# *PROBABILISTIC APPROACH TO COKE-OVEN LARGE-BLOCK CONCRETE BRICKWORK STRENGTH CALCULATION*

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*The new approach to calculate coke-oven large-block concrete brickwork strength is offered.*

The design of the elements of brickwork is an important stage of the coking batteries design.

The tendency in a choice of the geometrical dimensions of brickwork is, as a rule, to reach that active stresses are lower than assumed one, and to provide theoretically a sufficient strength and service life with the given dimensions of chambers.

To provide the efficiency of an oven chamber its division wall must possess the certain qualities providing performance of required functions. The failure of the division wall is the intolerable loss of one of its qualities– strength, tightness or shape. Various approaches to division wall design are known. The traditional approach includes an estimation of stressed-strained state (SSS) of brickwork and of limit transverse load for the load-bearing capability of the division wall [1]. Calculation is made by three criteria: deformation, stability and strength criteria.

It is known, that the refractory brickwork of the division wall resists well to compression and poorly to tension, first of all because of the presence of the joints filled with mortar, which possess low strength. In calculations it is considered by the third theory of strength. Limiting tensile stresses of a brickwork $\sigma_t^*$ = 50-80 kPa correspond to the industrial oven with height of 5,5 m which is considered base. In calculations the brickwork is considered as the continuous medium, and at its each of its point tensile stress cannot be more than the value $\sigma_t^*$: $\sigma_1 \geq \sigma_t^*$. Compressive strength of Dinas $\sigma_c$* reaches a considerable value (to 20 MPa) and it defines the second condition of strength of the brickwork: $\sigma_3 < \sigma_c^*$.

In the absence of fissures the division wall is calculated with the criterion use $\sigma_{equ} \leq \sigma^*$, where $\sigma^*$ – the calculation strength of a material, which is equal to the ratio of strength characteristic $\sigma^{cr}$ to safety factor for strength, reliability, operating conditions etc.; $\sigma_{equ}$ – the equivalent stress corresponding to the assumed strength hypothesis.

For the division wall calculation by the third strength theory which is considered to be valid for such calculations, the strength criterion for a flat plane state of stress has the following form [2]:

$$\sigma_{equ} = \sigma_1 - \frac{\sigma_t^*}{\sigma_c^*}\sigma_3 \le \sigma_t^*,$$

where $\sigma_1$, $\sigma_3$ – largest and lowest principal stresses.

Various schemes and models are applied to division wall design.

By the first model it is possible to treat a division wall as vertical, rigidly fixed-end beam, which takes for transverse uniformly distributed load $q_x$, own weight of beam, weight of oven roof G.

Practice has shown that the maximum compression stress on absolute dimensions calculated by this model will be lower by one order of magnitude (in absolute value) than the compression strength of Dinas brick .

In that case, within the scope of the given scheme it is impossible to explain appearance of defects during process of brickwork operation.

By the second model the division wall is treated as a beam of variable rigidity with a curvilinear axis, which connects the centers of gravity of compressed zones of cross-sections. But in practice, the brickwork is capable to sustain loads higher than these obtained as a result of calculations by the given scheme. This allows an occasion to assume that the division wall is capable to withstand tensile stresses for some time interval. The model of the heating wall oven chamber in the form of the orthotrophic slab offered by Sklyar et al. allows to assume ability of a brickwork during some time interval to resist without the formation of fissures to the vertical tensile stress the level of which corresponds to $\sigma_{max}$*. Using this model, it is probably to assess both vertical and horizontal stability of a brickwork to define a value of necessary anchor force $N_z$ from condition $N_z \le N_{torsion}$,

where $N_{torsion}$ – critical value of horizontal anchor tie of the brickwork, defined from the condition that the normal stress are equal to zero:

$$\sigma_y^{bend} - \sigma_y^{anchor} = 0.$$

It is evident, that stability of the brickwork of heating walls depends not only on the value of tensile stresses but also on the specific design of ties, properties of Dinas, mortar etc. However, authors [3] did not take into account all these factors and which is why it is impossible to define, a value of tensile stresses that the brickwork can sustain at a long operation and, hence, to estimate its real operation life.

However, the authors of [3] disregarded these factors, which is why we cannot determine the magnitude of tensile stresses that can be taken up by the brickwork during a long period of time and, hence, we cannot estimate its life.

If appearance of cleavage cracks in a brickwork is caused by the presence of tensile stresses exceeding the tolerable level, then "undercut" of the brickwork develop in those zones of a division wall where compressive stresses and an average level of temperatures are sufficient for creep appearance. At the conditions of cyclical loading the analysis of stresses redistribution in a dangerous zone leads to very complicated calculations. In this connection it is offered to use strain criterion of strength: $\varepsilon \leq \varepsilon_{st}$ Experimental researches by establishment of high-temperature creep of dinas brick [4], and also the analysis of calculations of ultimate strain $\varepsilon_{st}$ for coke battery with oven chambers of various height confirm the assumption that the brickwork material attains the critical value $\varepsilon_{st}$ = 0,4 %.

However it is necessary to note, that even at corresponding revision well-known methods of designing the brickwork, the essence of which has been described above, in our opinion, cannot be applied directly to design of large-block division wall of refractory concrete in connection with following essential features of the process of its operation and destruction [5-6]:

– presence of a considerable quantity of various defects in an initial stage of operation that it is necessary to consider, assumed limiting strength characteristics;

–origination of the main crack for cyclopean masonry yet does not mean an approach of a limiting condition by criterion of strength;

– blocks possess essential strength on a stretching, considerably exceeding this characteristic for a usual brickwork, and destruction cyclopean masonry on seams without block destruction is impossible, that is caused by a design of division walls;

– considerable superficial defects from coking box which arise at total influence of a gradient of temperatures, heterogeneity of concrete structure, mechanical deterioration, chemical processes on a surface of blocks;

– large-block division wall possesses considerably higher rigidity that reduces danger of occurrence of intolerable transverse deformations.

Taking into account stated above features for cyclopean masonry criterions of its limiting condition, i.e. failure criteria, are formulated:

– condition of blocks team-work along joints: $\sigma_j^* \geq [\sigma_{equ} = f(\tau_y)]$;

– strength condition at total action of longitudinal and cross-cut forces and the bending moments: $\sigma_j^* \geq [\sigma_{equ} = f(M_x\, Q_x, M_y, Q_y)]$.

The most realistic results of the calculation, considering the above-indicated feature of the operation and destruction of a large-block division wall, can be obtained by using a probabilistic approach. The probabilistic strength calculations allow to estimate the reliability characteristics of the object. With such an approach the load $\sigma_{equ}$ and strength $\sigma^*$ – random variables characterized by corresponding functions of the distribution densities f ($\sigma_{equ}$), f ($\sigma^*$) and the mathematical expectation M ($\sigma_{equ}$), M ($\sigma^*$). The reliability of the brickwork R is the probability P that the strength $\sigma^*$ will not be lower the loads $\sigma_{equ}$ taking into account their dispersions:

$$R=P(\sigma^*-\sigma_{equ}>0) \qquad (2)$$

The probability of the failure-free performance is connected with the probability of failure Q = P ($\sigma^*-\sigma_{equ}$ <0) by the known relation:

$$R = 1 - Q. \qquad (3)$$

On the basis of [7] for the probability of failure of the element $Q_i$ = F (t) where F (t) - is the function of the distribution of operating time to failure or the probability that the system will fail by the time t. If to accept an assumption that the law of distribution of load and strength is normal, for the given moment of time according to [8] the function F (x) should be expressed in terms of the tabulated Laplace odd function :

$$\Phi(z) = \Phi[-\frac{M\sigma_{эђ‰} - M\sigma^*}{\sqrt{S^2_{\sigma^*} + S^2_{\sigma эђ‰}}}], \quad (4)$$

where $S^2\,\sigma_*$ and $S^2\sigma_{equ}$ - a root-mean-square deviation of quantities $\sigma^*$ and $\sigma_{equ.}$

$$F(x)= \Phi(z) + 1/2. \quad (5)$$

It is possible to express probability of failure-free operation of the division wall in terms of $y = \sigma^* - \sigma_{equ}$:

$$R = P(y > 0) = \int_0^\infty \frac{1}{S_y\sqrt{2\pi}} \exp[-0{,}5(y - M_y/S_y)^2]dy.$$

On the basis of [15] taking into account (3) - (5) failure-free operation of the brickwork is calculated from the following dependence:

$$\mathbf{R = 1 - \Phi[-\frac{M\,\sigma_{экв} - M\sigma^*}{\sqrt{S^2_{\sigma^*} + S^2_{\sigma экв}}}].} \quad (6)$$

The characteristics $M(\sigma_{equ})$, $M(\sigma^*)$, $S^2\,\sigma_*$ and $S^2\sigma_{equ}$, which depend on many factors, should be experimentlly detirmined for particular moments of time under various conditions and modes. The random quantities $\sigma_{equ}$ is function of the temperature $\sigma_{ti}$ and mechanical stresses $\sigma_i$ acting in the material, random influences $V_{ni}$, nominal geometrical characteristics of the wall zone and, b, c etc.:

$$\sigma_{equ} = f(\sigma_{ti}, \sigma_i, V_{ni}, a,b,c).$$

The random quantity $\sigma^*$ depends on the strength of the concrete, which changes, depending on the time of the material performance $\sigma^*{}_i^T$ and its conditions $\sigma^*{}_i^C$ on the nominal cross-sectional area of the structure used in calculations of $F_i$:

$$\sigma^* = f(\sigma^*{}_i^T, \sigma^*{}_i^C, F_i)$$

The application of this approach makes it possible to estimate the probability of the limiting state of any particular zone of the division wall and to guarantee, with the specified reliability level, the account of all random situations and the influences leading to the failure of the division wall during the operation.

**References**

1. Рудыка В.И., Зингерман Ю.Е., Каменюка В.Б. и др. Совершенствование конструкций коксовых батарей по проектам Гипрококса // Кокс и химия. – 2004. – № 7. – С. 18-25.

2. Сопротивление материалов. Под общ. ред. Г.С. Писаренко. К.: Вища школа, 1973, 672 с.

3. Устойчивость кладки обогревательных простенков // Скляр М.Г., Васильев Ю.С., Вирозуб А.И. и др. Кокс и химия. 1987. N4. С.14-21.

4. Gaillet J.P., Isler D. Prolongation of coke oven service life in the European coke plants // 4-th China Int. Coking Technology and Coke Market Congress 2006. Beijing, P.R. China. – Sept. 2006. – P. 170-178.

5. Парфенюк А.С., Зборщик М.П., Веретельник С.П. и др. Пути повышения долговечности блочной бетонной кладки коксовых батарей // Огнеупоры. 1992. N4. С.24-26.

6. Парфенюк А.С., Веретельник С.П., Кутняшенко И.В. и др. Физические факторы надежности эксплуатации кладки коксовых печей из крупноразмерных огнеупорных блоков // Кокс и химия. 1992. N11. С.18-20.

7. Капур К., Ламберсон Л.. Надежность и проектирование систем. М: Мир. 1980. - 604 с.14.

8. В.В. Судаков. Контроль качества и надежность железобетонных конструкций. Л: Стройиздат. 1980. 166 с.

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# ABOUT CHANGE OF TIGHTNESS EMISSION-HAZARDOUS ASSEMBLIES OF THERMAL UNITS

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*To estimate reliability of thermal units it is offered complex criteria in which parameters of the technical state of assemblies and also the functions reflecting a degree of effect operational, mechanical and temperature factors on process of a depressurization and loss of functional properties of the unit elements are integrated.*

The main requirements to technical objects are reliability, profitability and minimum possible of environmental contamination. Thermal units of a traditional design (coke oven, blast furnace, glass furnace etc.) for the present in an insufficient measure correspond to modern norms under these characteristics, and increase of their individual capacity, along with positive results, is connected with increase in material losses and an ecological damage at refusals, idle times and repairs.