Using modern CAE systems for assessing the building structures made of traditional building materials technical condition

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Abstract. Modern "computer-aided design" (CAD) systems allow to process difficult researches on building structures of buildings and constructions. Program complexes, allowing to calculate and get performance predictions of materials and constructions made from them, considered as CAE (Computer Aided Engineering). CAE systems are used not only for creating and researching new materials, but also widely used for rating of traditional material condition. For brick chimney technical condition research program complexes SolidWorks and «Lira-W» were used. Using these calculation complexes structural rigidity, brickwork structures strength ratings were made, the need for taking measures to strengthen the construction was set. Using numerical researches, hazardous locations were identified along the height of the structure. For hazardous locations, a comparative analysis of obtained values of stresses in masonry was carried out in two calculation complexes.

1. Introduction

Materials, for example, brick, wood, concrete, metals [1-4], being used for long time, are considered traditional. Besides traditional materials, there are materials with upgraded properties, made, using new making knowledge and using scientists achievements, for example, polymers, plastics, reinforced plastics, composites and others.

Modern hardware and software allows to make researches on materials virtually. This allows to reduce time and material resources for producing experiments. Program complexes, allowing to produce calculations and get performance predictions of materials and constructions made from them, considered as CAE (Computer Aided Engineering). CAE systems are used not only for creating and for researching new materials, but also widely used for rating of traditional material condition.

Well-known program complex SolidWorks with calculation core CosmosWorks allows to produce structural and dynamical analysis of mechanical systems, simulated on the basis of solids. Results of brick chimney analysis in program complex SolidWorks are presented further.

2. Materials and methods

A brick pipe with 37.5 m height, scheme of which is presented on figure 1 was an object of our research. This structure was built more than 120 years ago. This structure is octagonal column with
29.5 m length, set on square pedestal with 8 m height. Structure is made of ceramic brick on concrete mortar. Trunk of structure has taper about 100. Side of the structure is 5.2 m. Low octagonal section of the column fits into a circle with a diameter 4.82 m; High section circle with a diameter 4.28 m (figure 1).

Researched structure was reconstructed, as a result, the octagonal trunk was enlarged by adding a 10 m high cylindrical part. The outer diameter of pipe cylindrical part is 3 m. Cylindrical part of the pipe was strengthened with steel rings.

During exploitation in pipe brickwork cracks appeared. The structure was researched several times, as a result of which was noted, that crack development increases due to time and amount of them increases. Taking into account the known information cracks develop due to difference of temperatures in brickwork cross-section. There is no excess pressure on pipe walls from exiting gases.

Authors made a visual-instrumental inspection of the pipe, took samples of brick and mortar, performed laboratory tests of their strength and made a conclusion on the remaining strength of the materials. For remaining load-bearing capacity of brickwork estimation numerical researchers of structure were made. Researches were made in two options: 1) not taking into account effect of cracks on the load-bearing capacity of brickwork; 2) taking into account reduction of the load-bearing capacity of brickwork. The influence of cracks on the strength of brickwork was taken into account.
using a decreasing coefficient to the brickwork load-bearing capacity, defined using recommendations [5]. This document contains brickwork strength reduction methodology due to presence, quantity and nature of damage.

The structure was subjected to dynamic and static analysis. Analysis of pipe were made using two program complexes «Lira-W» and CosmosWorks. As a result of pipe dynamical analysis own oscillation frequencies, volumes of inertial loads, reactions of system to them and deformation of structure were defined. As a result of static analysis of structure, displacements of calculation model nodes, the magnitude of internal efforts from action of calculated loads and their combinations, stresses in brickwork were defined.

The analysis of structure for pulsating load from the wind was carried out according to the methods set in regulatory documents [6, 7]. During using «Lira-W» program, pulsating load from wind was defined by algorithm of this program. Program complex «Lira-W» contains module, which calculates load from wind using documents [6, 7]. For using this module it is necessary and enough to input the following information about calculation model into program complex:

- weight of masses;
- construction characteristics (height, characteristic size of the part blown by the wind, etc.);
- terrain characteristics (type of terrain, wind area);
- surface characteristics (oscillation logarithmic decrement).

Computer automatically calculates value of wind load for required amount of oscillation forms and defines inertial reactions of system from their effect. As a calculation scheme for analysis of researched object in program «Lira-W» a simplified model was used.

Calculation model was a rod system with elements, rigidity of which was taken different for each new level along height of the structure (figure 2).

Figure 2. Pipe calculation scheme using "Lira-W".
Structure calculations using CosmosWorks was made for two types of analysis:

1. Modal analysis, as a result of which three first own oscillation forms of structure were defined (calculation scheme figure 3.a);

2. Static analysis, as a result of which the stresses and deformations of the structure from total effect of constant loads, static and ripple components of wind load were defined (calculation scheme figure 3.b).

![Figure 3](image)

Figure 3. Calculation scheme of the structure in the CosmosWorks:
a. For modal analysis; b. For static and dynamic analysis

3. Results and discussions

Controlling calculations of the structure were carried out according to two design schemes of the structure: for a centrally compressed rod (without wind - calm) and for a compressed-bent rod (with maximum total values of the static and pulsating components of the wind pressure). Analysis were made considering instructions [8] using recommendations [9, 10]. Structure brickwork strength test was made on the most hazardous cross-sections. For this structure three hazardous cross-sections were chosen. These cross-sections have the minimal size of brickwork, major weakening or extreme
stresses. For controlling calculations were used three cross-sections on heights: 0,000; 8,000; 37,500 (figure 4).

For selected hazardous locations, stress calculations in masonry were performed. For hazardous locations, a comparative analysis of the obtained stress values in masonry was performed for two calculation complexes. For research, the «Lira-W» and CosmosWorks calculation systems were used. The calculation results are presented in tables 1 and 2.

![Figure 4. Hazardous cross-sections of the pipe, chosen for controlling calculations.](image)

**Table 1.** The calculation results of the facilities under the Lira-W program.

| Section level | Design efforts, KN | The bearing capacity of brickwork, KN |
|---------------|--------------------|--------------------------------------|
|               | Not taking into account the effect of masonry cracks on reducing its strength | Given the effect of masonry cracks on the decrease in its strength |
| 37,000        | 432.3              | 1931.4                               |
|               |                    | 1190.7                               |
|               |                    | 1450.6                               |
| 8,000         | 6842.4             | 10770                                |
|               |                    | 8109.8                               |
|               |                    | 8077.4                               |
| 0,000         | 9311.4             | 18162.5                              |
|               |                    | 14901.9                              |
|               |                    | 13622                                |
|               |                    | 11176.4                              |

**Table 2.** The calculation results of the facilities under the CosmosWorks program.

| Section level | The calculated stress, KPa | The compressive strengths of masonry, KPa |
|---------------|----------------------------|------------------------------------------|
|               | Not taking into account the effect of masonry cracks on reducing its strength | Given the effect of masonry cracks on the decrease in its strength |
| 37,000        | 180                        | 210                                      |
| 8,000         | 660                        | 680                                      |
| 0,000         | 1152                       | 952.7                                    |
4. Conclusions

Due to analysis results following conclusions were made:

1. Rigidity of construction is enough for normal using of object.
2. Possibility of vortex excitation (resonance) for considered structure doesn't exist for three first own forms of oscillation.
3. The strength of the structure without taking into account the decrease in the load-bearing capacity of the brickwork with cracks is provided along the entire height of the structure.
4. Taking into account the decrease in the load-bearing capacity of the brickwork, due to recommendations [11], brickwork strength is not provided in low quarter along the height of the octagonal pipe (from level +8,000 to level +15,000).
5. Recommendations on improving strength of structure were developed basing on made analysis.

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