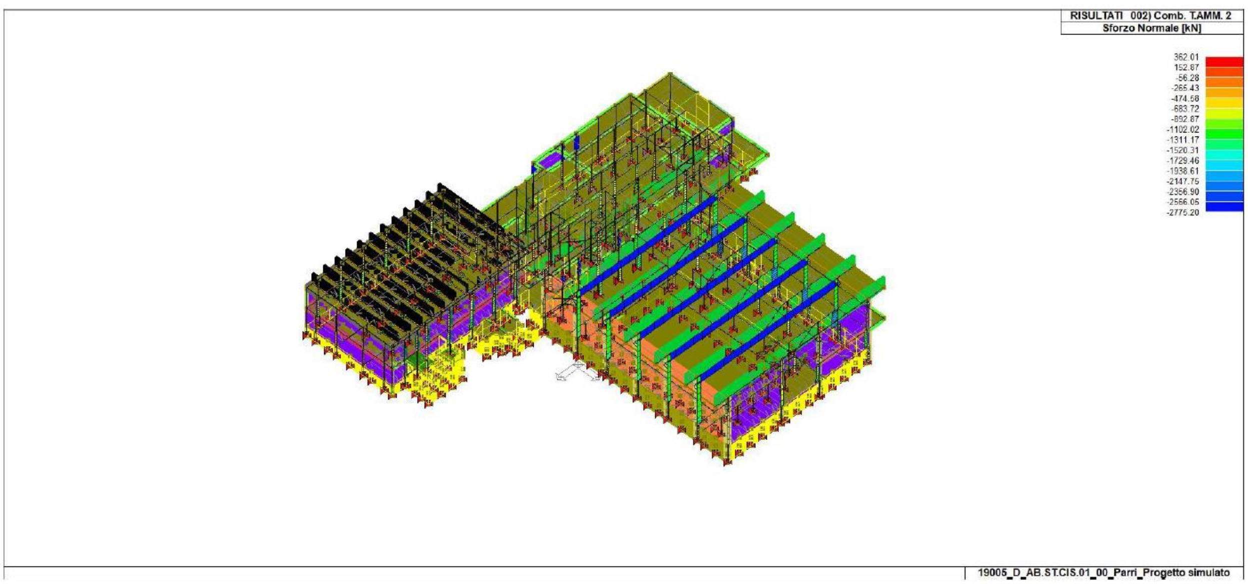

Figure 51: The Axial Force in the Beam Element

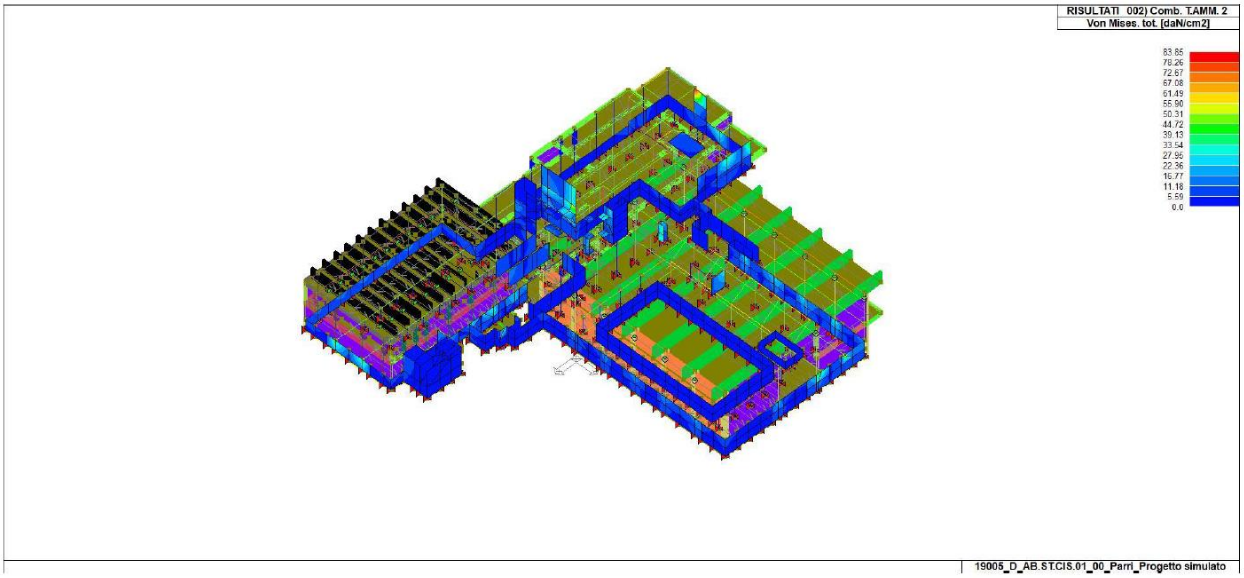

Figure 52: VON MISES Stress Analysis in D3 Wall Element

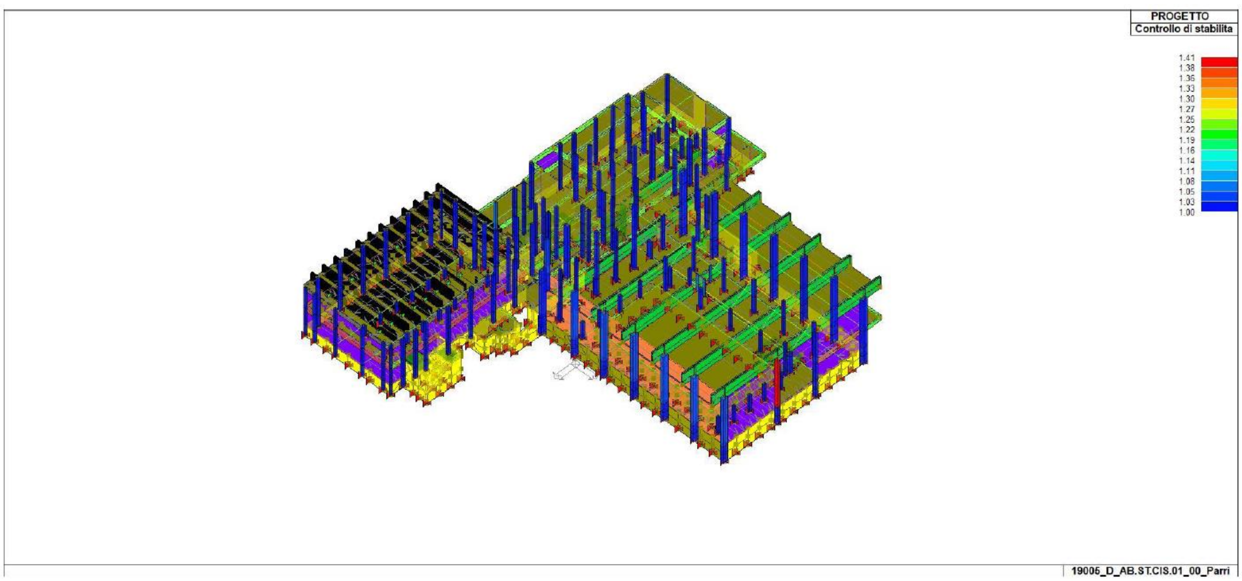

Figure 53: Verification of Stability in Column D2

6.From BIM to VAR &Visualization

6.1 Virtual Reality for Point Cloud

What's Virtual Reality

A good starting definition for the "Virtual Reality" (VR) meaning could be the one that emphasize the interaction of participants and no more in terms of class of visualization, but in terms of class of immersion, putting in opposition the "view"
People in the 50's were trying to find this kind of immersion that could be greater than the usual cinema or theatre experience. It all started in 1963 with Hugo Gernsback and his "teleyesglasses" (the first prototype of the modern headsets with separate screens for each eye, it could display stereoscopic), with the development of realistic video-games and it continued with the great products of cinematographic industries wanting the world to get familiar with the potentialities of the droid and virtual-made worlds: Robo Cop (1987), Tron (1982), Videodrone (1983), Terminator 3 (2003) were great VR candidates to give through the scenes an immersion as realistic as possible.
Indeed, the component of the realism of the scene isn't really capable of let the customer think that the space might be abstract, because of the change of direction in the perspective visualisation that characterizes the natural mechanism of the sight that moves according to the head's movements in real time like the latest Headsets mounted display (HMD): from the low-cost ones such as Google Cardboard and OpenDive to the expensive ones with Oculus Rift, Oculus Go (arriving in 2018 with no Pcs or wires, Samsung Gear VR, Google Daydream view VR, Playstation VR (aka Morpheus project in HTC Vive and Microsoft Hololens for mixed reality.
Furthermore, the real time movements revolution hasn't restricted its action limit to the single recreation of the head sight, but it has spread out with devices that

recreates the movements of the whole body which are projected into the virtual world and are capable of enhancing our self-awareness of the interactive experience. Indeed, we can find handy-controllers, joysticks, wands or sensors-equipped gloves designed to stimulate the perception of different stimuli such as Control VR, bracelets etc. Thanks to the creative wave of all these sensors based on the perception of pseudo-real stimuli, the future appearance of ”sensorial jackets” capable, for example, of inducing perceptions of temperature to the explorers (the cold, the hot and so on) according to the real time environment weather conditions of the VR experience, it wouldn’t even be a ”wow factor” anymore.

Heritage, Architecture and VR

This is a new type of experience in comparison with those of galleries, museum and visiting tours: virtual reality has allowed to create immersive *walkthroughs* around architecture buildings during the planning phase, around virtual heritage sites no more accessible, or archaeological sites at risk, historical buildings, monuments destroyed by hazards, sculptures and so on. This field is strictly linked also to the scientific visualization of cultural heritage in general which, thanks to the accuracy of scientific methods and technologies of survey and 3D modelling, have brought to create a new frontier of heritage protection.

Construction and VR

The collaboration between construction industry and virtual reality seems to be, as the heritage field, extremely promising and useful in the future. In the current present already, the virtual environment, instead of a 3D render, provide many benefits not only in the envisioning part but also in the experimental part of the designed spaces: the testing phase of factors without any cost, without waste of time in order to reduce the number of error in the complete construction.

Engineering and VR

In the same mode of operation wave of constructions, here it comes the engineering field which covers other fields of knowledge such as the design cycle, rail and car design etc. Virtual reality shows itself as an efficient partner in time, money and quality saving process, in terms of safety conditions for workers and in terms of maintenance.

Figure 54: First Person Virtual Walk-Through [1]

In recent times, various popular technologies have continuously detonated the market, and VR (Virtual Reality) has become popular. After reading various cool VR applications, have you ever thought about the combination of point cloud and VR? Most VR applications are focused on launching visual perception impacts on users, which makes people emulate them. Behind the user's perfect experience is actually the hard work of the scene creator. VR virtualizes the three-dimensional space of our lives, which is also the main reason for its ubiquity, because it can be related to everyone! In this case, for different application requirements, the production of VR scenes also needs to be flexible and diverse. One of them is to use point clouds to directly generate virtual scenes!

Some people call three-dimensional laser scanning a real-world replication technology, which is also a very appropriate term. Through this technology, the spatial location and corresponding color information contained in the real-world information are quickly and accurately obtained, and it shows us Has created a virtual but real space, which is exactly what VR applications need. When it comes to using point cloud as a VR scenario, the first reaction of many friends may be: how to transfer such a large amount of data, how to display information, will the effect be good, what are the benefits of directly using point cloud, etc.

The Benefits of Point Cloud in VR

Timeliness-No need to spend a lot of manpower and time to create a virtual VR scene, the spatial data collection is completed, a little processing can be put into use, Strong authenticity-with real space coordinate information, you can measure any position; the information collected on the real site can be described as the perfect Copy of the real space, Spatiotemporal meaning-Spatial information changes with time, and point clouds can store accurate information about the same spatial location in different periods.

Any point cloud bearing platform (such as Veesus Arena4D Data Studio) that can be used in conjunction with VR equipment can realize the VR presentation of point cloud information! As shown in the figure below, users can wear VR equipment while experiencing point cloud VR, control it through the gamepad, and stroll in the virtual environment. Of course, if you want to add other elements to the environment, almost any type is fine.

How to Transfer Large Amounts of Data

The amount of point cloud in a scene can easily reach tens, hundreds of GB, or a few TB. This amount of information must be a problem in the transmission link. If it cannot be solved, the combination of point cloud and VR will be limited by localized applications. If you want to share a large amount of point cloud data remotely and quickly, of course it can have to take the usual path. By using AREANA VPC 4D CREATER, the data of RECAP PRO or PTS format can be converted to the VPC file format, because the VEESUS platform can only read the vpc file format.

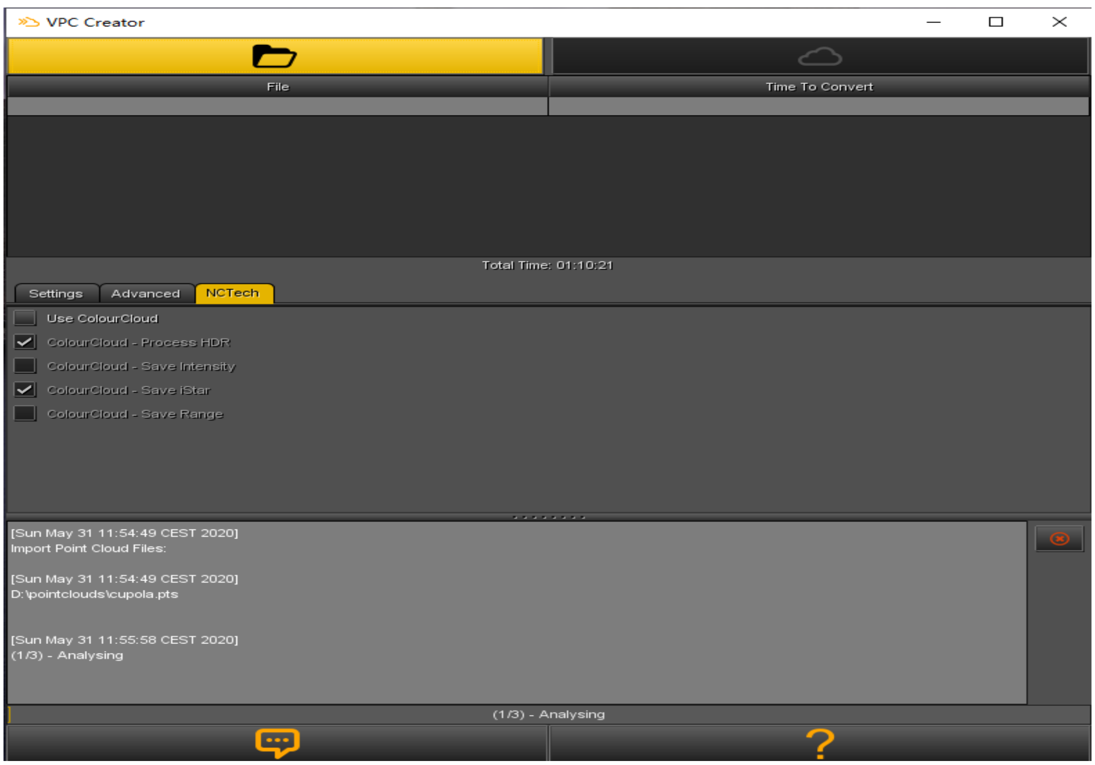

Figure 55**:** Transfer Point Cloud Aata Using VPC Creator

The Arena 4D Virtual Reality module is a tool enabling you to take visualization of point cloud data and any other data to the next level. A combination of headset and game controller slows you to virtually move freely and without limits around the point cloud. The integration of Oculus Rift, HTC Vive and Powerwall / Cave

Projector shows that viewing point clouds in VR is important for industries of the future. Compatibility with Virtual Reality devices:

- Oculus Rift
- HTC Vive
- Powerwall / Cave Projector

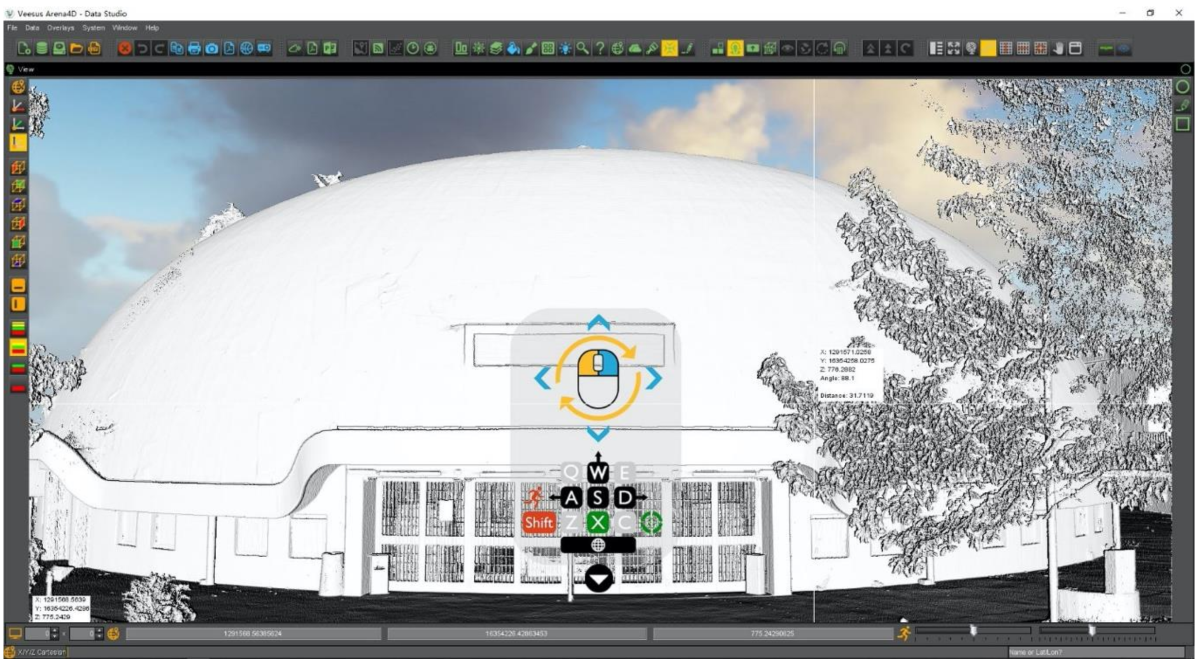

Figure 56: Point Cloud VR

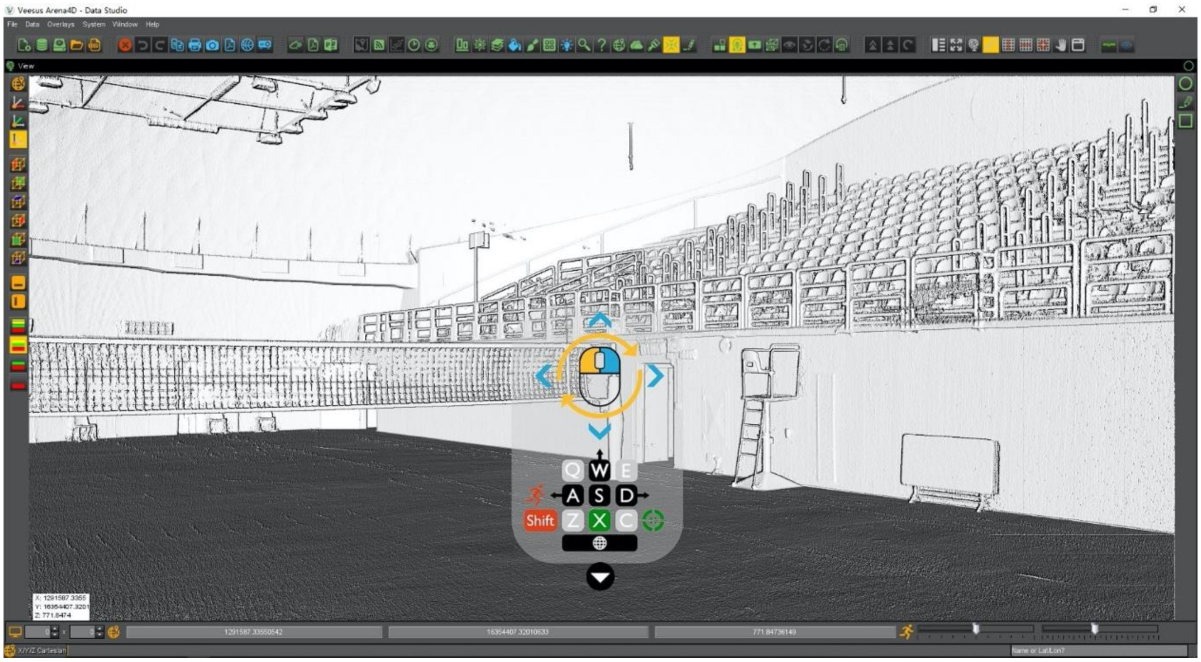

Figure 57: Point Cloud VR

6.2 Virtual Reality for BIM Model and Real Time Rendering

Twinmotion is a real-time 3D immersion software that produces high-quality images, panoramas and standard or 360° VR videos in seconds. Developed for architecture, construction, urban planning and landscaping professionals. Twinmotion combines an intuitive icon-driven interface with the power of Unreal Engine by Epic Games. regardless of the size and complexity of the project, the materials, the user's IT knowledge or their preferred BIM modeler. Direct synchronization with AUTODESK Revit allows users to move from the BIM model to a VR experience.

By using DIRECT LINK or IFC, one-click synchronization of models and BIM information from ARCHICAD, Revit, SketchUp, Rhino. After synchronization, changes in the design software will be synchronized to Twinmotion in real time and see the results.

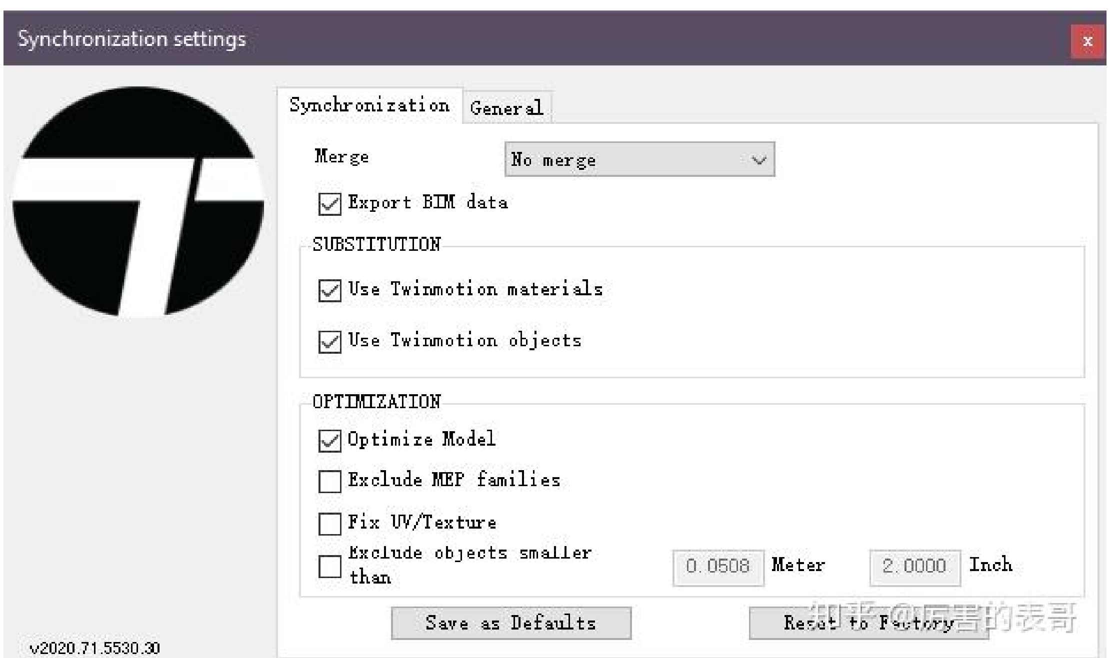

Figure 58: Twinmotion Interoperability Panel

However, Twinmotion software really greatly reduces the technical threshold and improves the interoperability efficiency between the BIM software. Its real-time rendering technology can do more, it successfully solves the problems encountered by architects and Engineers when using CAD / Revit: how to display real photo images and technical information on the same platform at the same time, let all Participants and principals can fully understand and review a design. It is a platform that can show all design content to everyone, including non-technical personnel. When the design and other technical information are imported into the software, customers can view, explore, collaborate on design and review the design and all its technical information on a single interactive platform.

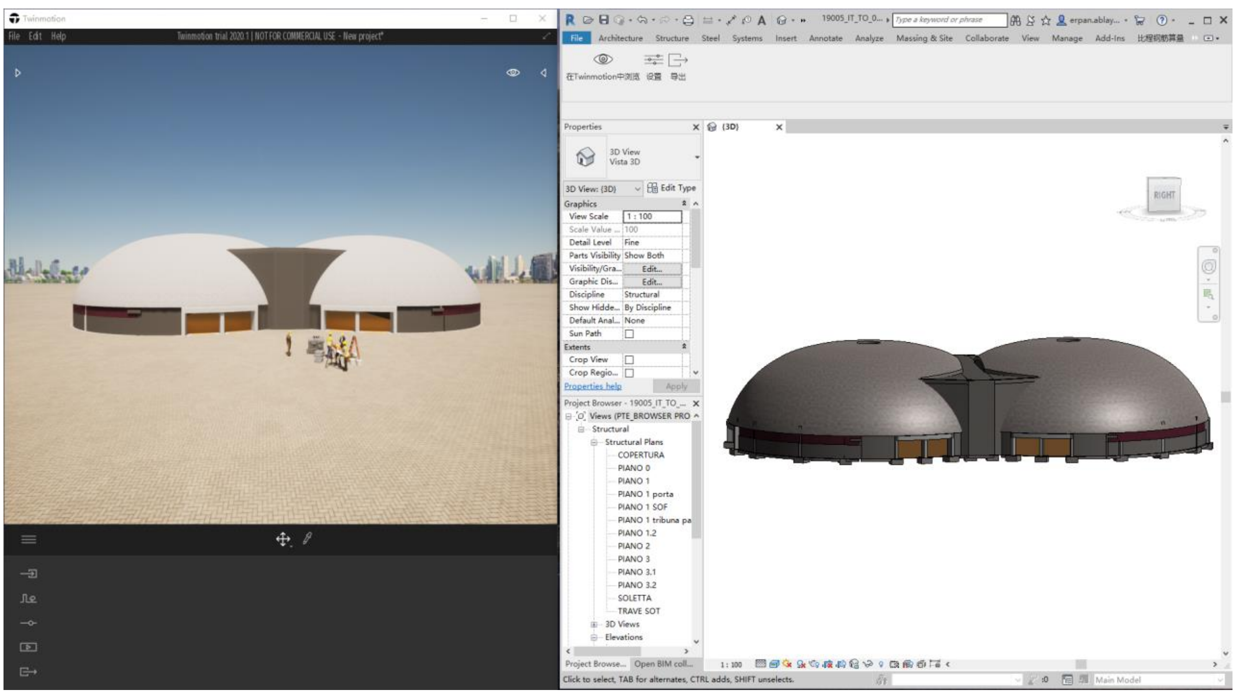

Figure 59**:** Real Time Rendering with Revit and Twinmotion

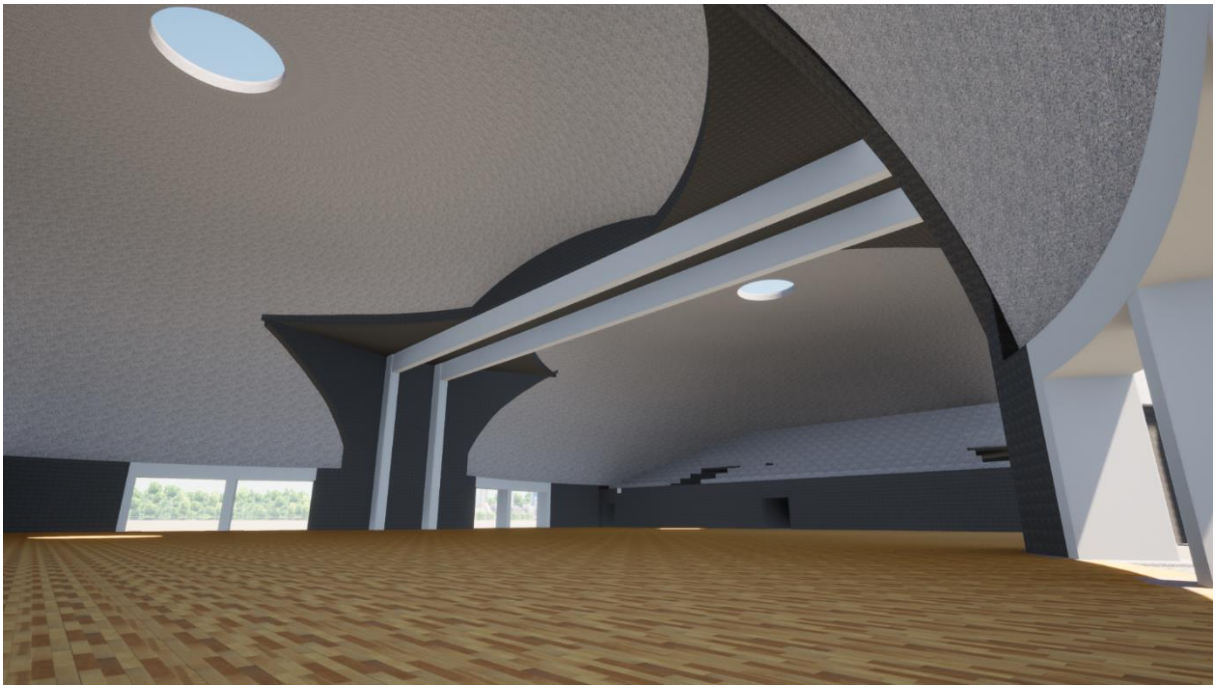

Figure 60: Cupola Building VR in Twinmotion

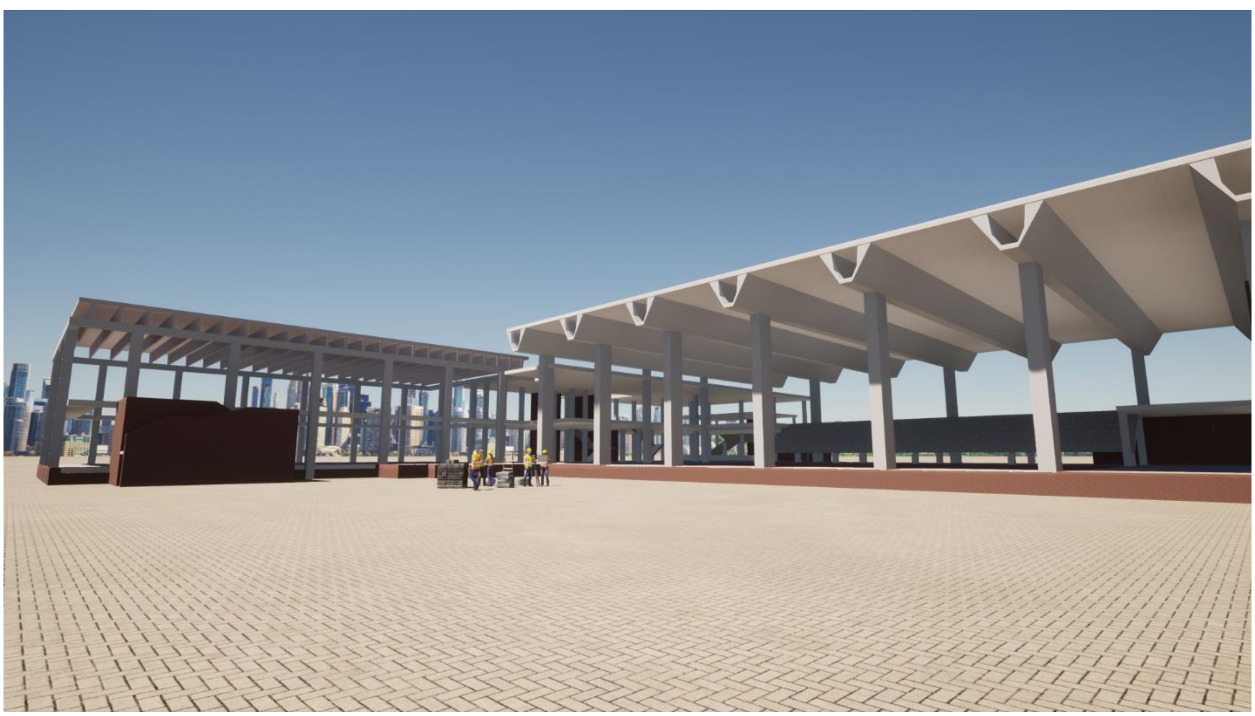

Figure 61: Parri Building VR in Twinmotion

Figure 62: Parri Building VR in Twinmotion

Figure 63: Parri building VR in Twinmotion

6.3 AR for BIM Model

Augmented Reality (AR) as a technique where users are allowed to see the real world, with virtual objects superimposed upon or composited with the real world. To achieve this effect, AR either use semi-transparent displays, or devices with a front-mounted display in combination with a back-mounted camera. Augmented Reality has come a long way since the first prototypes in the 1960s, and the use in new application areas have been accelerated the latest years with access to smaller and more powerful devices. This section covers the history of AR, a brief explanation of what the term Mobile Augmented Reality (MAR) include, the techniques AR use to track the user, and how AR can position information as overlays and ensure it is placed correctly relative to the surroundings.

Application advantages of combining BIM and AR in construction guidance Through AR technology, BIM models and information can be seamlessly integrated into the real environment, real-time interaction between BIM and field personnel can be achieved, and it can guide the completion of construction tasks. The advantages of the combination of BIM and AR are very obvious. First, BIM can provide the virtual models and information required for AR to be used in construction guidance; second, AR technology can use BIM models for construction guidance. In short, AR technology can improve the application value of BIM in construction guidance. Eventually, it is possible to develop a digital toolkit for field personnel based on this technology.

Construction guidance application scheme based on BIM and AR to achieve construction guidance application based on BIM and AR, first of all, you need to create an AR virtual scene model based on the BIM model, including 2D text information, 3D model, 4D construction simulation, etc. Then use AR technology to integrate it with the real environment of the construction site and guide the workers to complete the corresponding construction tasks in real time. These models have their special application value in different occasions. There is no better performance. Matching the corresponding models according to the actual application requirements can achieve better application results, sometimes Used in combination.

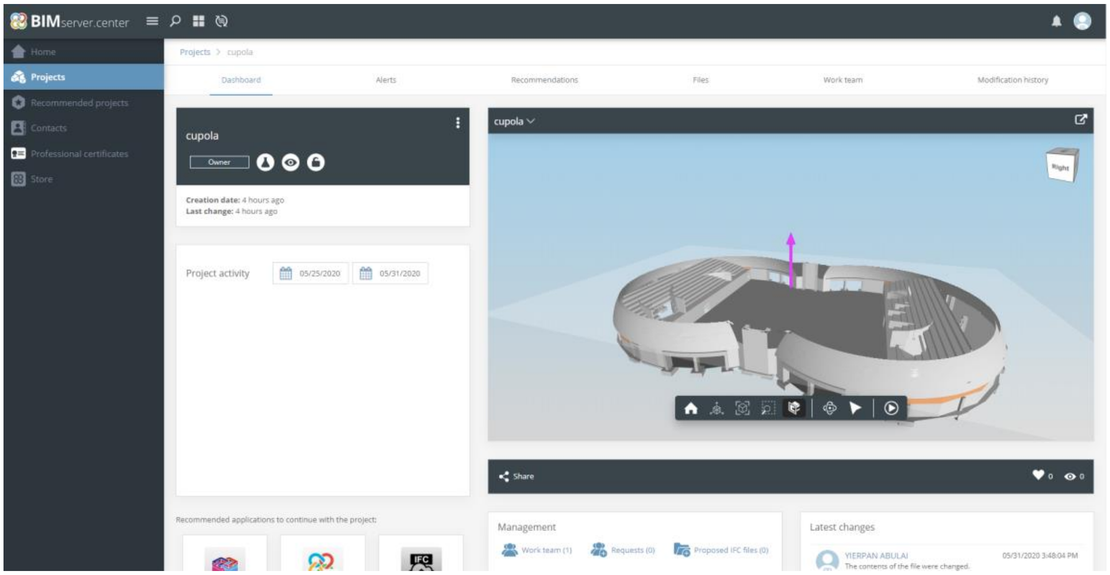

Figure 64: BIMSERVER.CENTER Interface

The application of AR in BIM can be achieved through BIMSERVER.CENTER.it is a free open-BIM platform. The IFC files exported through REVIT can be managed and viewed in the cloud of BIMSERVER.CENTER platform also the BIM model can be viewed through mobile platform.

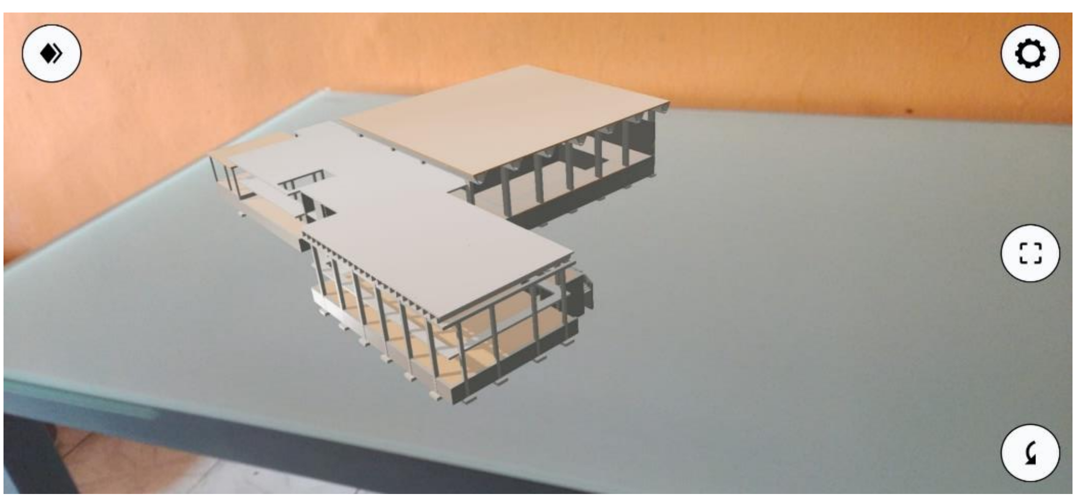

Figure 65: AR of Parri Building Using Smartphone

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