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DESIGN AND ASSEMBLING PROBLEMS ON THE EXAMPLE OF DENVER'S INTERNATIONAL AIRPORT DEVELOPMENT AND THE POSSIBILITY OF SOLUTIONS IN DESIGN STAGE

PROBLEMY PROJEKTOWO-REALIZACYJNE NA PRZYKŁADZIE ROZBUDOWY MIĘDZYNARODOWEGO PORTU LOTNICZEGO W DENVER I MOŻLIWOŚCI ICH ROZWIĄZANIA NA ETAPIE PROJEKTOWANIA

Abstract

In the paper a process of designing and assembling complicated steel structure is described. The object is a glass roof over the railroad terminal. The object's body makes it impossible to assemble elements of the structure on the building site just having a structural 2D drawing. It was essential to create visual animation illustrating the chronology, in what way the particular elements of the structure should be assembled to achieve the effect assumed by the architects. However, the architectonic form of the whole object was so interesting and valuable that it is worth to destine investment means and time to achieve the desired aim.

Keywords: designing, assembling, steel construction, visual animation

Streszczenie

W artykule opisany został proces projektowania i montażu skomplikowanej konstrukcji stalowej. Obiekt jest przeszklonym dachem nad stacją kolejową. Bryła uniemożliwia „złożenie" elementów konstrukcji na budowie na podstawie rysunków konstrukcyjnych. Niezbędne było stworzenie animacji obrazującej, w jaki sposób należy nasuwać na siebie części konstrukcji, aby osiągnąć efekt założony przez architektów. Jednak forma architektoniczna całego obiektu jest na tyle ciekawa i wartościowa, że warto zainwestować ogromne środki pieniężne i czasowe, aby osiągnąć zamierzony cel.

Słowa kluczowe: projektowanie, montaż, konstrukcje stalowe, animacja

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1. Introduction

Imagination and creativity of the architects has no limits and modern engineering tries to keep up with them. More and more often structures are erected that until recently we all could only dream of. Construction engineering moves with time and structures are no longer erected on the basis of drawings, but thanks to animation.

On the example of the development of the international airport in Denver it can be easier to understand where the modern world is, in possibilities to erect complicated and difficult architectural forms. Engineers and designers (also from Poland) concentrate not only on the project of the structure and assembling its elements, but also on creating animations, on the basis of which particular elements of the structure are "put together" on the building site.

When erecting such a difficult structure as the Denver Airport, apart from the people professionally involved in civil engineering, engineers specializing in quite different branches must have also participated in the project. These were mainly IT specialists whose abilities and knowledge allowed to create an original structure.

2. History

The International Airport in Denver was built in 1995. It caused the closing down of another international airport: Stapleton International Airport. The planned cost was an enormous $1.7 billion yet in the end it rose several times more.

Denver International Airport is currently fifth in the United States in terms of the number of passengers. Up till now, as one of the few in the world, it is not connected with the city by railway.

Thus, when planning the development and extension of the terminal, building a railway line was suggested, with a final station right next to the newly built hotel, which is planned to be an integral whole with the objects of the airport. Within the whole complex a conference centre as well as many trading and service points will be built.

The project was conceived in Gensler, having its headquarters in Denver. One of the designers was Santiago Calatrava.

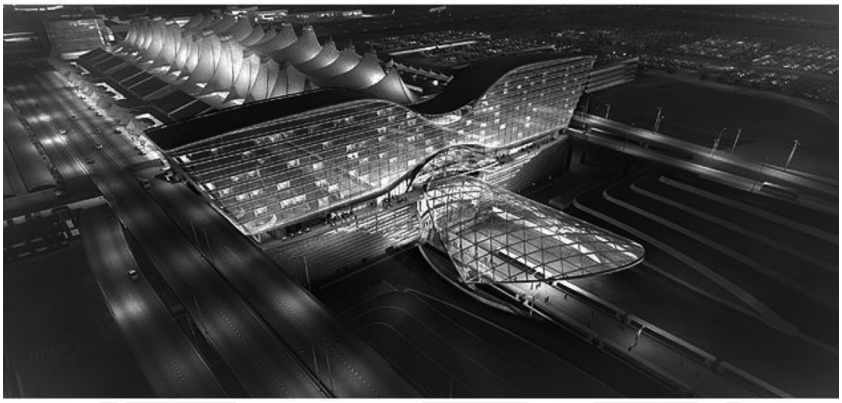
3. Investment Components

The whole complex consists of several parts being separate wholes of completely different functions. A railway arch bridge, forming a symbolic gate, leads to the port. The rails stop just before the hotel building whose solid form reminds a bird with outstretched wings, getting ready "to take off". Over the railway station there is a arch steel arch roof, finished in glass. Over it there is a similar but smaller roof, situated in the central, bottom part of the hotel, forming a smooth visual passage between the railway station and the hotel building.

The extension of the airport takes place in a few stages. The first one was completed in 2012 and included building a railway bridge and a hotel. At present, construction of the railway station and the vaults over it are being realized. The project is to be completed in

2014, and its cost is planned to be $650 million. The next stage will include renovation of the existing terminal (plus $250 million). The whole airport should be put into operation in 2016.

Ill. 1. Hotel and a roof over Railway Station – view at a day – visualization Gensler



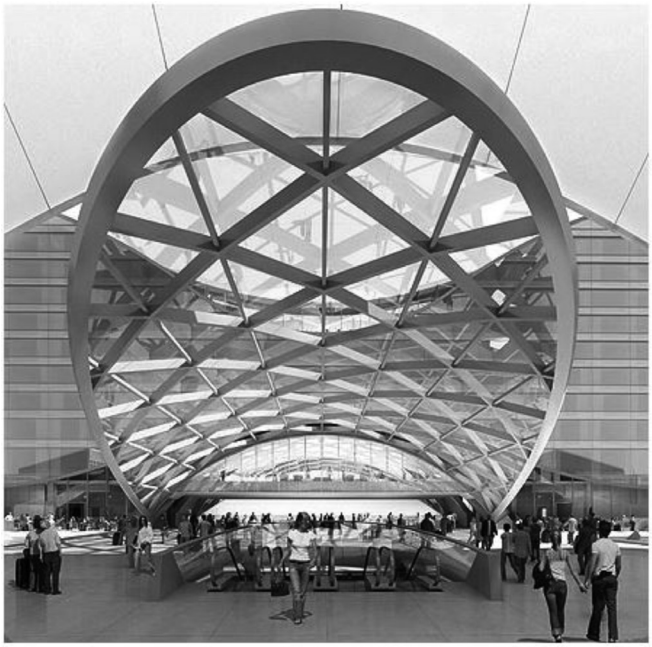
Ill. 2. Hotel and a roof over Railway Station – view at night – visualization Gensler

4. Cooperation when realizing the project

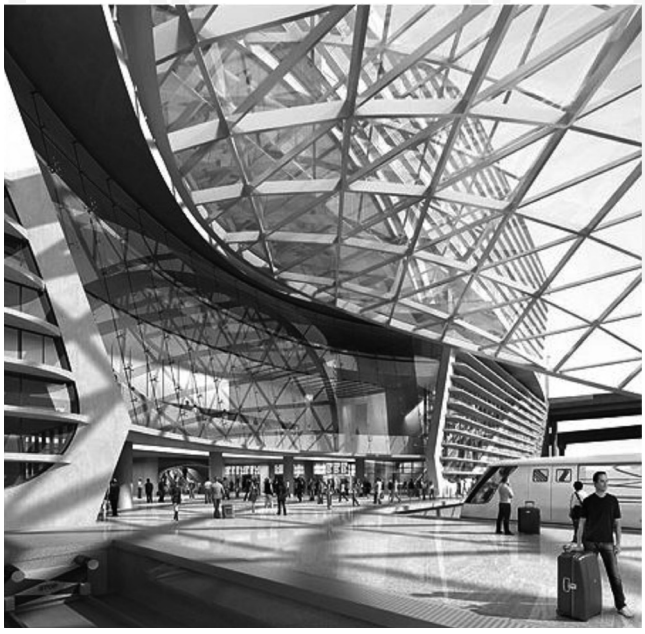
The investment is of great interest because of its architecture, huge dimensions, very high cost and a great number of people (6.6 thousand) involved in completing the project.

In designing a beautiful roof structure over the final railway station were engineers from Cracow Anatomic Iron Steel Detailing office involved. Project documentation is created in Tekla Structures Programme.

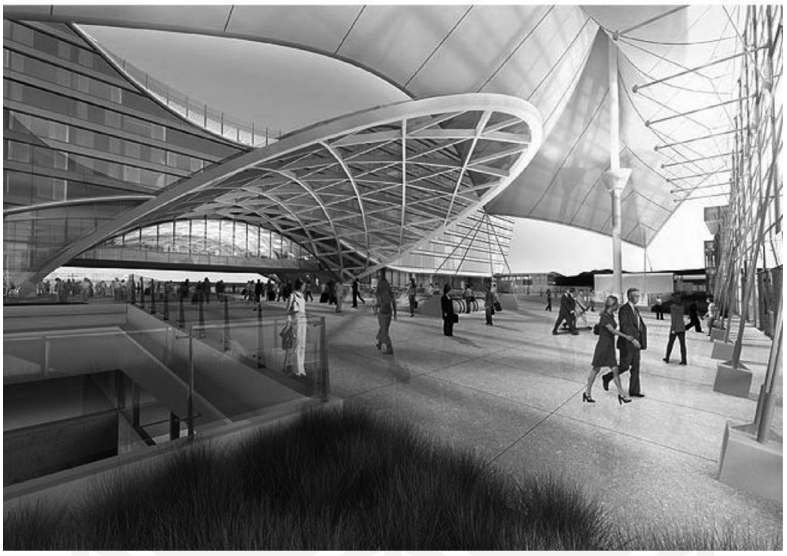
The office is responsible for the load bearing construction of the steel roof. The construction project was performed by engineers from the United States and passed on to Polish designers who were detailing the structure. For example, the three-dimensional model with the solutions of connection details was made by them.



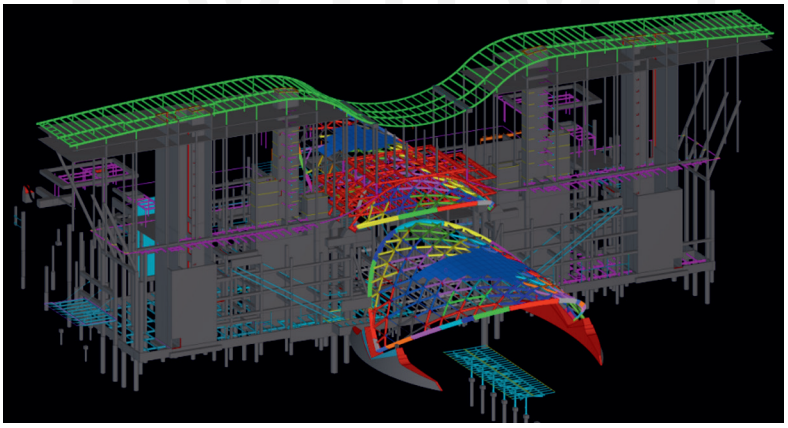
Ill. 3. The final station International Airport In Denver – front view – visualization Gensler



lll. 4. The final station International Airport In Denver – bottom view – visualization Gensler



Ill. 5. The final station International Airport In Denver – side view – visualization Gensler

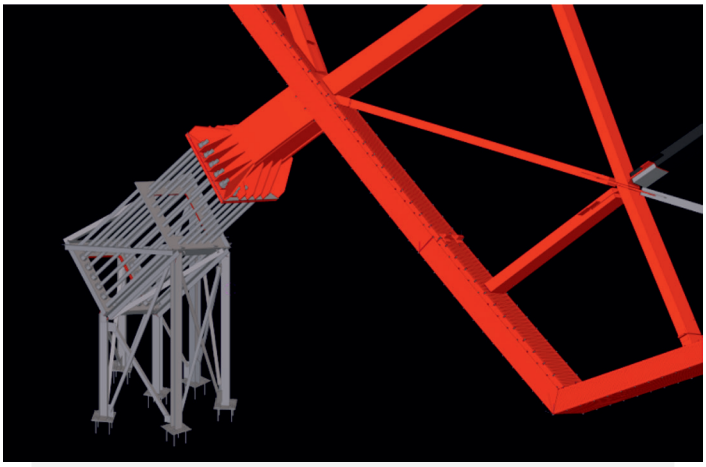


Ill. 6. Computer model of the steel roof structure – Anatomic Iron

5. Modeling and detailing

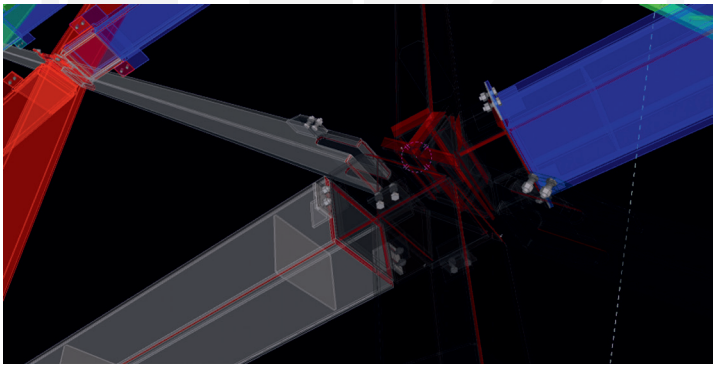
The process of detailing roof construction began by modeling bearing elements of the structure.

The first problem to solve was to fasten the steel structure of the roof to the foundation. The vault is supported on two massive foundation blocks and fastened at four points. The supporting planes are at a proper angle to allow fastening a steel box being an external contour of the solid. The forces exerted on the foundation are caused by a huge steel and glass overhang of arch cross section.



Ill. 7. Anchorage structure to the foundation – Anatomic Iron

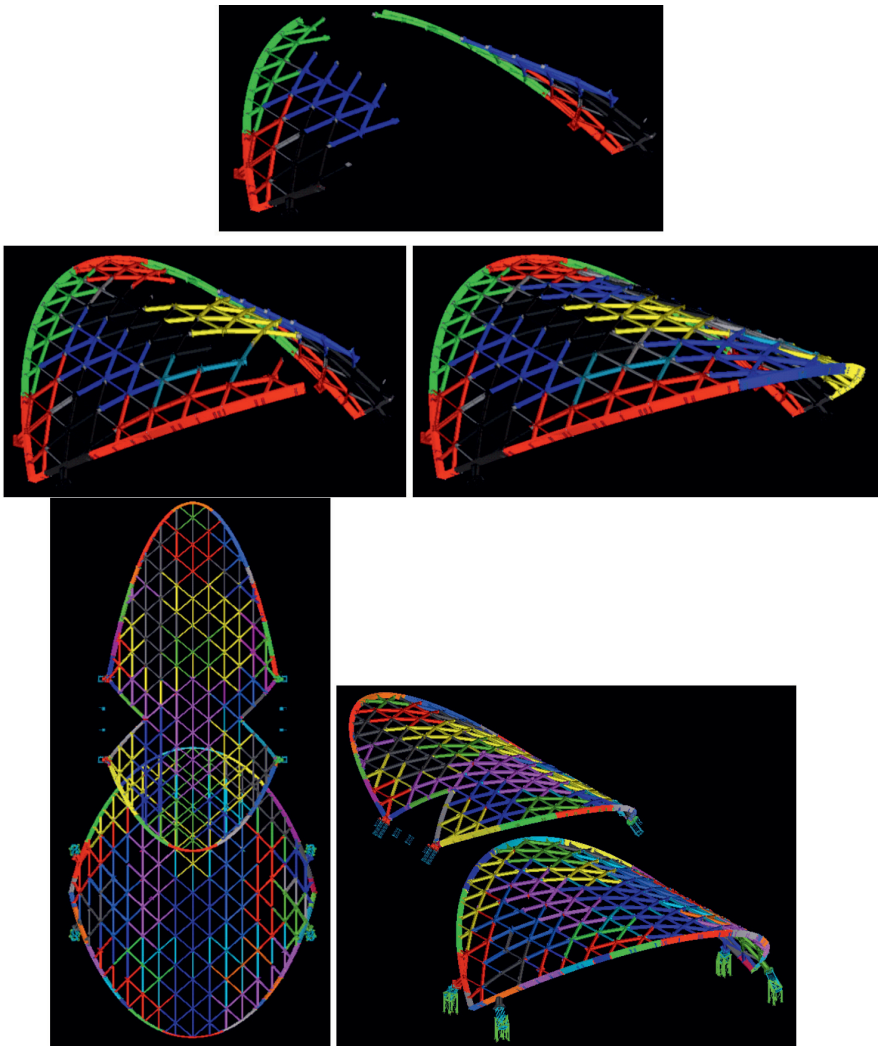
Because of the roof shape each bar is under a different angle. Each joint is individually considered and solved. Just creating a spatial model and checking whether the particular construction points are placed correctly was a great challenge for the Polish engineers. A great help in this was an advanced software programme, among others the Tekla Structures programme. It helped considerably in the designing and structure realization process. The engineers from Poland and the USA had to cooperate at all times. Creating a 3D model in Cracow took place simultaneously with making calculations in Denver. The two teams had simultaneous access to the same virtual model so that they were able to introduce changes (continuous mutual control helped to minimize the number of errors).



Ill. 8. Node – a combination of design elements – Anatomic Iron

Complications appeared when it came to determine the construction schedule. It became clear that the construction cannot be assembled in a random and comfortable way. Each detail of assembling was to be well thought over and planned with a precision rarely met in building today. Each step had to be made according to the previously established rules.

Particular construction parts, suitably cut, bent and prepared for assembling were then joined into modules which were next put together into larger units and assembled onto the earlier prepared elements. The process was to be well thought over, planned and checked. It was necessary not only to determine the sequence and depth of inserting the bars and joints, but also the angle of sliding the modules one over another.



Ill. 9. Installation steps – Anatomic Iron

Construction drawings, which are the basis for each construction work, proved insufficient. It was necessary to create animation, thanks to which the contractor is able to put up the bearing structure. The constructors, making use of Tekla Structures programme, planned and presented what the whole process should look like. Having analyzed it in detail, it appeared

that that a change in assembling just one small element may result in making subsequent bar assembling impossible. Then it was decided to create an animation on the basis of which the construction was made.

6. Fabrication

Steel profiles were specially ordered in a steelwork and are produced from high strength steel. Each element is cut, bent and prepared for assembling. The producer received the whole documentation in an electronic version. Thanks to the Tekla programme it is possible to generate all kinds of reports, lists and to compose especially enlarged files. They are compatible with the producer's machines. Owing to such a method each side can check whether the model is correct (3D) and correct mistakes. The precision of designing and realization here is remarkable.

Having suitably prepared particular elements they are joined into larger modules (earlier determined by the designers) on the building site. Such sets are then in their proper order (shown in the film) slid over one another to form one huge whole.

7. Final effect

After having set the modules, welding joints are made. Because of the demands and quality the object must acquire, the welds were worked and ground to make the final effect perfect.

8. Conclusions

The project will be completed in 2014. Then the whole group of Denver International Airport buildings will be opened. With new possibilities and achievements of science (computer programs, modern materials used in construction, development of computers), collaboration of specialists from around the world is possible and its results are structures that could not have been realized before. Assembling of the International Airport in Denver is one of many examples the effects of which bring a combination of experience with modernity and creativity.

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