Saimaa University of Applied Sciences
Faculty of Technology, Lappeenranta
Double Degree Program in Construction and Civil Engineering

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Modeling and extraction of technical characteristics of BIM model in program Tekla

Bachelor’s Thesis 2012

ABSTRACT
Daria Shuravina
Modeling and extraction of technical characteristics of BIM model in program Tekla, 28 pages
Saimaa University of Applied Sciences, Lappeenranta
Faculty of Technology
Double Degree program in Civil and Construction Engineering
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In this thesis for Oy Juva Engineering Ltd, a quantity survey was made using a building information model. The purpose of the survey was to estimate the price of the construction. The survey was performed on a building model that was created with program Tekla Structures.

Tekla Structures is 3D building information modeling (BIM) software used in the building and construction industries for steel and concrete detailing. The software enables users to create and manage 3D structural models in concrete or steel, and guides them through the process from concept to fabrication

In the first part of the thesis the main functions and features of the program Tekla Structures were considered. The analysis was made on the base of the model of the football stadium in version 16.1 of program Tekla. This football stadium was made with the help of architectural drawing, which was made in Larkas and Laine OY. In the second part all main structures of the building are considered. They include beams, slabs, columns, walls and others. Every part has its own features, which are also described. Eventually the material bill of quantities was made and the price of materials, according to the Russian rates, was given.

The bill of quantities can help us to determine approximate price of the construction for preliminary stage when we don’t need accurate result and when we need to prove the possibility of such buildings as mechanic stadium.

Keywords: Bill of quantities, quantity survey, Tekla modeling, BIM model

Content

1 INTRODUCTION

There are a lot of tasks in engineering field. When you begin making a project you must to take into account type of soils, climate region, earthquake factor and others. But the two most important tasks when you make the project are designing and implementation.

Designing is a component of engineering process and nowadays it is connected with computers very much. There are a lot of different programs for creating 3D models and 2D drawings. The thesis work will consider program Tekla Structures. Tekla Structures is 3D building information modeling (BIM) software used in the building and construction industries for steel and concrete detailing. The process of making of model in Tekla is very simple. When you make a model, you give all necessary characteristics to structures. For example, you can name the type of the concrete, give the appropriate size to the beam, choose between the cast and pre-cast element. After that you have a BIM model from which you can find out how much materials you need, what is the area of formwork and others.

The original purpose of the thesis is to show the way of making a model in program Tekla Structure to material report, which allow us to define the material and project cost.

The thesis work was made on the base of the modeling of a football stadium. This is the new innovative project. The stadium has a moving football field and two arenas. The stadium was calculated on different loads and all main structures (such as beams, slabs, columns and others) were made in program Tekla. The result was a report where all structures were classified. And as we know the prices of materials, we can estimate the price of the whole stadium. This estimation is shown in the second part of the thesis work.

2 TEKLA REVIEW

The basic functions of Tekla Structures are similar to other BIM applications for structural design: instead of drawing 2D structural plans and sections engineers can use Tekla Structures to create a complete digital model that simulates a real-world structure and combines both the physical model as well as the analytical model. It can then be used for the different types of structural analyses engineers need to perform to design their structures, as well as to derive the construction documentation needed to build the structure. Thus, the scope of Tekla Structures is the entire structural design process from conceptual design to construction. This makes it a particularly compelling choice for structural engineering firms who want to extend their range of services to include detailing. Tekla Structures has been used on several projects around the world, the example of which is illustrated in figure 1.

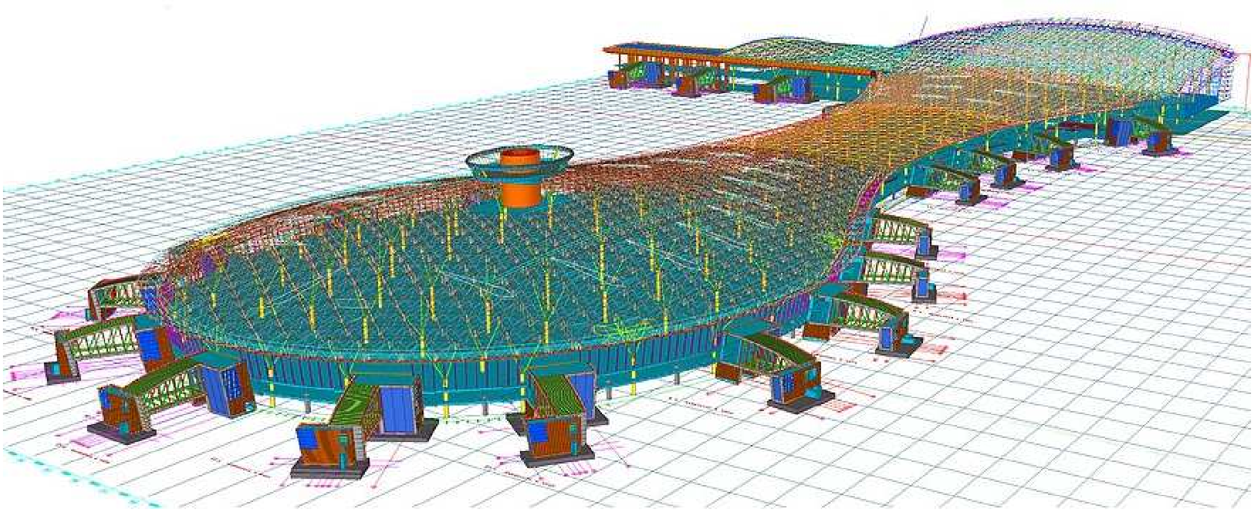


Figure 1. The use of Tekla Structures for structural design and detailing

2.1 History of program

By the mid-1960s, computers and automatic data processing were well established in Finland. Companies that performed advanced engineering computing had also adopted Automatic Data Processing (ADP).

Due to the ever-increasing amount of computing work and lack of resources, a group of engineering offices established a joint software company. The company, named

Teknillinen laskenta Oy ("technical computing") was registered in February 1966. The same spring, the company trading name was abbreviated to Tekla. Tekla's first office was located in Helsinki, Finland.

Tekla started operations on July 1, 1966. Tekla’s first programs were completed in 1967. Computerized calculations changed the way of working in engineering offices. Time saving calculations made engineering more efficient. In addition, more comprehensive and reliable plans could be made. The costs of calculations using a computer were also significantly lower than in manual calculation. And as engineering offices learned to invoice their customers for the computing time used and add general expenses to that, their income conveniently increased. This encouraged engineering offices to adopt ADP even more.

The foundation for Tekla's operations was defined as ADP consultation, computing services, training courses and software development. Six planning committees were formed in 1967 for the latter purpose, representing the different industries of the shareholding companies. The goal of the planning committees was to define the features of common software in cooperation with Tekla employees. (From punch cards to product modeling, p.6)

In fact, these committees created the model for Tekla's future way of working: starting projects to develop new programs in conjunction with customers.

Tekla has continued its strong investments in the international market for the last few years. Tekla’s 40th anniversary shows that persistent work bears fruits. International operations accounted for 75% of net sales in the first half of 2006, and the second quarter of 2006 was Tekla’s all-time best in terms of operating profit. Today, Tekla has customers in more than 80 countries.

2.2 Main functions

Tekla has a lot of various configurations including Standard Design, Steel Detailing, Precast Concrete Detailing, Reinforced Concrete Detailing, and Full Detailing. The Standard Design configuration is the typical one for engineers—it includes the modeling of a structure, all general arrangement (GA) drawings, reports, and other output. The other configurations can be purchased and added to the base application as required, based on the type and extent of detailing a firm is interested in doing.

Tekla Structures can be compared to program Allplan Nemetchek. Just like Allplan Nemetchek, it works with a central database, which means that all drawings and reports are derived from and stay linked to the model, get updated automatically, and are never out of date regardless of changes in the model. However, at the same time, the file sizes of Tekla models are much smaller than that of Revit. For example, one of the largest Tekla models created in actual practice contains over 1 million objects, yet it is only 25 MB in size, compared to Revit, where file sizes of close to 200 MB are not uncommon. (Structural Engineering Design in practice, p.37)

Creating a new Tekla Structures project creates not just a file, but a project folder that contains the model file and a sub-folder for the drawing files(see Figure 2).

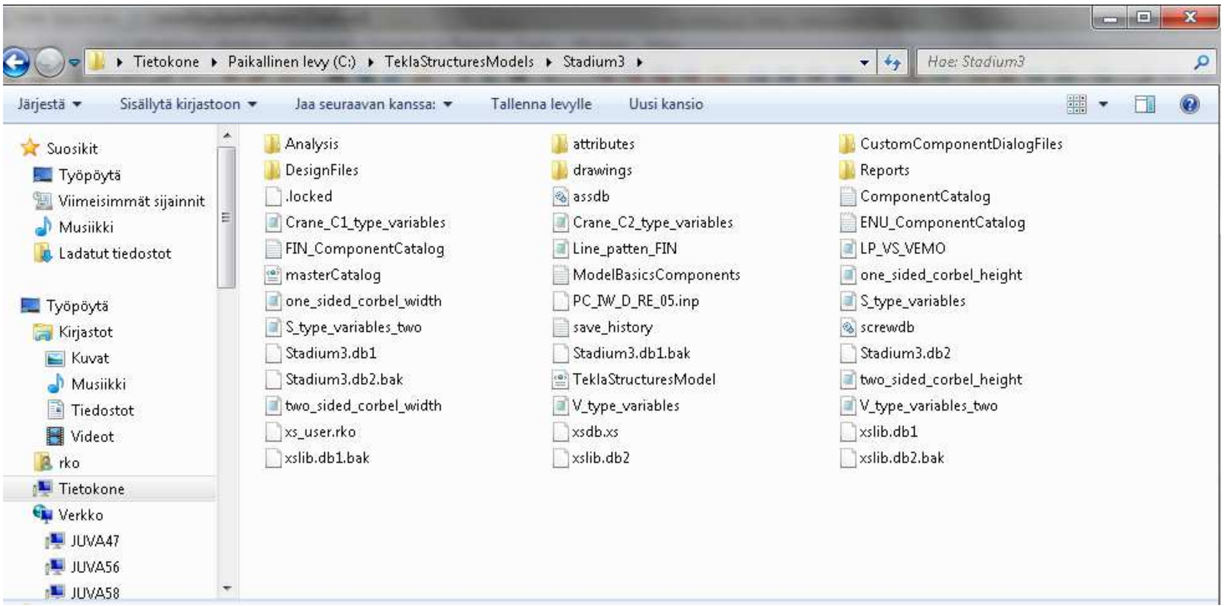


Figure 2. The Project Folder for a new Tekla Structures project that is empty.

The typical task for Tekla Structures is to model the structure from scratch or import an architectural model or drawing as a reference graphics. You will start by editing the grid that gets created for a new project and change its coordinates. Figure 3.a shows the grid settings specified for a new project. Just as with other structural modeling applications, grids in Tekla Structures allow easy positioning of objects in models, as you can snap to grid lines and their intersections. Additionally, they are useful to create plan and elevation views in Tekla Structures. There is no concept of floor levels as such, which means that there are no plan views automatically associated with floor levels as in Allplan Nemetschek. Once you define the grid, you can use it to create a series of “named views”, from which you can then select the ones you want to make visible. You can also create views by defining 2 or 3 points, by selecting an object plane, or by typing in an elevation value. Figure 3.b shows six of the Named Views created using a grid that were selected and moved over to the Visible Views section.

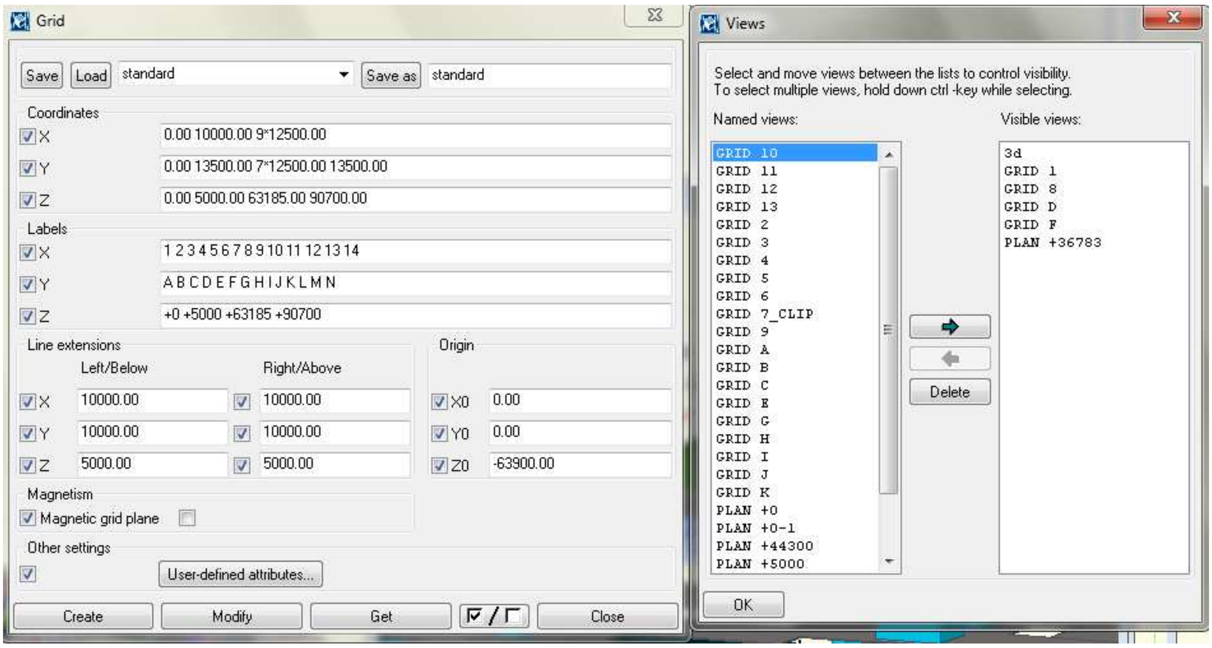


Figure 3 a,b. The grid settings and then using the grid to generate views along the grid lines

When you have grid and views, you can start creating the model using the various tools for typical parts such as beams, columns, plates, slabs, walls, polygon beams, etc. Related tools are grouped together into toolbars: for example, the Steel toolbar contains tools for creating steel beams, columns, and plates; the Concrete toolbar contains tools for creating concrete parts and reinforcements; the Detailing toolbar contains tools for trimming parts etc. There are several additional toolbars containing tools for modeling connections, details, and other components, editing elements, creating and managing views and work planes and so on. These toolbars are open and displayed along the top of the modeling window, as shown in figure 4.

The modeling can be done in any of the open views—the application automatically detects which view is current active. So, for instance, you can start a modeling operation in the 3D view and continue it in one of the plan or elevation views, without needing to first activate the view. View-related tasks such as zoom, pan, and rotate are built into the middle-mouse button, allowing you to carry them out quickly without selecting tools.

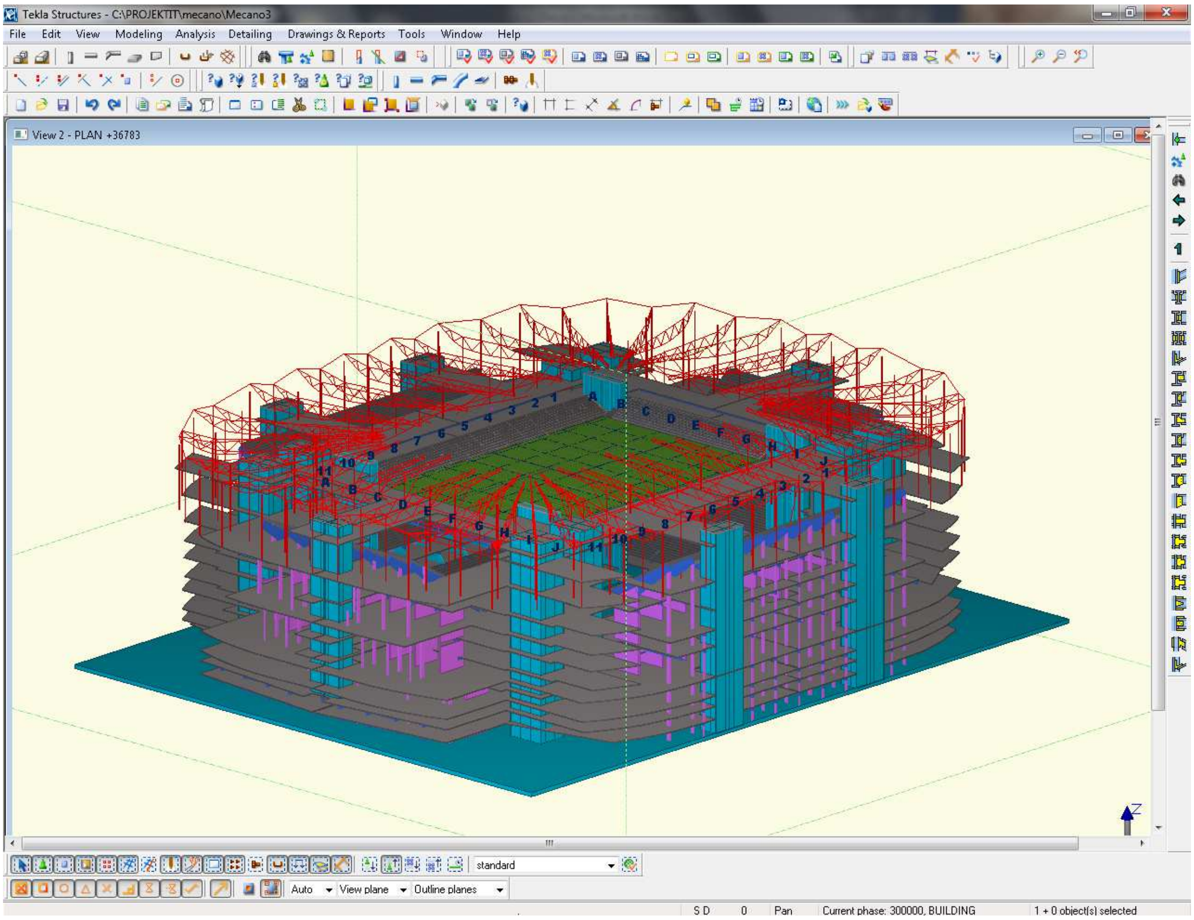


Figure 4. The model of mechanic stadium

In Tekla you can define the properties of components before creating them or modify the properties after creation. An example of this is shown in Figure 5, where a beam properties dialog is opened. You can choose the profile from an extensive catalog of steel and concrete sections, select the material from a catalog of industry standard types. In addition to specifying various other properties needed for analysis and design including loads, support conditions, etc., you can also define your own attributes for any object which can be listed in reports or referenced into drawings.

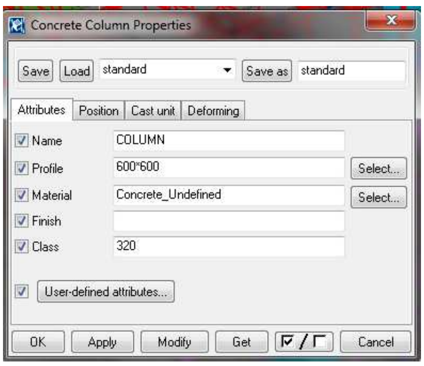


Figure 5. The Beam Properties dialog

2.3 Advantages and disadvantages

Tekla Structures is a very powerful and comprehensive program for any kind of structural engineering. There is a wide variety of analysis tools. It also has a big library of connections for both steel and concrete. All connections from the library also can be changed with appropriate parameters. It is also very easy to get drawings from Tekla. It can be drawings of model or drawings of connections. Drawings can be saved in dwg type and can be changed in AutoCad. Another program advantage is the possibility of quick moving between different views.

Next detailed advantages can be mentioned: extensive repertoire of modeling and detailing tools for both steel and concrete construction, allowing integration of processes from design to fabrication; centralized database which ensures that all drawings and reports stay coordinated with the model; innovative data structure that makes file sizes concise, even for large and complex projects; extensive library of parametric components that automate the tasks of creating details and connections; excellent viewing and model navigation capabilities; ability for clash detection with native objects and reference models; good interoperability with other design applications and downstream manufacturing and construction technologies; bidirectional link to several analysis tools; good support for multiple users working on a project; allows web models to be published that can be freely shared with others. (http://www.tekla.com)

The biggest disadvantage of the program is the relative lack of modeling instruments. It can be very difficult to model structures with the non-standart shapes (in such cases program STAAD can be used) for example the roof of the stadium.

Next detailed disadvantages can be mentioned: complex application with a very overwhelming interface; entirely text-based documentation that does not support self-learning well, mandating the use of professional training to learn the application; poor interface for making adjustments to the analysis model; more expensive compared to other BIM applications for structural engineering; does not directly integrate with other architectural and MEP BIM applications. (http://www.tekla.com)

3 MODELING OF BIM MODEL

Building information modeling (BIM) is a process involving the generation and management of a digital presentation of physical and functional characteristics of a facility. The resulting building information model becomes a shared knowledge resource to support decision-making about a facility from the earliest conceptual stages, through design and construction, then through its operational life before its eventual demolition.

Building information models are utilized throughout the building's life cycle, starting from the initial design and continuing even during use and facility management after the construction project has concluded.

Tekla is a program with the help of which we can make different BIM models. Every element in structure has its own characteristics such as size, material, cast unit and others. All these parameters influence on future reports, drawings and cost analyzes and change of even one detail will change all reports.

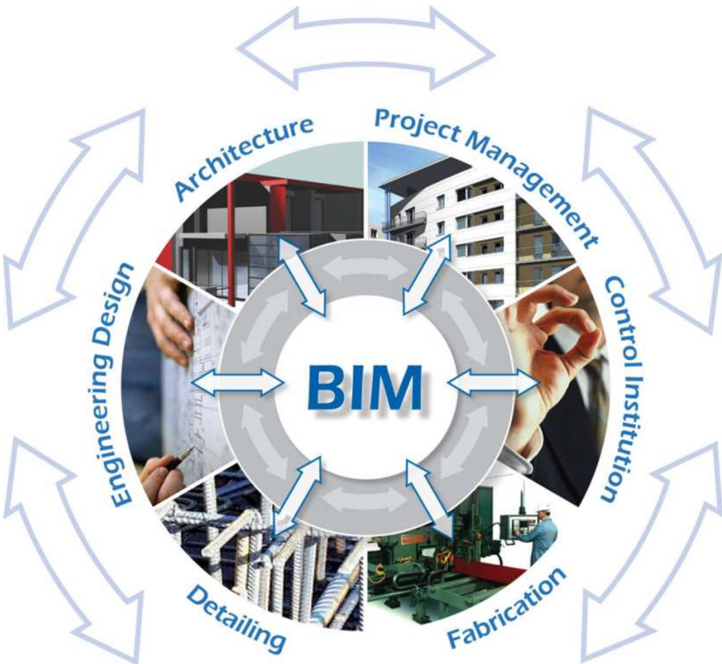


Figure 5. BIM connections

4 MECHANIC STADIUM

4.1 Short description

Mechanic Stadium is a new innovative project. It is not only for sports: multiple activities can be held simultaneously above and below the field.

The main idea of this event center is a vertically moving activity field (120x100 meters). Four towers containing the lifting devices make this possible (see figure 6).

Figure 6. The architectural view of Mechanic Stadium

There are two possible locations of the field (see figure 7):

Activity field up

- On top – football training match or outdoor event for 10 500 spectators.
- Underneath – concert for over 53 000 spectators, sports activities like indoor football for 10300 spectators or tennis tournament for over 30 000 spectators.
- Possibility to isolate smaller areas with rollable partition walls suspended to the grid.

Activity field down

- On top – football match or outdoor event for 40 000 spectators.
- Underneath – concert preparation, indoor activities in cupolas central area.

Possible use of side stands for auditorium type activities.

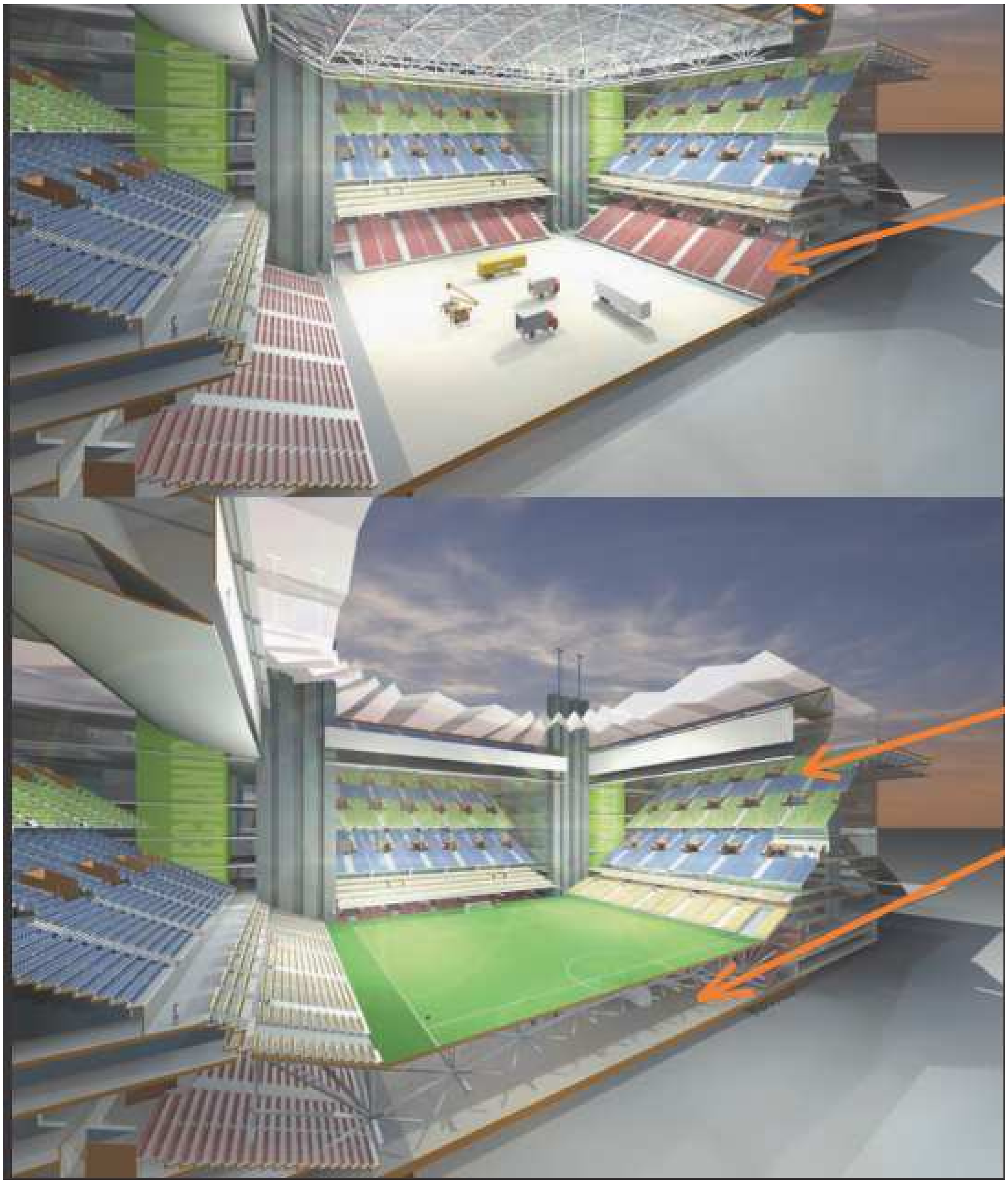


Figure 7. Possible location of the field

Dead load of the field is about approximately 900 kg/m^2. This is the load that is on when the field is moving. The allowed live load at spectator area is 400 kg/m^2 and on the field 200 kg/m^2. (Structural Engineering Design in practice, p.18)

The stadium consists from the slabs, beams, columns, walls and stands. All structures have its own properties and different materials. For example, there are main and secondary beams which situated in perpendicular direction.

4.2 Description of structural model

There are a lot of programs for making 3D models. One of the most popular programs is ArchiCad. It is very easy to make 3D model there because of the big amount of modeling tools. There are also a lot of functions for transferring model from ArchiCad to other programs. Although it is very simple just to transfer the architectural model from ArchiCad to Tekla, there can appear a lot of mistakes and all future calculations with this model will be wrong. That is why this model was made in Tekla without using ArchiCad. All elements were made just according to the dimensions from plans and advices by supervisor about possible thicknesses and location.

Another important notice about this model is that there are no intersections of elements. As you can see in figure 8, the column stop on the level, where the beam begins. There are no such cases where in one place two or three intersections of material. That was made for the more accurate material cost analysis.

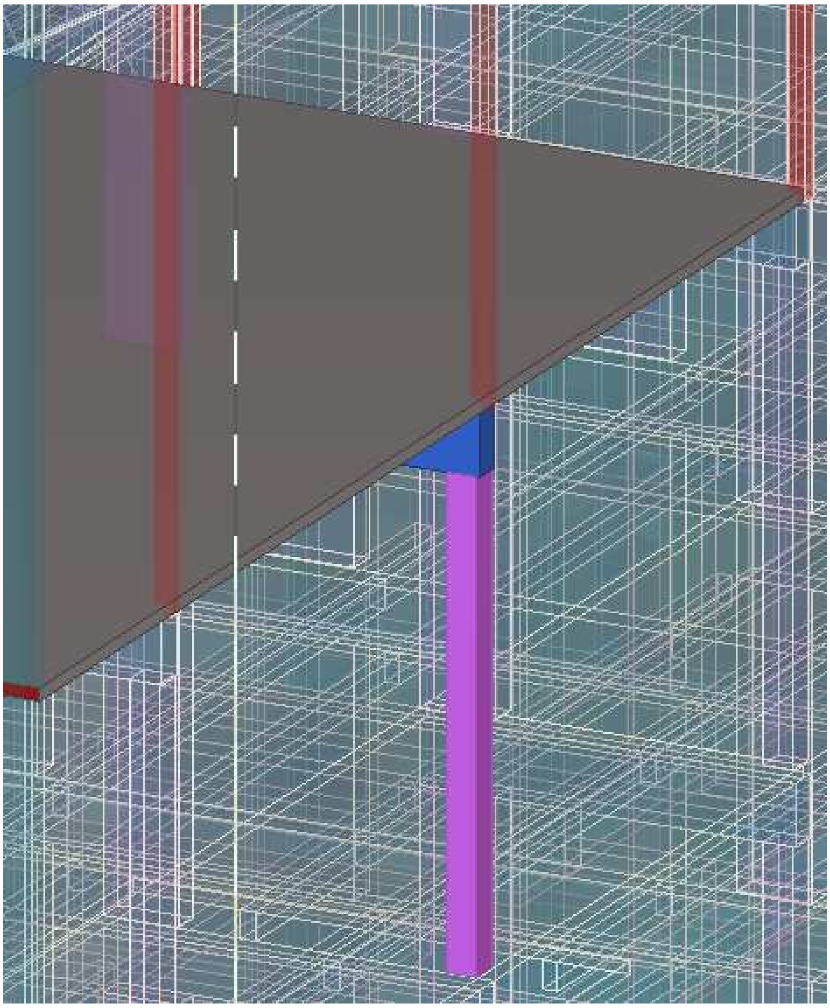


Figure 8. Joint of column, beam and slab.

4.2.1 Slab

Mechanic stadium is a unique structure. There are no same buildings in the world that is why all information about frame structures was taken just from the previous experience of making of usual stadiums. It was corrected and applied to this stadium by Juva engineering company and architectural Larkas and Laine company. Larkas and Laine company made architectural drawings with help of which it became possible to make structural model.

Mechanic stadium slabs are made of concrete. A concrete slab is a common structural element of modern buildings. The thickness is 250 mm. These in situ concrete slabs will be built on the building site using a formwork - a type of boxing into which the wet concrete is poured. (Finnish Architecture,p.27)

These slabs were made according to the architectural plans with all necessary holes and required shape. One floor slab consisted of four parts, which are reflected one from another with function mirror in program Tekla.

These slabs are shown in figures 9 and 10.

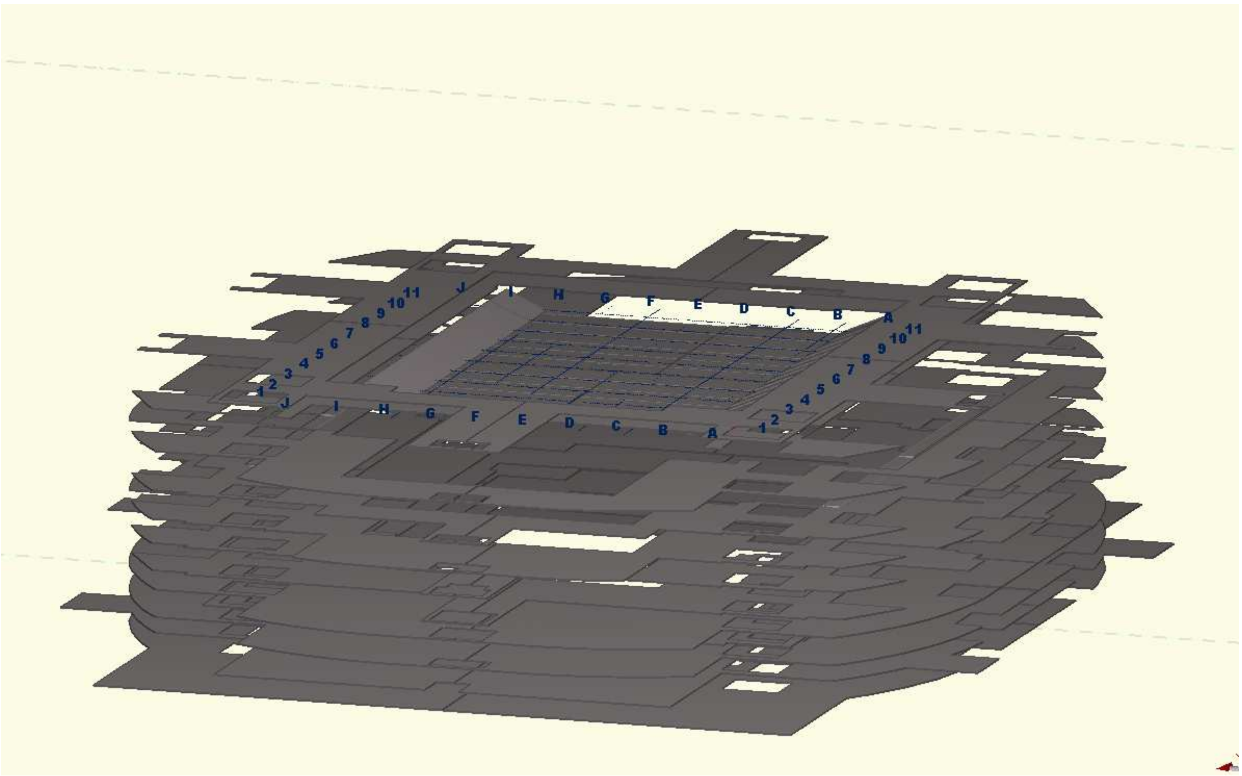
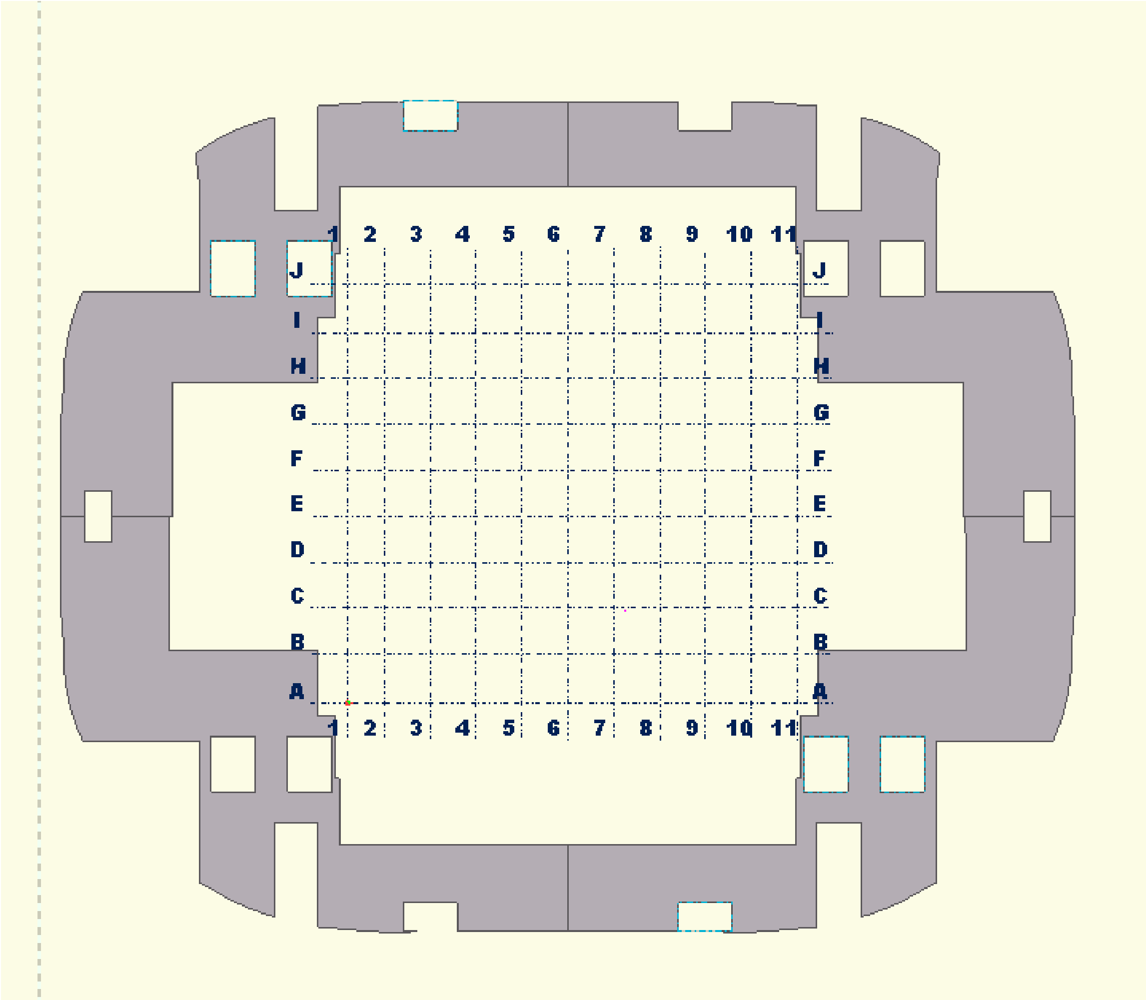


Figure 9. 3D view of slabs



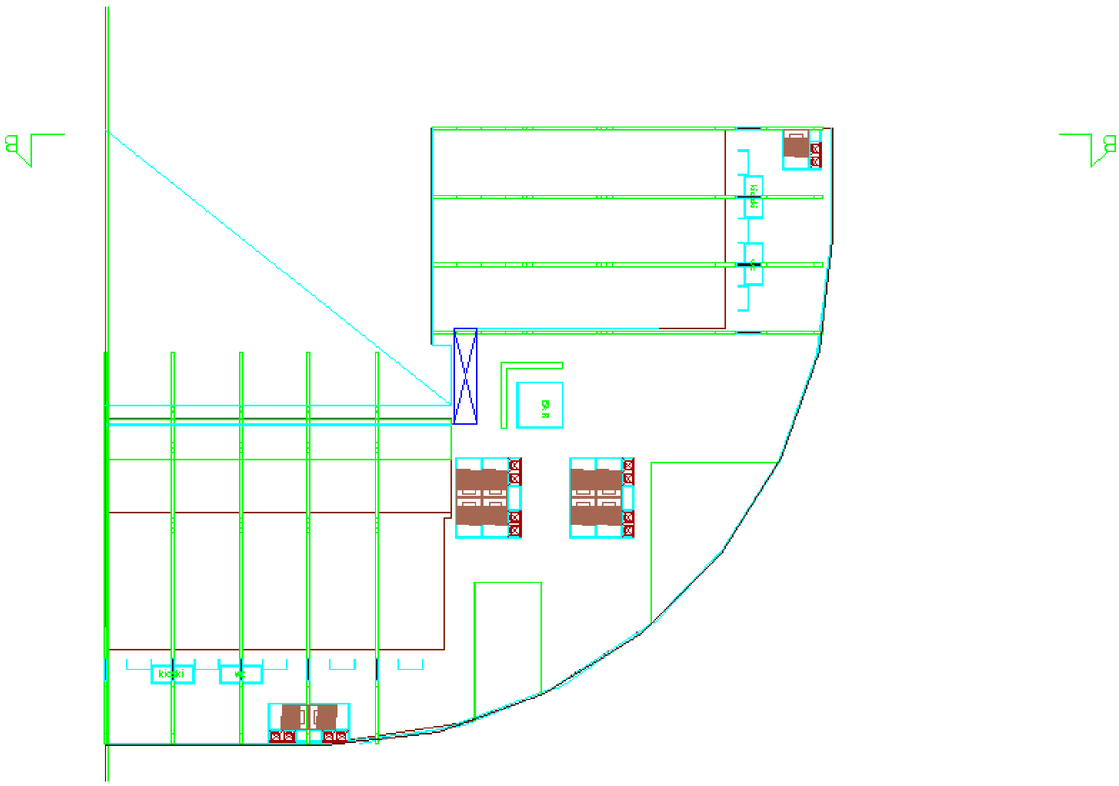


Figure 10. Slab view from Tekla Structure and from AutoCad

4.2.2 Beams

A beam is a horizontal or vertical structural element that is capable of withstanding load primarily by resisting bending. The bending force induced into the material of the beam as a result of the external loads, own weight, span and external reactions to these loads is called a bending moment.

Beams are traditionally descriptions of building or civil engineering structural elements, but smaller structures such as truck or automobile frames, machine frames, and other mechanical or structural systems contain beam structures that are designed and analyzed in a similar fashion.

There are three types of beams in Mechanic Stadium. The main horizontal beams are made from concrete and have a rectangular cross section 1200x600 mm. In direction which is perpendicular to them secondary beams with the sizes 550x300 mm are situated. And the last type of beams is situated under the stands. They have a slope and trapezium shape with the profile 2500x600 mm. (Finnish Architecture,p.39)

All horizontal beams are situated directly under the slabs and supported by columns.

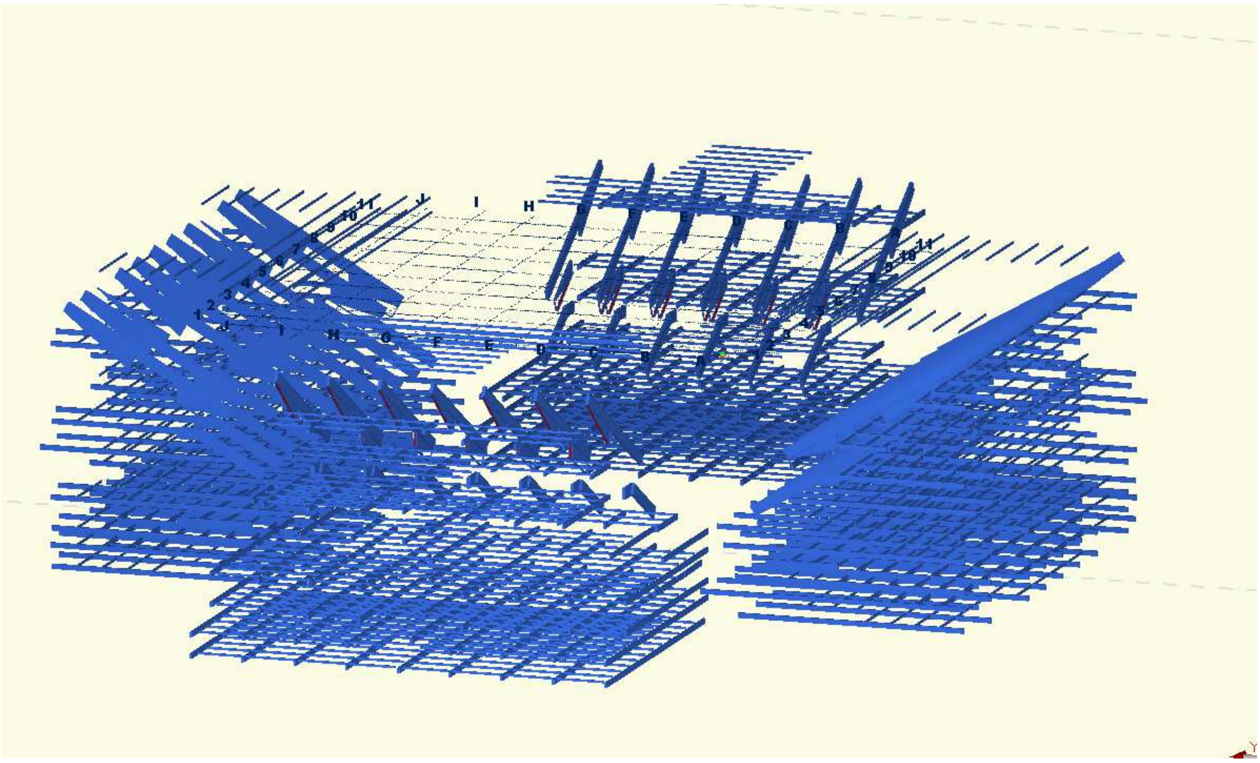


Figure 11. Beams

4.2.3 Columns

Column or pillar in architecture and structural engineering is an structural element that transmits, through compression, the weight of the structure above to other structural elements below in, other word column is a compression member. For the purpose of wind or earthquake engineering, columns may be designed to resist lateral forces. Other compression members are often termed "columns" because of the similar stress conditions. Columns are frequently used to support beams or arches on which the upper parts of walls or ceilings rest. In architecture, "column" refers to such a structural element that also has certain proportional and decorative features. A column might also be a decorative element not needed for structural purposes; many columns are "engaged with", that is to say form part of a wall.

Because of the different distances between slabs, columns also have different height. As you can see in the figure 12, they also have different width and shapes. Under the stands we have slope columns with sizes 12000x600. Other columns have sizes: 600x600, 1500x600, 2000x600 and others. All columns are situated under themain and secondary beams. (Finnish Architecture,p.53)

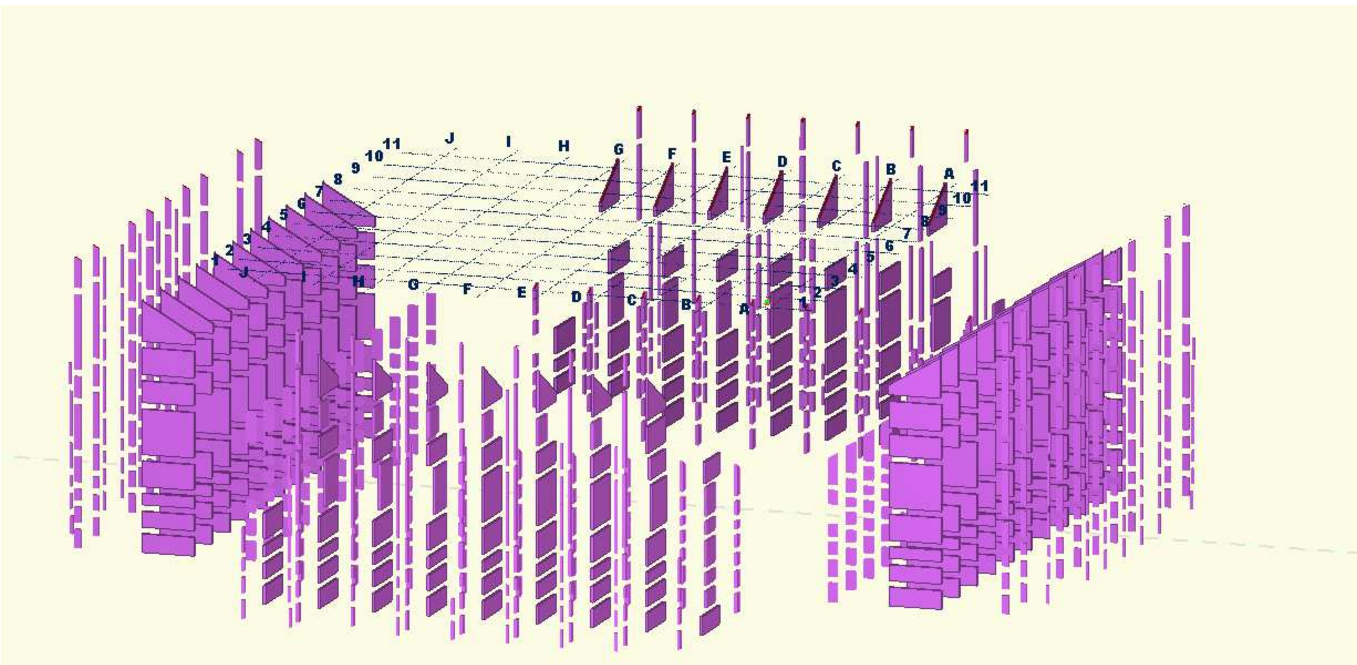


Figure 12. Columns

4.2.4 Stands

Stands or bleachers are raised, tiered rows of seats found at sports fields and other spectator events. Stairways access the horizontal rows of seats, often with every other step gaining access to a row of seats.

Seats range from simple plank seats to more elaborate seats with backrests. Many bleachers are open to the ground below so that there are only the planks to sit and walk on; if something is dropped, it can fall off the planks to the ground. Some bleachers have vertical panels beneath the seats, either partially or completely blocking the way to the ground.

The Mechanic Stadium has stands attached to the moving field and static stands, see figure 13. They are all made as precast concrete elements with sizes 1150x780 mm. All stands wade with a slope according to the architectural drawings. The slope is approximately 35 degrees. (Finnish Architecture,p.79)

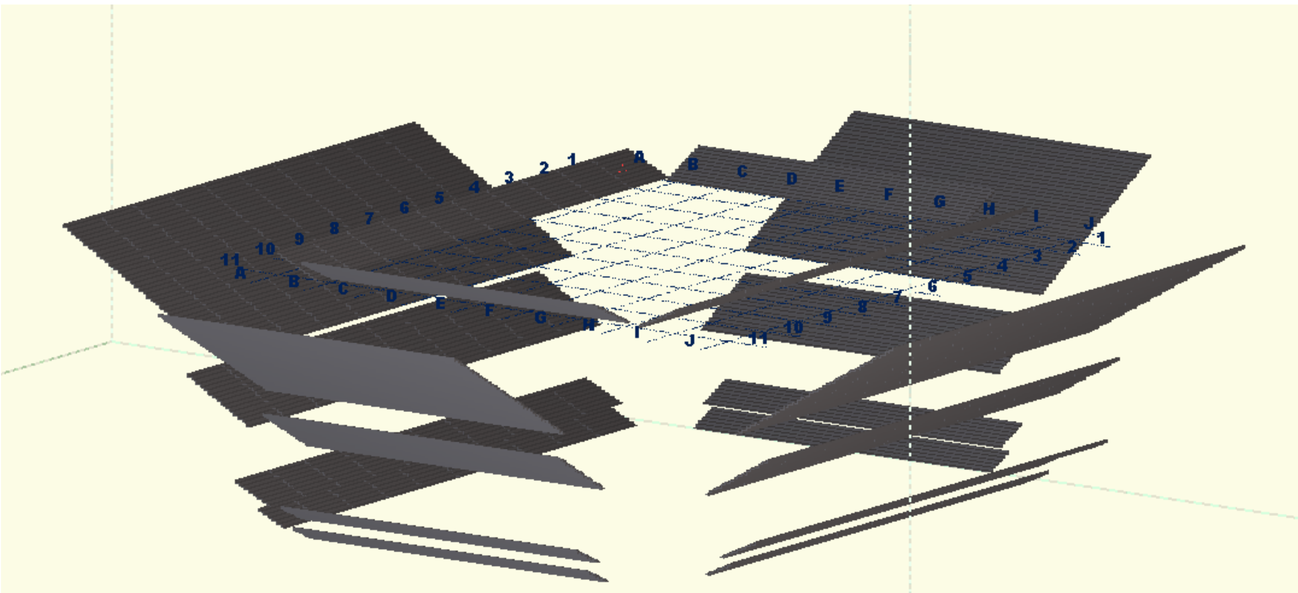


Figure 13. Stands

4.2.5 Roof

A roof is the covering on the uppermost part of a building. A roof protects the building and its contents from the effects of weather and the invasion of animals. Structures that require roofs range from a letter box to a cathedral or stadium, dwellings being the most numerous.

In most countries a roof protects primarily against rain. Depending upon the nature of the building, the roof may also protect against heat, sunlight, cold, snow and wind. Other types of structure, for example, a garden conservatory, might use roofing that protects against cold, wind and rain but admits light. A verandah may be roofed with material that protects against sunlight but admits the other elements.

The characteristics of a roof are dependent upon the purpose of the building that it covers, the available roofing materials and the local traditions of construction and wider concepts of architectural design and practice and may also be governed by local or national legislation.

The roof has a comprehensive structure. It consists of trusses. Trusses are made of steel rectangle beams with sizes in cross section 350x350 mm. The roof was calculated in program STAAD by Heikki Jarvinen and then transferred to Tekla as 3D lines. Then these lines got beam characteristics. Eventually we get a roof consisted of steel beams.

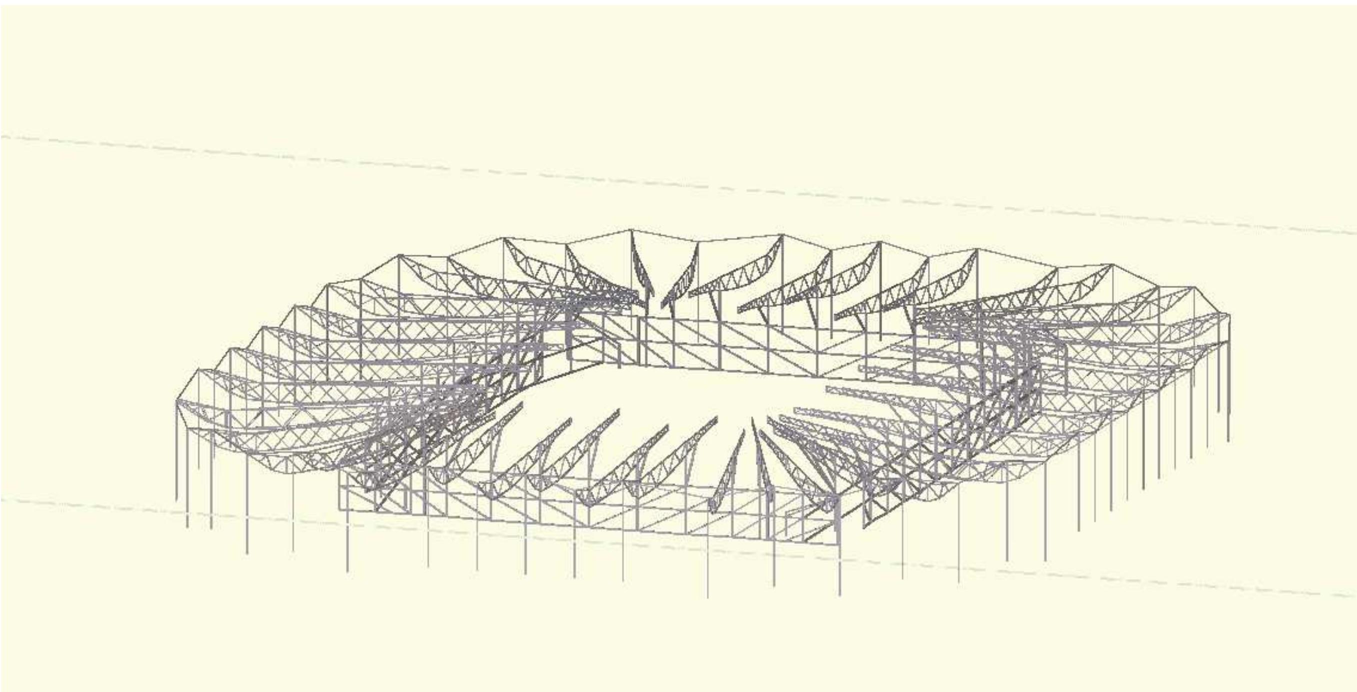


Figure 14. Roof

4.2.5 Football field and supporting system

Football field consist from horizontal, diagonal and vertical trusses. The field was calculated in program STAAD and then transferred to Tekla as 3D lines. Then these lines got beam characteristics. All constructions which were transferred from STAAD for quick and easy work in Tekla consist only from the quarter of its own size. Then in Tekla they copied twice with the help of function mirror.

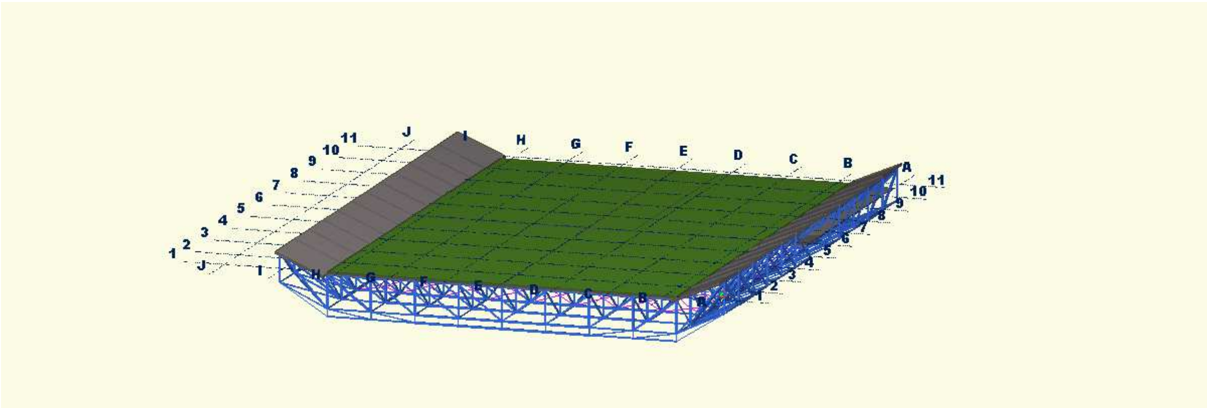


Figure 15. Football field

Pylons and wire channels were made for simple moving of the field up and down. There are three channels on every side of pylon for stable work of construction. The accurate calculation of pylon and channel sizes was made by Heikki Jarvinen.

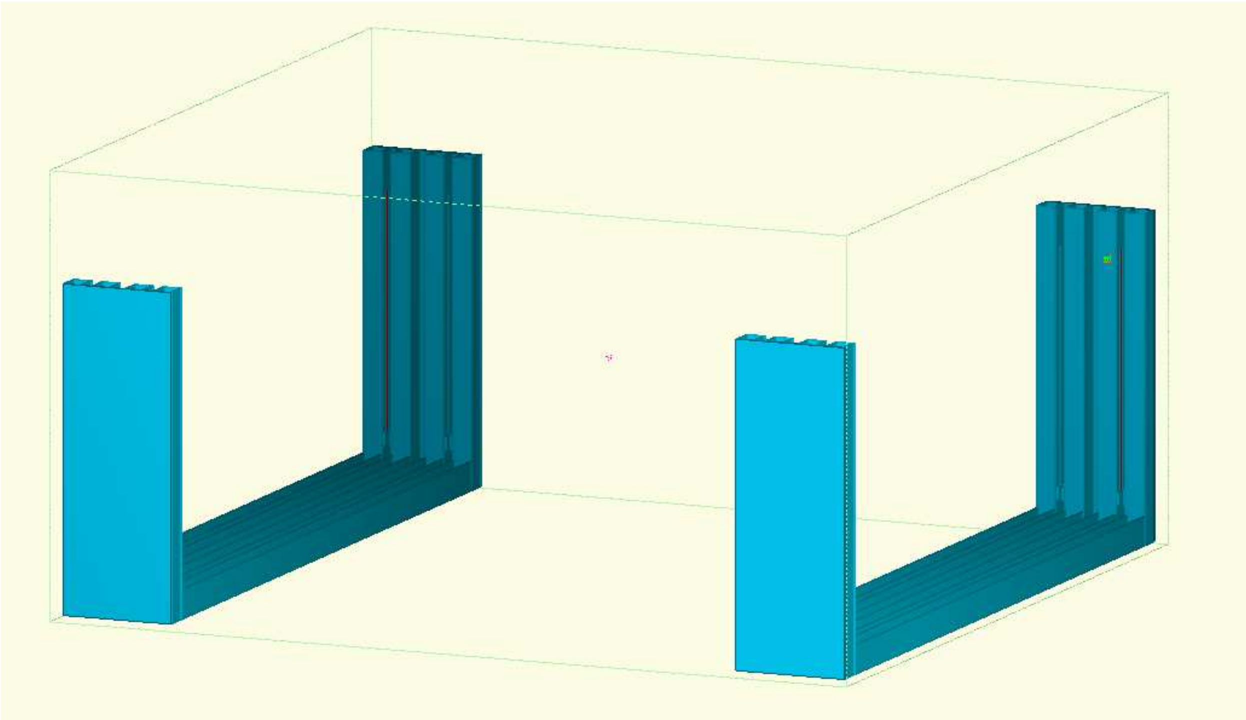


Figure 15. Pylons and wire channels

5 QUANTITY SURVEY

Quantity survey is a mathematical process used in estimating the cost of a new building construction, improvement, or reproduction.

For the Mechanic Stadium according to the BIM model it is possible to make a material bill of quantities. All elements in Stadium have different properties, it is possible to make a report about their amount. According to this amount we can make a table which is called bill of quantities and which can be used for future calculations.

All prices were taken according to the Russian material costs as the average price in different building companies. (Железобетон в современном строительстве, p.77)

Foundation is not included in this cost analyze because it was not considered in the structural model because of unknown type of soils.

Table 1 Material bill of quantities

Name of element	Name of material	Number of elements	Form area,m2	Volume,m3	Price,rub
Solid Slabs	Concrete	49	155376,5	36232,44	181162200
Beams	Concrete	2828	107684,1	21590,23	107950000
Columns	Concrete	1204	56535,4	14765,82	73829100
Walls	Concrete	391	229017,4	28743,45	143717250
Roof parts	Steel	1637	-	17725,32	87343211
Football field parts	Steel	973	-	8247,63	42171605

The total price of materials is 636173366 rub.

So according to the model in Tekla we get the price of materials. The price of work don't included in this amount. All other additional expenses must be summarized with the material price.

6 SUMMARY

Tekla is one of the most popular program for structural engineering in Finland. A big variety of tools such as modeling or making connections between different elements make this program more suitable than for example AutoCad. But there are a lot of advantages of this program and one of the biggest is opportunity to make BIM models in this program.

BIM model is an information model in which every part is connected with each other and if you change one property all reports about this model will be changed accordingly.

In my thesis work I made a short description of the main functions of program Tekla. It is a convenient program for making 3D models. The model of Mechanic stadium is the simpliest example of it. In Tekla you can make all the main structures of building and then according to it, make a quantity survey. All this process was described in my thesis.

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APPENDIX 1. MODEL MADE BY TEKLA

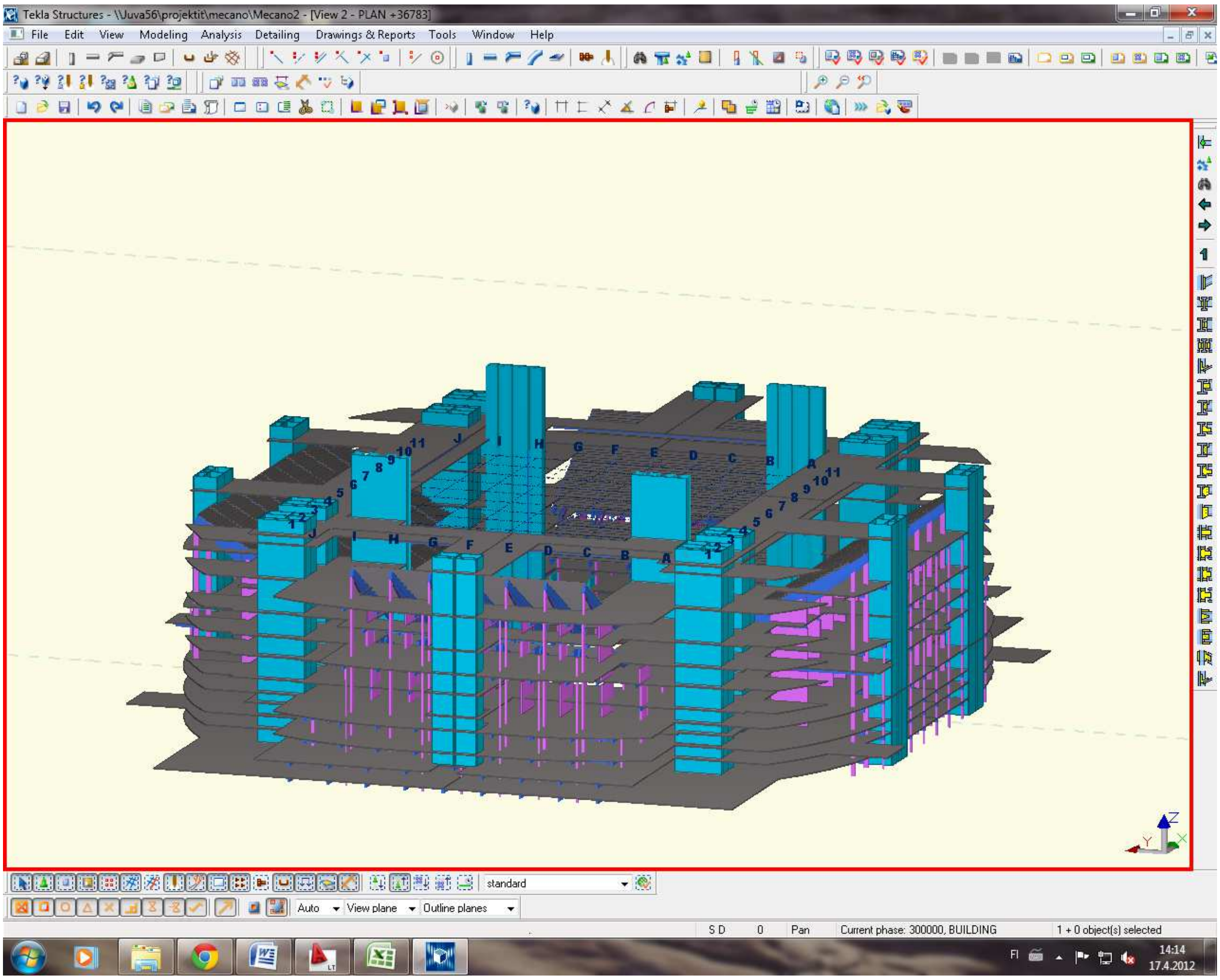

Figure 1. 3D model of mechanic stadium

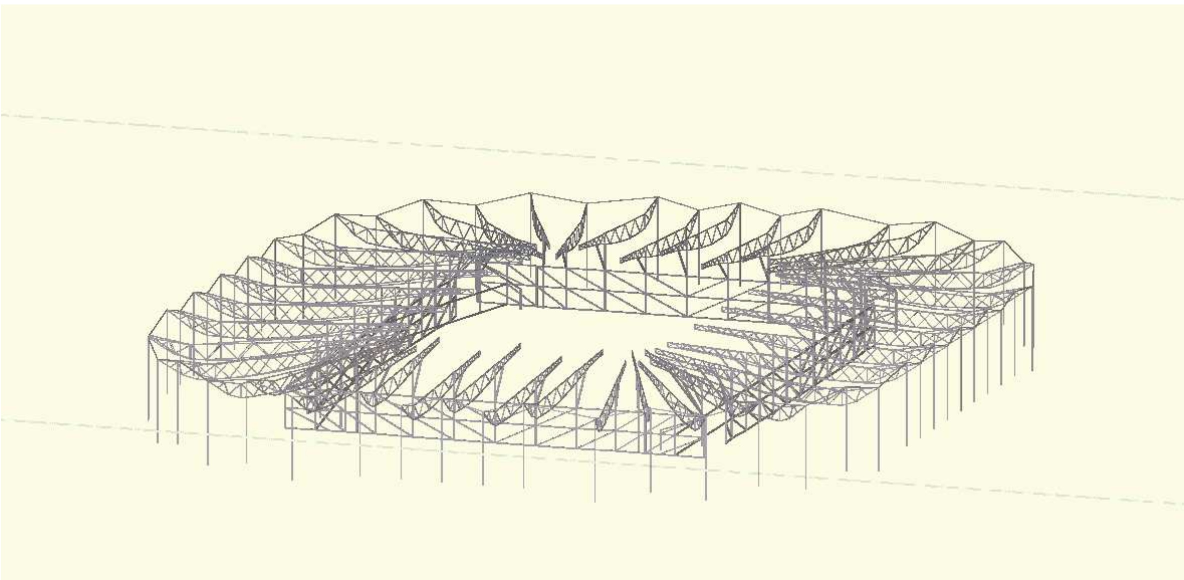

Figure 2. Mechanic stadium roof

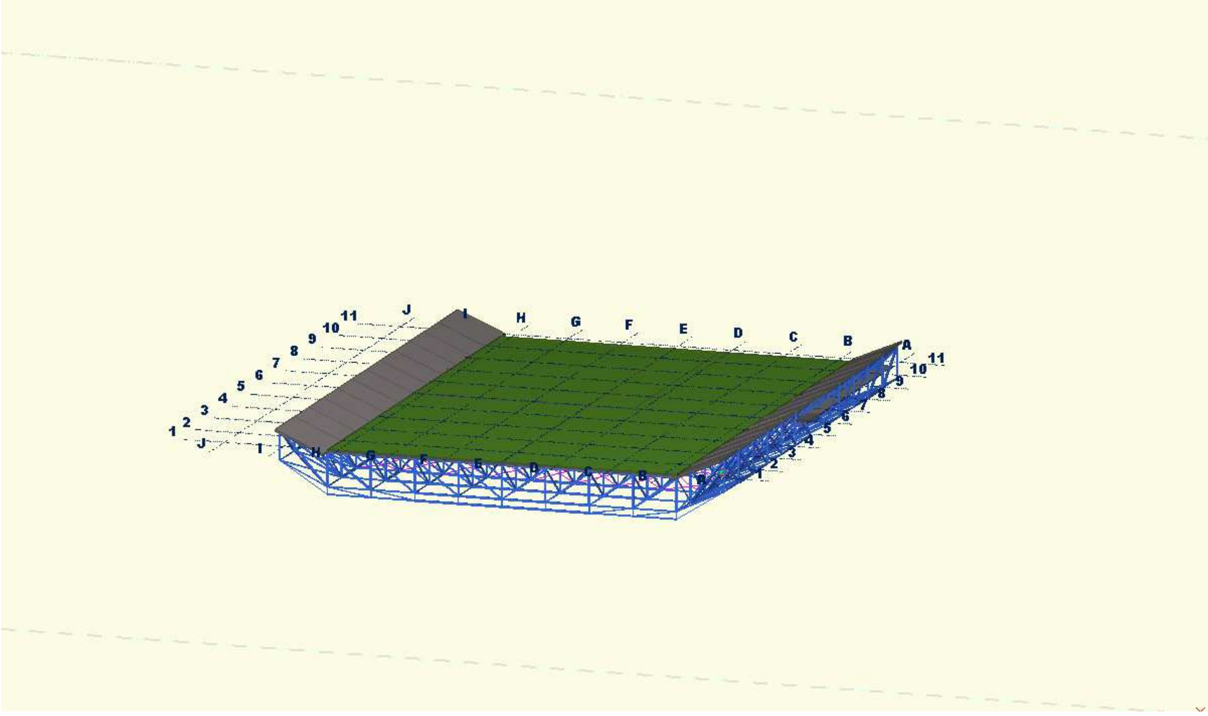

Figure 3. Mechanic stadium football field

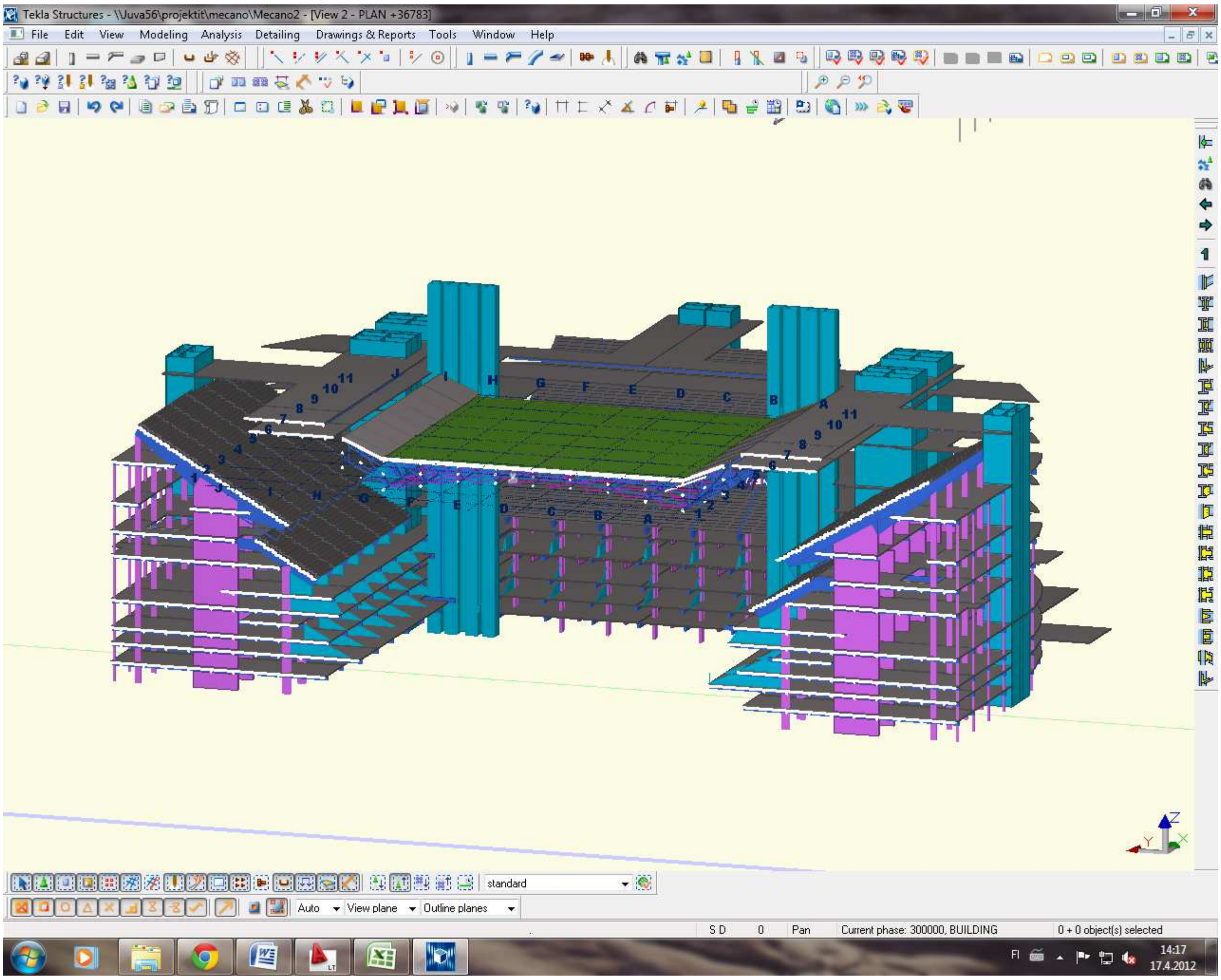

Figure 4. Cross section of mechanic stadium

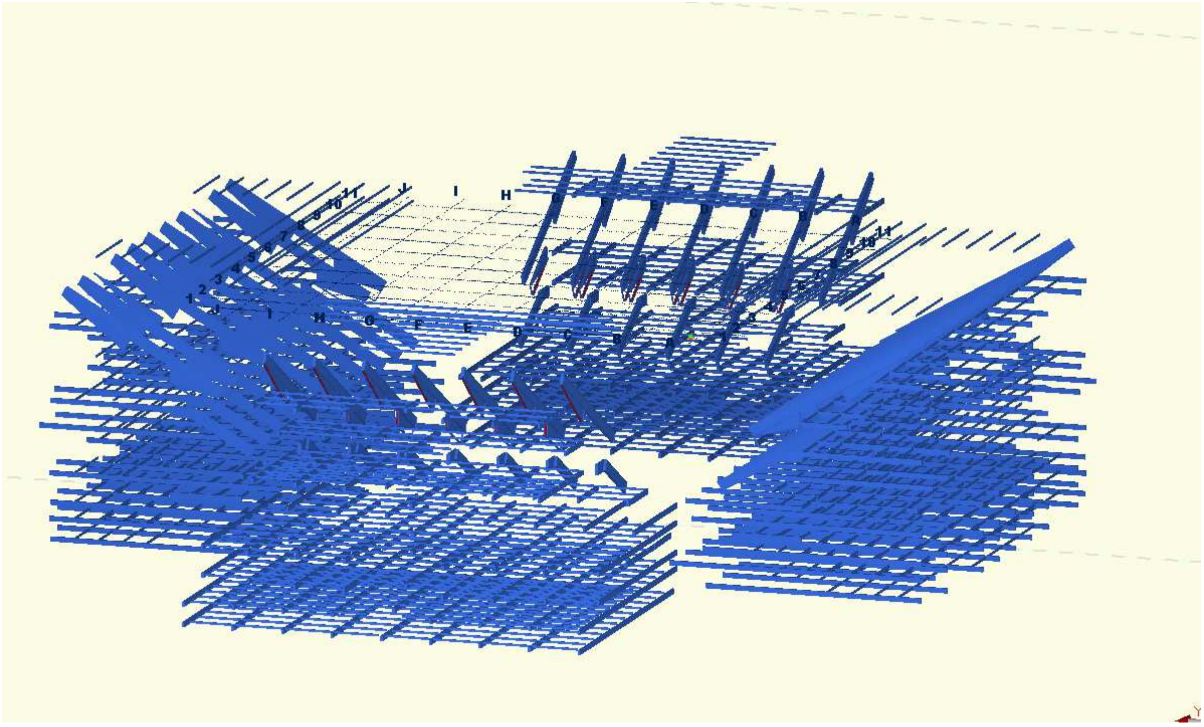

Figure 5. Mechanic stadium beams

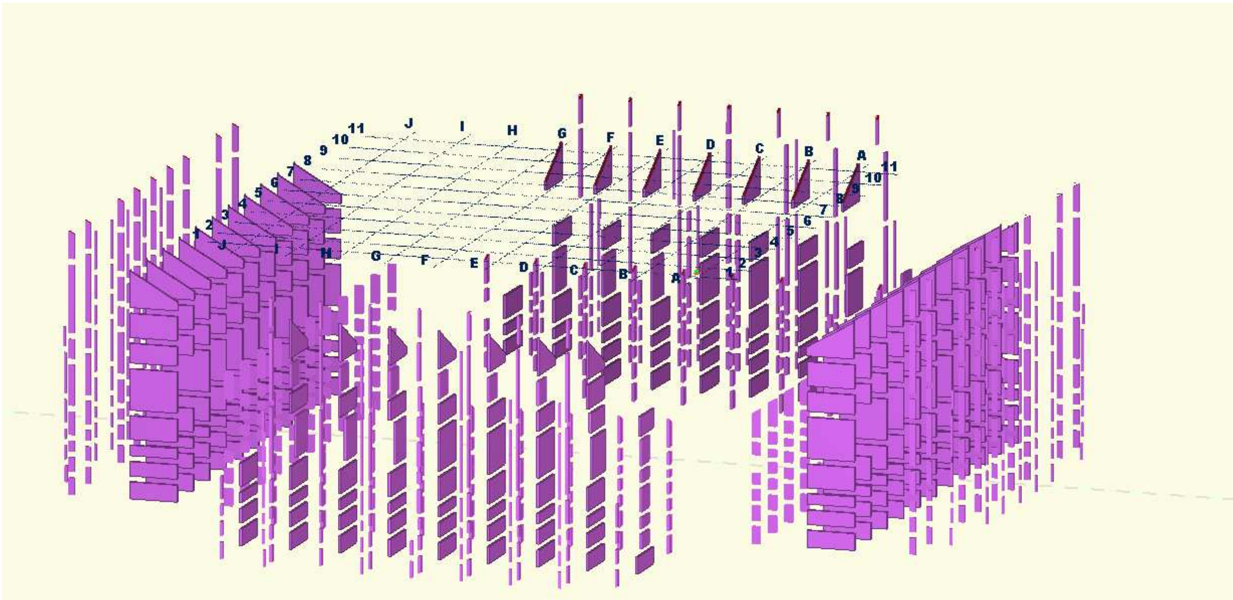

Figure 6. Mechanic stadium columns