

THE INFLUENCE OF LOCAL DIMPLES ON THE FUNCTION OF BEARING SHELL CYLINDRICAL HIGH-RISE STRUCTURES

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Abstract. *Areas with various defects and damages, which reduce carrying capacity, were examined in a study of metal chimneys. In this work, the influence of the local dimples on the function of metal chimneys was considered. Modeling tasks were completed in the software packages LIRA and ANSYS. Parameters were identified, which characterize the local dimples, and a numerical study of the influence of local dimples on the stress-strain state of shells of metal chimneys was conducted. A distribution field of circular and meridional tension was analyzed in a researched area. Zones of influence of dimples on the bearing cover of metal chimneys were investigated. The bearing capacities of high-rise structures with various dimple geometries and various cover parameters were determined with respect to specified areas of the trunk. Dependent relationships are represented graphically for the decrease in bearing capacity of a cover with respect to dimples. Diameter and thickness of covers of metal chimneys were constructed according to the resulting data.*

1 INTRODUCTION

A survey of a series of metal chimneys showed that many chimneys operate with various defects and damages, thus reducing the load carrying capacity. This paper shows the influence of local dimples on the function of metal chimneys. Parameters were identified, which characterize the local dimples. Additionally, results of numerical research on the influence of local dimples on the stress-strain state of cylindrical shells of metal chimneys are provided. The researched areas consist of distribution fields of circular and meridional tension. Zones of influence of the concavity on the bearing shell of metal chimneys and also the carrying capacity of high-altitude areas of the trunk of cylindrical structures with different geometry and the concavity of the various parameters of the investigated cylindrical shell were identified. Loss of stability (buckling) was investigated for studied sites. Diagrams of dependence of reduction of bearing capacity of cylindrical shells from the extent of concavity, diameters, and thickness of shells of metal chimneys, were constructed from the received data.

2 RESEARCH TOPIC

2.1 Relevance of the Research

Metal chimneys are used in different industries, but are particularly widespread in the energy industry. A metal chimney is a high-rise sheet construction, intended for the removal of exhaust gases into the atmosphere for further dispersion. Geometric deviations include concavity and the eccentricity of docking drawer side and ellipse form, which reduce the carrying capacity. These areas are the foci of this study of metal chimneys. These geometric deviations or their combination can cause a decrease in efficiency, or lead to the destruction of the site or of the whole structure. These effects can not only have great financial impact, but they can also result in casualties. The existing principles of design for metal chimneys as compressed-bent rods does not account for the influence of geometric variations on the stress-strain state. By modeling the chimney shell as a cantilever rod, we cannot take into account the reduced tension in the area with geometric deviation. For example, reducing the cross section and then calculating the resistance of the steel indirectly.

It is difficult to estimate the influence of geometric variations on the stress-strain state of such structures in the normative literature [1, 2, 3], but there are indications of the need for such accounting in the design of structures. This fact requires a precise professional knowledge of the real work and the stress-strain state of this type of structure. Research in this area would develop new and improved engineering methods for calculating local stresses and considering their influence on the overall stress-strain state of the structure.

2.2 The Object of the Research

The objects of the research are areas of chimneys with geometrical deviation in the form of dimples. As a constructive solution, metal chimneys are divided into free-standing elements, supported by braces or rigid braces, or in a lattice frame (extraction tower). The main types of constructive solutions for metal chimneys are shown in Figure 1.

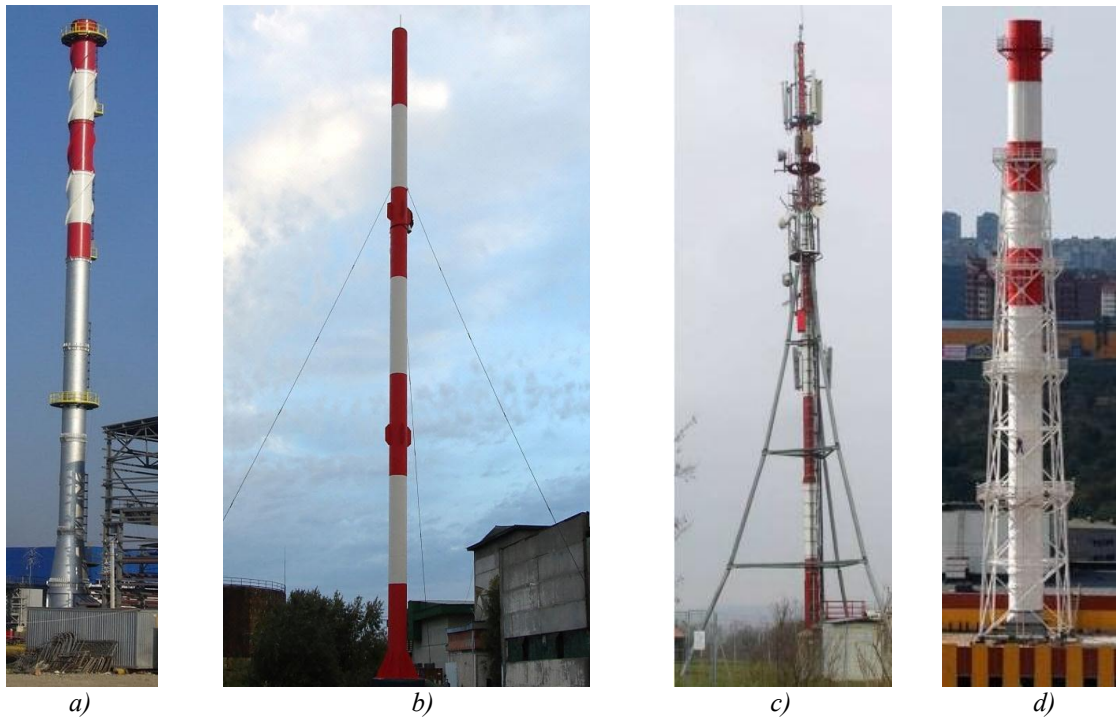


Figure 1. The main types of constructive solutions for metal chimneys. a) freestanding; b) with braces; c) with rigid braces; d) in a lattice frame;

Geometric deviation of this type of structure translates to deviation of the actual shape of the object from the ideal (reference). This research will consider one of the types of geometric deviations - the concavity of the shell of metal chimneys.

Concavity of shell structures for the deviation is defined by the deviation of the actual profile from the ideal. When this occurs, points of the real profile from the adjacent segment expand from the edges to the middle. (Figure 2)

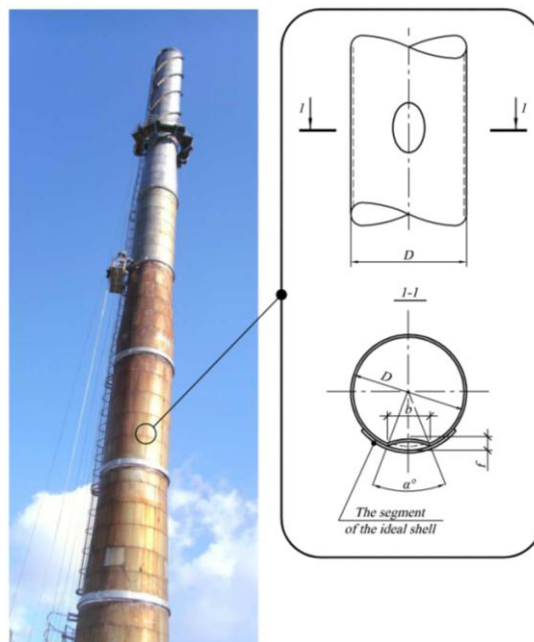


Figure 2. General view of the site with the dimple of the shell of metal chimney

The concavity is characterized by the following parameters:

- An angle of coverage of the concavity (α°)
- Opening width of the concavity (b)
- Depth of the lesion (f)

2.3 Purpose of the Study

Analysis of the influence on the local concavity of the stress-strain state of metal chimneys and the improvement of engineering methods of calculation of such structures, taking into account the local concavity.

2.4 Research Task

- To characterize the geometric parameters of the concavity;
- To determine the influence of geometry of the concavity on the stress-strain state of cylindrical shells;
- To determine the carrying capacity of the trunk sections of high-rise structures with different concave geometry, and with various parameters of the investigated membranes.

2.5 Method of Study

This paper will examine the influence of the concavity of the high shell and the shell of medium length, which, according to [7] chimneys with a ratio of length L to the radius r and equals $L/r > 20$ relate to. Metal chimney with a height of 60 m with different parameters of the diameter and thickness of the shell was investigated in this work.

To solve this problem, computational schemes in the software packages Lira (The Ukraine) and ANSYS (USA) have been developed. The calculation was performed taking into account the wind load with characteristic value, which equals 600 Pa according to [4], and also taking into account the self-weight of the structure.

Four settlement schemes were compared to determine the stress-strain state of the stack.

The first computational scheme is adopted as a cantilever rod with an analytical calculation according to [4];

The second computational scheme is adopted as the dimensional sheet structure with analytical calculations according to [4];

The third computational scheme is adopted as the dimensional sheet structure in the form of a perfect shell in the software package ANSYS.

The fourth computational scheme is adopted as the dimensional sheet structure in the form of a perfect shell with a local dimple.

Local dimple takes the size $150 \times 150 \text{ mm}$ and depth of the concavity equal to the shell thickness (t). The location of the dimple - 0.5 m from the base of the compressed shell of the chimney - was chosen as the most unfavorable (Figure 3) according to calculations by the third calculation scheme (Figure 4).

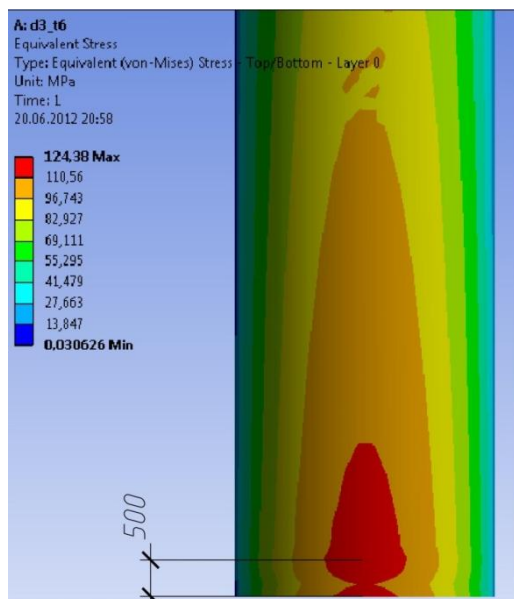


Figure 3. The zone with the proof stress (calculation of Ansys)

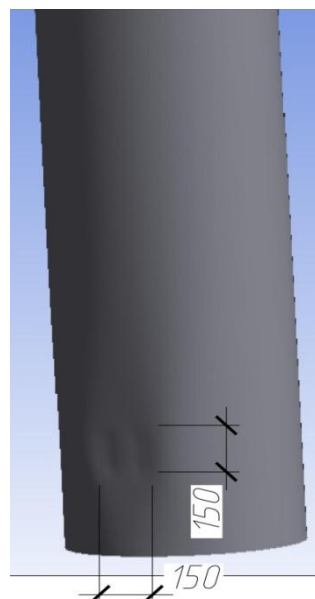


Figure 4. The general form and location of the dimple

Analysis of the stress-strain state of the four calculation schemes showed the next proof stress given in Table 1.

Table 1. The proof stresses in the chimney for different variants of calculation

Ø, mm	t, mm	Core model	Sheet construction	Sheet construction (Ansys)	Sheet construction + dimple
		σ , MPa	σ , MPa	σ , MPa	σ , MPa
2400	6	193,1	167,8	179,2	315,2
	8	146,5	125,1	134,2	275,4
3000	6	125,3	105,1	116,4	209,1
	8	95,6	81,2	87,5	170,8

Stresses by the third calculation scheme were taken as a standard, because the computational scheme was most appropriate for the ideal structure. Modeling the chimney as a cantilever rod, the technique presented in [4] is therefore used to calculate the chimney at the design stage. This calculation shows excessive stress of about 10% margin. In the zone of the local dimple, bursts of local stresses were observed. The stresses of these bursts were twice as high as the standard calculation scheme and were not included in the calculation of the first and second design schemes.

3 FEATURES OF THE STRESS DISTRIBUTION IN THE CONCAVITY ZONES

The software package LIRA was used for the numerical investigation of the influence of the concavity on the stress-strain state of the metal chimneys. Qualitative changes in the stresses of the concave chimney shell were obtained (Figure 5). On the basis of these results,

the stress distribution on the ring of the shell was constructed (Figure 6) and the height of 4 m of the computational model of a cylindrical shell (Figure 7).

Characteristic of the object: $D = 3M, \alpha^\circ = 10^\circ$

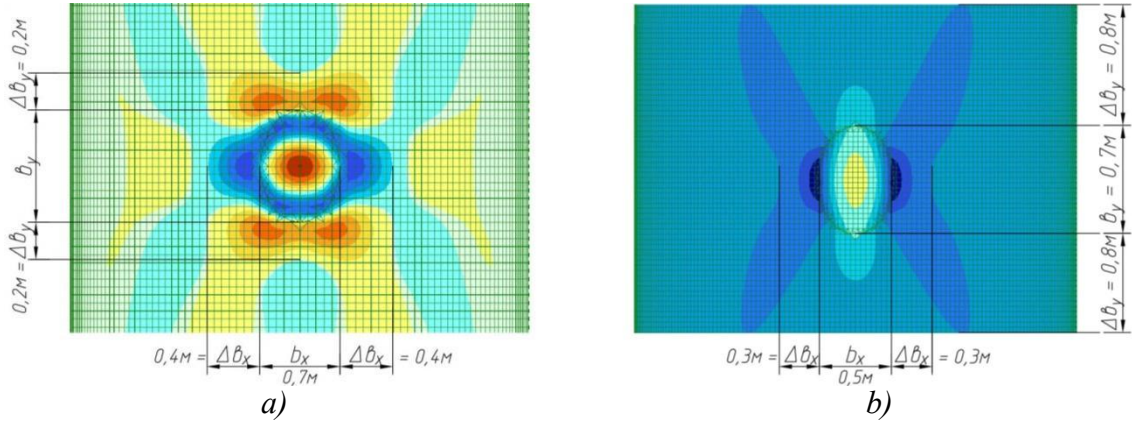


Figure 5. Changes in stresses on the concave part of the shell. a) circular strain (σ_x); b) meridional strain (σ_y)

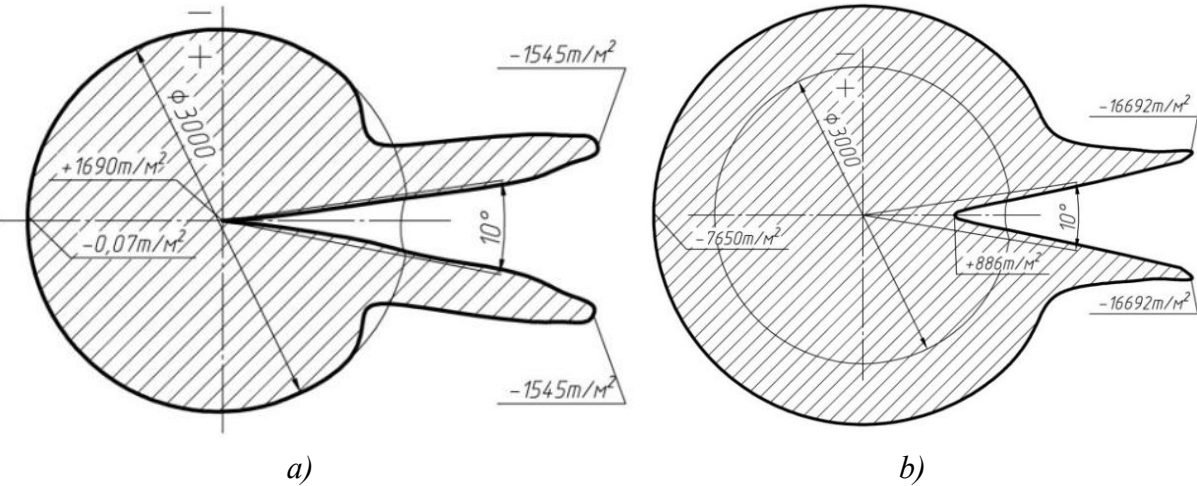


Figure 6. The stress distribution on the ring of a cylindrical shell. a) circular strain(σ_x); b) meridional strain (σ_y)

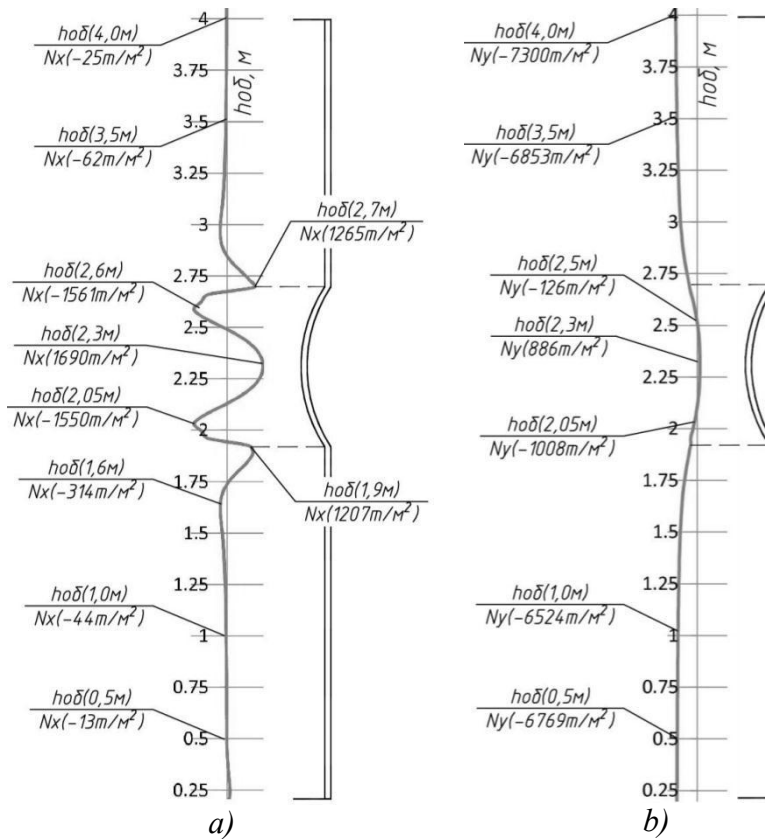


Figure 7. The stress distribution on the height of the computational model membranes. a) circular strain (σ_x); b) meridional strain (σ_y)

From these results, we can see that local stress peaks occur in concaved areas of the chimneys' shell. We also can conclude that the stress peaks at an angle of coverage of the concavity of $\alpha^\circ = 10^\circ$, observed at a distance of $0.2m$ to $0.8m$ from the boundary concavity.

3.1 The Stress-strain State Chimneys with a Concave Shell

Establishing the dependencies of influence of various factors on the stress-strain state of parts of high-rise structures with a concave shell.

Matrix of research:

D, m	1.2	1.5	1.8	2.1	2.4	2.7	3	3.3	3.6	3.9	4.2
t, mm	4	6	8	10	12	14	16				
α°	10	20	30	40	50	60					

1. Dependence of the stress σ_{pr} on the diameter (D_{shell}) of the computational model on the site with the concave shell (Figure 8).

The initial parameters of the calculation: $D_{shell} = 1.2 - 4.2m$ with a step $0.3m$, $t_{shell} = 10mm$, $\alpha^\circ = 10^\circ$.

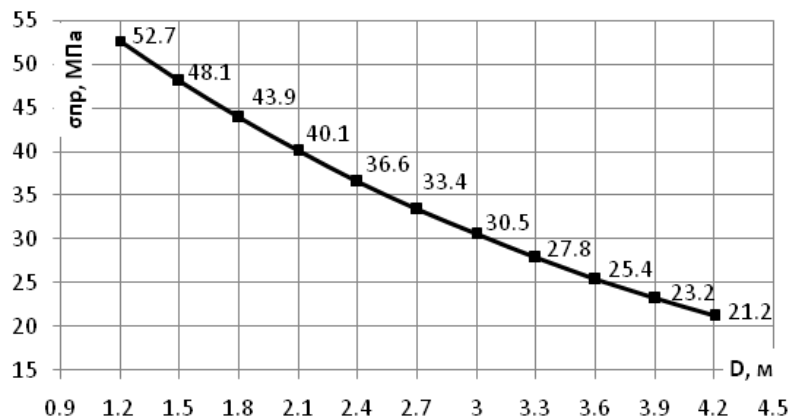


Figure 8. Change in stress (σ_{pr}) from the diameter of the computational model

2. Dependence of the stress σ_{pr} of thickness (t_{shell}) of calculation model in the section with the concavity of the shell (Figure 9).

The initial parameters of the calculation: $D_{shell} = 2,1\text{m}$; $t_{shell} = 4 - 16\text{mm}$ with a step 2mm .

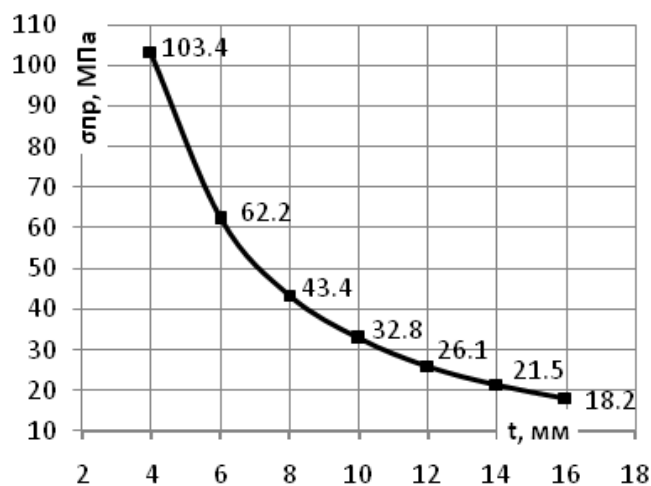


Figure 9. Change the stress (σ_{pr}) from the thickness of the computational model

3. The dependence of the stress variation from the angle of coverage of the concavity (α°) (Figure 10)

The initial parameters of the calculation: $D_{shell} = 2,1\text{m}$; $t_{shell} = 10\text{mm}$, $\alpha^\circ = 10^\circ - 60^\circ$ with a step 10° .

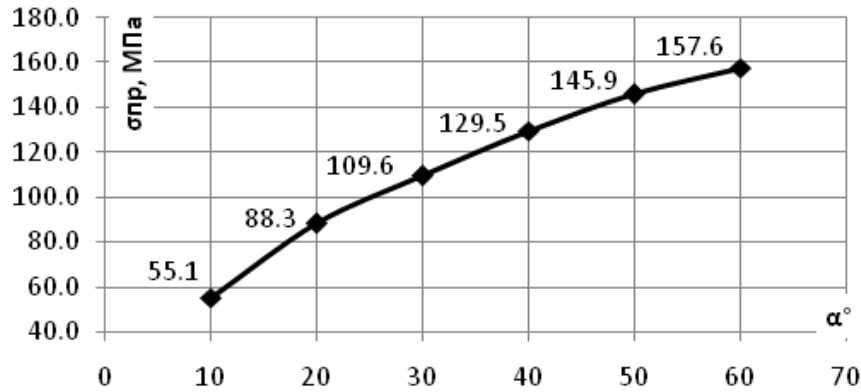


Figure 10. Change in stress (σ_{pr}) from the angle coverage of the concavity

The calculations revealed that:

1. The influence of concavity is reduced with increasing diameter of the computational model; approximating curve has a quadratic dependence of the results given by the formula $\sigma_{pr} = a + bD_{shell} + cD_{shell}^2$.
2. The influence of concavity is reduced with increasing thickness of the computational model; approximating curve of the results has the dependence: $\sigma_{pr} = at_{shell}^b$.
3. The local stresses in the shell increases with increasing angle of coverage of the concavity; approximating curve of the results has the dependence: $\sigma_{pr} = a\alpha^{ob}$.

4. CONCLUSIONS

1. Parameters characterizing the concavity are defined - angle of coverage of the concavity (α°), width of opening concavity (b) and lesion depth (f).

2. On the basis of numerical studies of the work of shells of metal chimneys, the dependences between changes of stress from the size of concavity, diameter and thickness of the shell were obtained. We also established that:

- At the concavity of the shell with an angle of coverage of the concavity from 10° to 60° , reduces stresses in the local area by factors of 1.4 - 3.9.
- At changing of the diameter of the computational model from 1.2 m to 4.2 m and the angle of coverage of the concavity $\alpha^\circ = 10^\circ$, results in a 2.5 decrease in the local area reduced.
- Changing the thickness of the computational model from 4mm up to 16mm and the angle of coverage of the concavity $\alpha^\circ = 10^\circ$, decreased the stress in the local area by a factor of 5.7.

3. It is necessary to analyze the impact of the concavity on the stability of the shell in order to create engineering techniques that consider the influence of concavity on the stress-strain state while examining the high-rise structures.

4. Bursts of local stresses exceed the stress on the three different design schemes by about 2 orders of magnitude in the zone of local dimple. These stresses are not included in the calculation by the regulatory procedure of Building Code. Thus, taking into account the local stresses, while projecting the chimneys with random dimples, is an urgent scientific task.

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