RESULTS OF ENGINEERING ANALYSIS FOR THE RESTORATION OF ST. BASIL'S CATHEDRAL (TEMPLE OF BLESSED VIRGIN'S COVER ON THE DITCH) IN THE RED SQUARE, MOSCOW.

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The preservation of historical and cultural monuments in our country is a task of great responsibility and complexity, which may be accomplished only based on a thorough examination of their current condition. One of the basic constituents of this process is a comprehensive engineering research, including land measuring, site exploration, basement and foundation inspection, examination and calculation of the bearing structures.

Presently, Kreal, a specialized company, carries out a comprehensive examination of the restoration process of the St. Basil Cathedral " Temple of Blessed Virgin's Cover on the Ditch" along the above-indicated lines. The work is carried out on the basis on state-of-the art technologies and engineering tools.

All engineering and land measuring works are performed using electronic land measuring equipment, which helps to develop a comprehensive concept of the structural condition and identify the peculiar features of its architectural and constructive solutions. Examination of the base and foundations, as well as other engineering land works include electric-contact dynamic reconnaissance of the ground, seismological probing of the foundations, seismological prospecting of the upper part of the ground and deep radar profiling.

The structure and current conditions of the Temple sections are determined through a detailed visual examination thereof with a view to the establishment of parameters of the cracks and other damages with the help of acoustic facilities. Testing of the mechanical properties was carried out by non-destructive methods with the help of Smidt hammers (made in Switzerland), which were designed specially for ceramic tiles and similar solutions. The search for interstices and channels in the masonry was carried out with the help of Russian-produced radars; and the identification of metal components and their positions – with the help of electromagnetic probing with the use of Profometre 4; geophysical studies of the internal masonry layers – with the help of exclusive domestically-produced tools. The architecture of the Cathedral is based on a clear-cut construction scheme – the posterior temples are located on a high landing along the basic diagonals as seen from the central tower. Four square-like churches adjoin the central temple corner wise. The landing of the temple is comprised of a massive base of pillars, which are interconnected by corridors.

Based on the results of our engineering and land measuring work, we have developed a three-dimensional digital model of the Temple (see Figure 1), which gave us a new vision of the concept based on which the Temple has been built. Primarily, all the surrounding pillars of the temple are slightly inclined towards the central pillar. Secondly, the geometrical centers of the pillars and landing do not coincide. Naturally, we have concluded that it happened due to an inadequate pre-construction layout. However the landing calculation made with due account of the window and door embrasures showed that the pillar axes closely coincide with the gravity centers of the landing sections. Therefore we assumed that in the 15th century builders deliberately shifted the geometrical axes of structures (see Figure 2). We have undertaken a thorough examination of the position of the bell tower, which has a noticeable inclination. In 1951 Mosgorgeotrustcom tried to determine the degree of the inclination; the obtained result was that the shift from the stylobata cornice axis up to the "apple" made 790 mm and 2° verticality deviation. The results obtained by KREAL basically coincide with the results of Mosgorgeotrustcom (2°09'); so, a conclusion was that, at present, the belfry position has stabilized.

Based on the results of our in-depth seismological prospecting, as well as the archive materials, we inferred that the engineering and geological conditions of the site have the following geological – lithologic structure: the surface is made up of 2 – 18 m-thick fill-up soil, underneath are predominantly alluvial 12-m - thick friable sands. One of the unfavorable features of a geological structure of the site is that it is located on a steep slope of a preglacial valley with a degraded Jurassic aquiclude. In the framework of this research the surface and underground waters were not stripped to the depth of 14 m from the surface of the earth. There is a strip foundations under the walls of the building made of mortared limestone crushed rock and ashlar. In some areas the Temple foundations partially rest on previously-erected structures. The foundations are formed by fill-up soils and mostly loose sands. The state of the "foundation-soil" contact is unsatisfactory.

Significant deformations have been identified, which may have been caused by the hetergogeneity of the foundation ground, presence in the base of older buried foundations, uneven load distribution in different areas and an ongoing sand boil process. The analysis of the research results shows

that the base deformation process continues and may cause a further deformation of the building components.The study of the building construction showed significant structural changes, which occurred in later periods; some of these changes have not been reflected in the available historical – archive materials. In particular, in the garret the traces of a previously built brick vault were identified; the time, when this vault had been built is unknown. Six 60 x 60 forged steel frames were installed in order to support the pillars. One of the most interesting and complex constructive solutions is the "flat" brick ceiling in the north-west part of the temple, which is located under these frames. The ceiling brickwork is made up of small-size vertical spirally-laid brick. At several points the ceiling has been suspended so that the control-rods are directed towards the steel forced horizontal rods (see Figure 3). In the structures of the Temple there are multiple cracks of up to 40 mm (see Figure 4). The coating of the internal gallery has been almost destroyed, the majority of the vaults are supported by wooden poles, which are corroded by the wood-grinder. The majority of cracks are concentrated in the western part of the building along the perimeter of the central pillar, which looks like a foundation failure. The largest cracks are located along the conjunction lines between the separate parts of the building. Besides, we have identified vertical cracks in the pillar walls; the reasons for the appearance of these cracks is yet to be found.. The study of the cracks demonstrates the most intensive formation falls was in the 1950s and then the crack formation process slowed down but did not stop. The measurement of the vibrational amplitude in the structures showed that the impact could not adversely affect the durability of the structures. Based on the geological and physical research it can be concluded that in numerous areas the durability of the internal masonry layer is lower. Based on the research it can be inferred that, despite the numerous defects, the basic structures of the Temple walls, landing and group floor overlaps are not in the state of emergency; the coating however is in a state of emergency. It should also be noted that there are no data on the biochemical and physiol-chemical research. Such research is only in its initial stage beginning and the results may be quite interesting. In particular, the said research may help to explain the emergence of the vertical cracks in the pillar masonry.

It appears reasonable, after the completion of the comprehensive engineering research, to carry out a detailed calculation of the Temple as a single "building – base - foundation" system with due account of the existing damages. We believe that an approach based on the initial examination and structure calculation would provide optimal solutions as to the restoration of the St. Basil's Cathedral "the Blessed Virgin's Cover on the Ditch" in Red Square in Moscow.

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Natalia M. Almazova has been elected to membership of the International Association of Quality Practitioners (Great Britain) in the grade of Fellow in 28 July 2000.


Figure 1

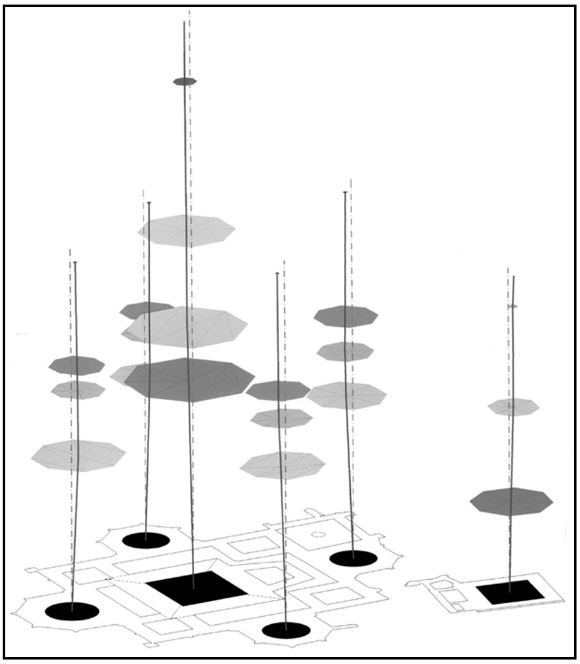
Figure 2

Figure 3

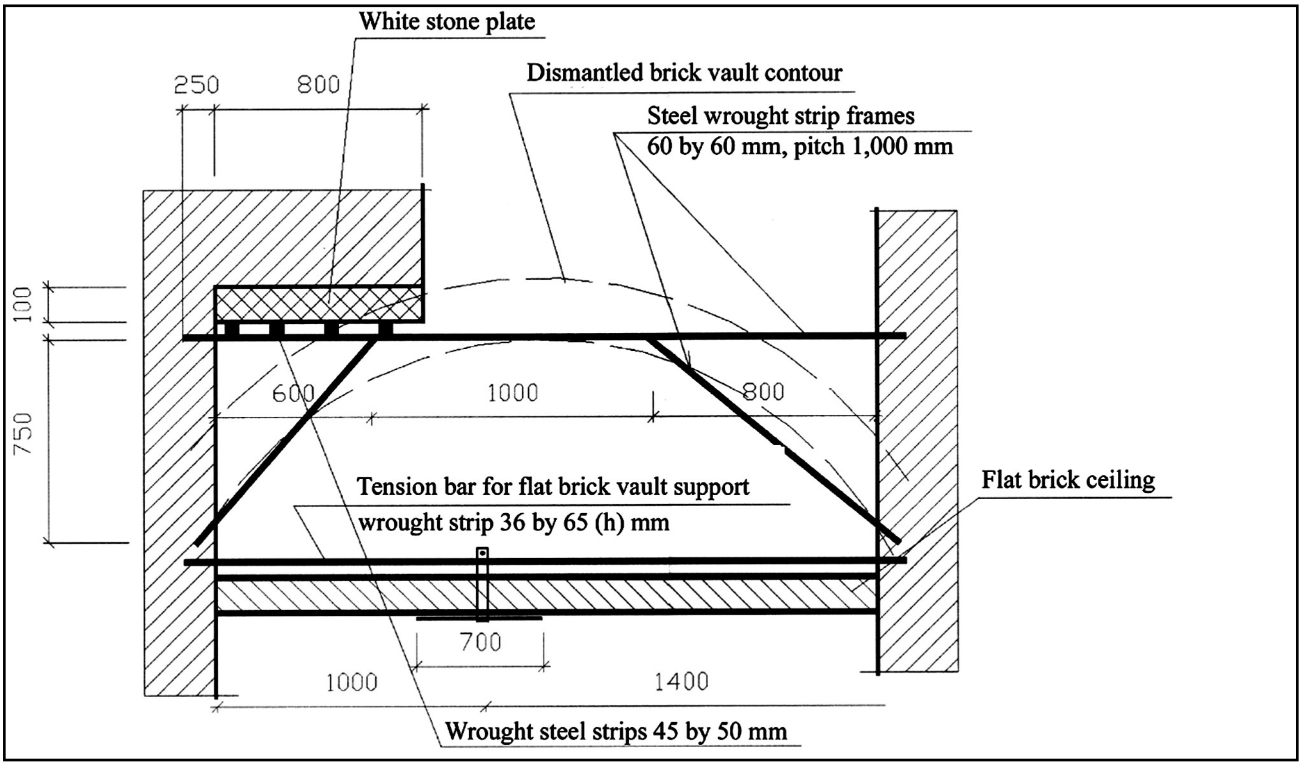

figure 4