Automatisation of the Integrated Experimental - Numerical Design Process

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1. Abstract

The complexity of the tensile structures design process, and the modern engineering practice requires stronger integration between its phases. The main goal of this work is to develop the possibilities of integration of the model research phase into whole design process.

The intention was to use digitised data about the shape of the model, for further: **a)** computer visualisation (commonly used for the architectural project presentation) done by CAD software, and **b)** form optimisation done by numerical analysis with assistance of FEM software. Digitised shape of the model is achieved by automatised topometric optical sensor. Output result is cloud of up to 400.000 point 3D co-ordinates. **Special method is developed for automatic selection of reference points which create numerical model suitable for further calculation.**

Accuracy and suitability of the method is tested on practical project for membrane roof covering.

2. Introduction

Simple physical models may be made already in the early phase of designing tensile structure, based on first scetches. They are very common models which are made out of an elastic net fabric such as this one on Fig.1:

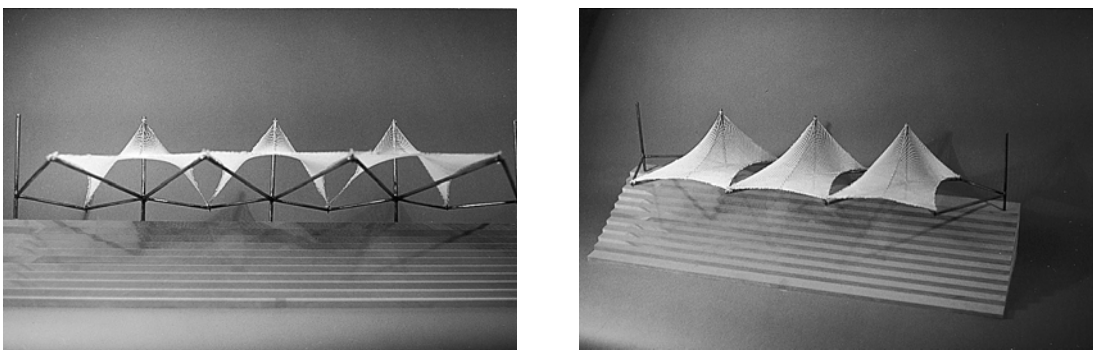


Figure 1.

Architectural model of a membrane roof

They are usefull, first of all, for architects who may be aided by them to check out the estetical characteristics of their ideas. At the same time, the models confirm that it is really possible to build a real structure of an approximately same shape.

Since the issue is about physical models it is not possible to use them in the later phase of designing, for which a digital data about the item which is being designed is neccesary. For that reason, photographs of such models have been used mainly for the presentation of primary project.

The basic idea of integrating physical models into the designing process lays on the the following hypothesis: in case it would be possible to get a 3-D shape of a model in the form of a data of surface points coordinates, the results could be used for: a) a computer visualisation and b) as a fundament for the final numerical form - finding and calculation. Throgh this method, already in the early phase of designing, it is possible to achieve very usefull "contuors" of the future structure (for visualising) and a quality link between the architect and civil engineer (... the integral process guarantees that the object a construction engineer builds will match the architects idea...) (Ref. 2)

The intention of our work is to show the application of our achievements on a particular problem - the grand stand roof of a football stadium in Zagreb (Fig. 2). The roof shall be made out of a textile membrane. The construction which carries the textile is steel. The size of particular membrane elements are 7 x 17 m.

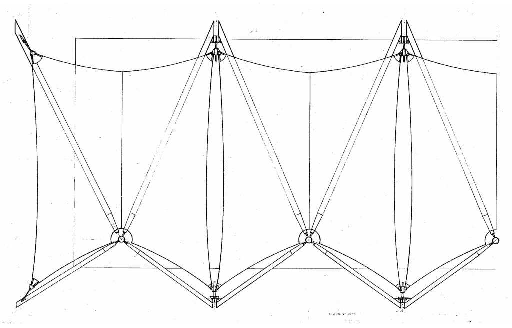
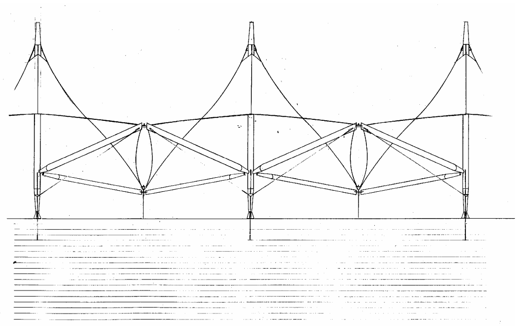



Figure 2.

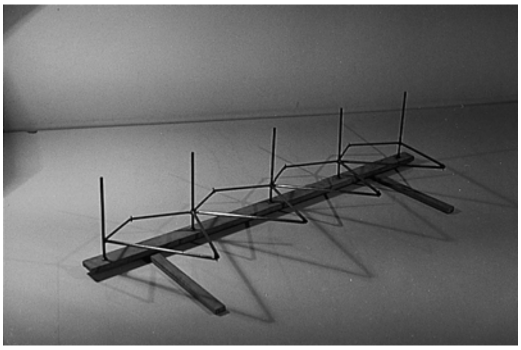
Architectural scetches of the grand stand roof of a football stadium in Zagreb

3. Procedure

3.1. Construction of the model

We tested our method on a model manufactured by the ussual method (Horst Berger - Light structures). We made it on basis of first architectural scetches of the construction (Fig. 2.) in scale 1 : 75. For the construction of the model we used steel bars for the carrying construction, and an elastic net textile for the membrane (the size of net spans is 2 mm when the textile is not strecthed).

The first step for manufacturing the model was making the steel girder (Fig. 3). Then we fastened to the steel girder an assisting surface which helped us to stretch the textile. On that surface we draw a plan of the membrane designed in the first scetches (Fig. 4.). After that we stretched the textile and fastened it to the assisting surface by pins. We drawed (copied) on the textile contours of the edges from the plan (Fig. 5). Then we put in some thread, along the signed edges, which were to represent the edge cables. We sewed the thread and tightened it partly (Fig. 6). At the end we cut off the excess of the textile and executed the final stressing of the thread in order to adapt the form of the structure to the aimed one (Fig. 7 - 8).



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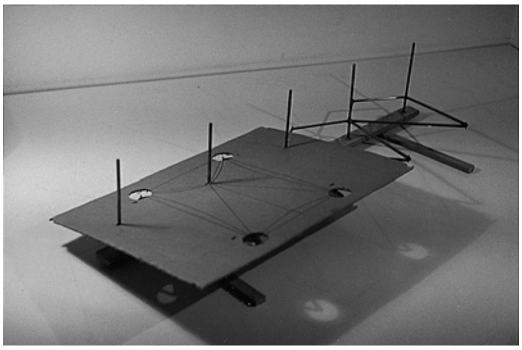

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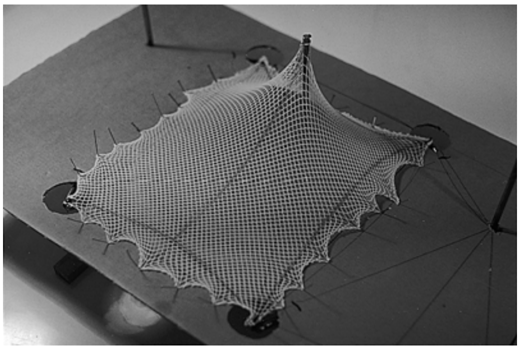

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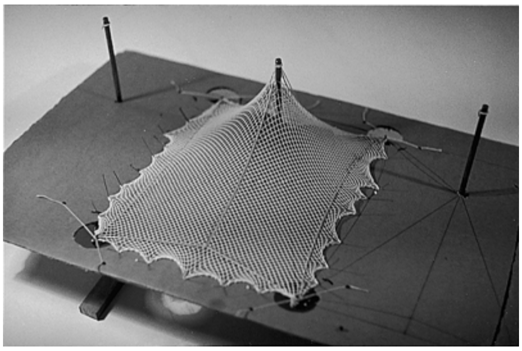

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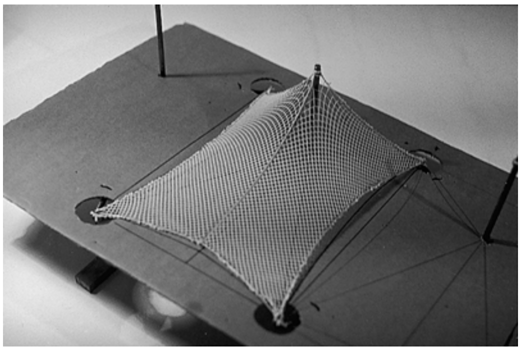

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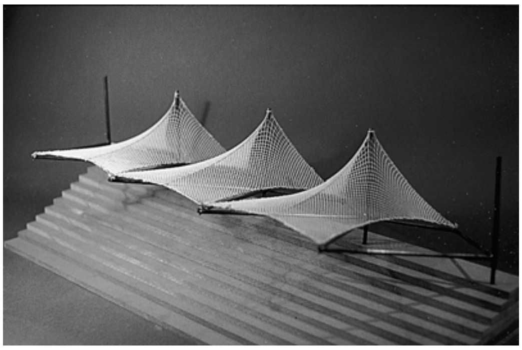


8.

Figure 3. - 8.

Creation of the model

3.2. Measuring procedure and processing the results

We measured the 3D model form by ATOS (Automatic Digital Topometric System). That is a system consisting of two CCD cameras and a projector which projects various fringe paterns onto the object surface. The camera records each of them. The records get digitized and are sent to the computer which calculates 3D coordinates for each of the camera pixel.

Before the measuring procedure takes place the computer automatically handles the system calibration (Fig. 9).

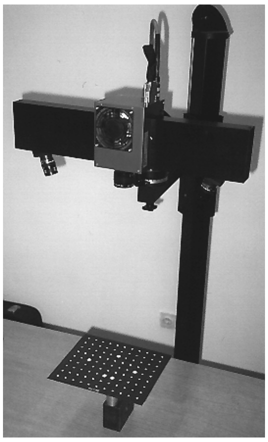


Figure 9.

Automatic calibration of the system

After the measuring procedure, in a short time, the result is a cloud - a file which in txt format contents the coordinates of all measured points (there were 120.000 of them in our case), which represent the digitized 3D model of the recorded object (Fig. 10).

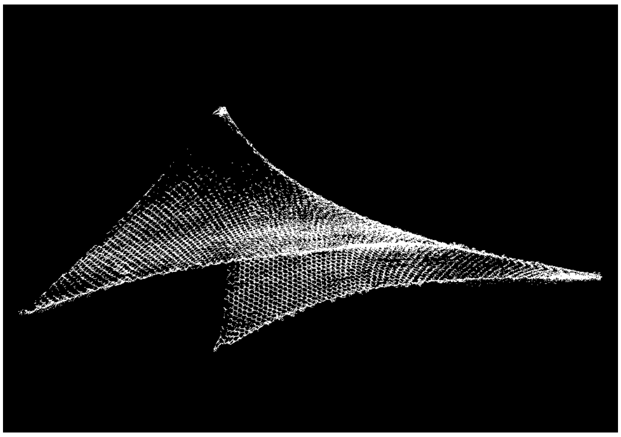


Figure 10.

Cloud

This technique of measuring is very fast and, thanks to the pleasant software surrounding, simple to use. The preciseness of measurement, in comparison to the preciseness of the model is even more than sufficient. However, the basic problems appear with data processing. The measured group of 120.000 points is too large (unfavourable) in order to serve for a net of final elements (which shall be used in further form-finding) or for usage during visualization in some CAD package.

Therefore, we developed a method which shall choose those points of a group which are nearest to the beforehand selected XY plane grid. That results with a reduced group of points, but with equal density which defines well the construction surface, as well as its edges.

Determing the scale and the coordinate system presents an aditional difficulty during data processing.

In order to solve that problem we used the system posibilities of ATOS - the possibility of measuring coordinates of model knots which were selected in advance. They are determined by placing the marker on the very model.

By comparison of the measured knots and their projected values, the method makes it possible to harmonize the scale and coordinate system of the experimental data with the project data, using the transformation stencil.

The final result of applying the method is a computer model of the surface which is usefull for further processing by some CAD or FEM package (Fig. 11).

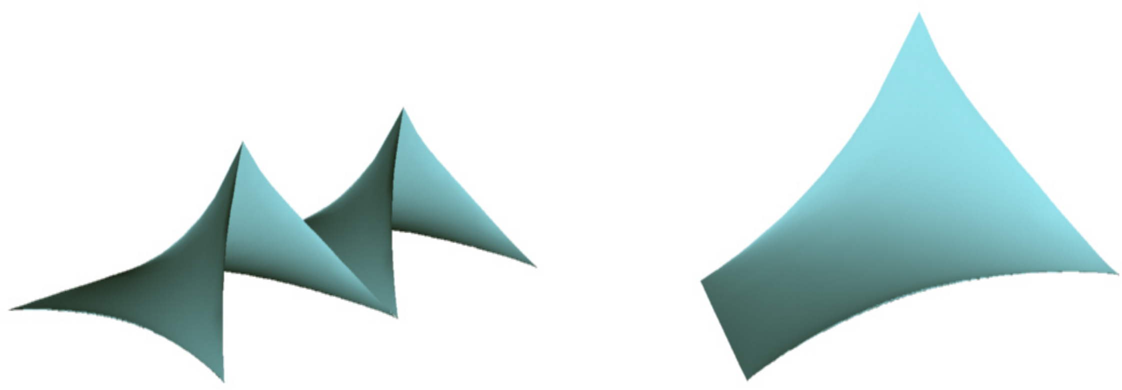
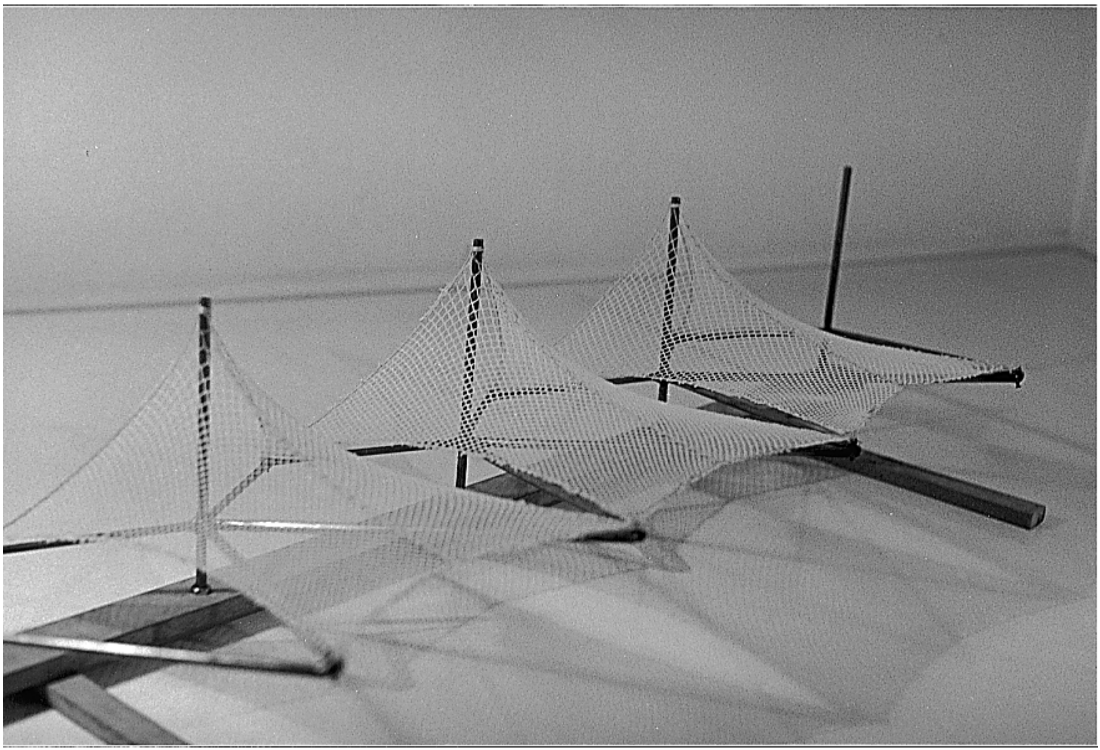


Figure 11.

Computer model – the final result of applied method

4. Conclusion

The complexity of the procedure of designing textile structures is a result of the fact that their shape is defined by mechanical principles on which a designer cannot influence directly. Therefore, the primary study is mainly worked out in detail by physical models. The integration of the model into the whole design process is possible by the use of the presented method.



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