ABSTRACT: This paper presents a methodology and results of a research project which subject was to simulate a construction of historical tower roof using computer technology. The objective of this paper is to demonstrate a potentially proper method of simulation that enables integration of historical, architectural and constructional procedures for creation of any construction. To illustrate and demonstrate these ideas results of a single case study of roof tower of Saint Elizabeth Church in Wroclaw are presented.

1 INTRODUCTION

The objective of this paper is to present a method for simulating by computer different procedures that go into the creation of tower roof of historical church. Problem of architectural and constructional modelling of this type of construction is directly connected with criterion and techniques for restoration. Any decision concerning restoration should only be taken after a careful diagnosis and evaluation of the safety of the structure in its present state. The extent and the nature of the actions must then be balanced so as to achieve the new required safety levels. The type of solution must derive from a consideration of the kind of actions that affect the building, the type of materials and the structural behaviour. The criteria for choosing a particular solution must take into account compatibility with the techniques and materials used in the construction of the monument and a regard for its original conception and historical value.

2 SHORT HISTORY OF SAINT ELIZABETH CHURCH IN WROCLAW

The Saint Elizabeth church was built in the beginning of the 13th century. Initially it was keeping in Roman style. However building of Gothic church in the form that preserved today is dated from first half of the 14th century. The Saint Elizabeth church has 68.2 m length and 34.4 m width. Non-symmetrical tower erected near south-west corner of church over its aisle, from centuries is very characteristic element of city's panorama. The tower was erected between 1482 and 1486 in keeping with an architectural building system characteristic of the Gothic era. The height of tower is 64.3 m. Initially tower roof had spire shape and height tower was 130.48 m. Unfortunately the highest construction of Wroclaw preserved only to 1529 because the roof fall down due to strong wind in winter of that year. During the period covering the years 1534 -1535 new Renaissance dome is erected. After this time the height of tower is 86.4 m. In 1960 the roof of tower was damaged due to thunderbolt. It was rebuilt in 1965. In 1975 and 1976 during the fires the roof of tower, wooden floors and supported construction under bells were completely damaged. The new roof and the strengthening of tower was designed by Engel and Pasit who worked in Institution of Preservation of Historical Monuments (Engel and Sieczkowski 1981). In the process of creation of the new roof tower did not use computer technique and took no account of
many very important constructional aspects that can be investigated through computer simulation of static and dynamic construction. The authors of this paper wanted to concern these aspects and present possibilities of computer technique that improve process of architectural and constructional modelling of historical buildings (Tidafi and Booth 1997).

Figure 1: Variant no. 1 of tower roof.
3 ARCHITECTURAL AND CONSTRUCTIONAL MODELLING OF TOWER ROOF

The design for restoration and retrofitting of historical masonry buildings is a difficult task for architects and engineers because a preliminary deep knowledge of the state of damage is necessary for a good choice of the intervention technique. During architectural and constructional modelling of tower roofs designers should take into account not only soil settlement, wind and earthquake but damage caused by their own weight, which can bring them even to collapse. The architectural and constructional design of historical constructions needs a preliminary investigation based on the geometrical and historical survey, the experimental and analytical study of the materials and of the structure. Survey procedures need to be set up in order to have an appropriate investigation for each case. The best tool in this process is computer technique that allow us to create many geometrical variants, present its architectural visualisation and test resistance of all construction. In the process of architectural and constructional modelling of tower roof of historical church the authors made the following procedures:

• Computer visualisation different variants of geometry of new roof tower using CAD system.
• Selection of the most favourable variant with the architectural and economical point of view.
• Creation of a numerical model of all construction.
• Computational calculations of resistance of main constructional elements using FEM take into account soil settlement, wind and earthquake actions and own weight.
• Finally design of main constructional elements with keeping of historical style.

The authors prepared 3 variants of geometry with differentiation on applied material (Figs. 1-3).

Figure 2: Variant no. 2 of tower roof.
Figure 3: Variant no. 3 of tower roof.
Figure 4: Construction of tower for variant no. 1.

The most favourable variant in architectural and economical point of view was assumed variant 1 in which applied reinforced concrete and steel (Figs. 1, 4).

Numerical analyses were carried out to evaluate the state of stress and strain in the first variant of masonry tower. The tower was modelled by FEM under three load conditions: 1) dead loads, 2) wind, 3) soil settlement. The compressive stresses due to the dead load increase from the top to the bottom with the concentration at the edges where they reach 2.4 N/mm$^2$. The wind action increases the values on the east side by 0.35 N/mm$^2$. For a more realistic approach, the modulus obtained in the unloading-reloading branches of the tests was calculated. The value assumed in the analysis was 3600 N/mm$^2$ and giving a very close match to the first frequency (0.625 Hz). A
first dynamic analysis was made applying an harmonic force calculated from the movements of mass of the bell, in the form: \( F = F_h \sin(2 \pi f t) \).

4 CONCLUSIONS

The design for restoration of historical monuments using computer technique carried out in different steps starting from a preliminary investigation based on the geometrical and visual survey. The experimental and analytical study of the materials and structure is also a very important step. The objective of this paper was presentation a method for simulating by computer the different procedures that go into the creation of tower roof of historical churches. Most available computer technologies that are used for representing historical buildings are derived from drawing techniques. The important proposition of this paper is that correctly selected and implemented computer technology can help rectify the shortcomings of present architectural representation and constructional procedures.

REFERENCES