Analysis of non-axially pressed reinforced concrete building constructions of metallurgical plants under local heating

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Abstract
The article is devoted to improving the method of calculating of the strength and deformation in compressed reinforced concrete elements under the local heating. The peculiarities of temperature strength changing under local heating and exploitable loading, are studied. The comparative analysis of the theoretical quantities confirms the acceptance of the proposed improvements.

Keywords: LOCAL HEATING, COMPRESSED REINFORCED CONCRETE ELEMENT, STRENGTH, DEFORMATION, TEMPERATURE STRESSES, TEMPERATURE FORCE.

Introduction

Functioning of metallurgical and mining plants is often followed by local heating of reinforced concrete elements [1]. Unfortunately, the influence of the local heating on such constructions, in particular on the compressed elements, is insufficiently known and needs additional researches. During last years such researches were executed at Lviv Polytechnic National University. The purpose of these researches was studying of the compressed elements durability under local heating and service loading.

Materials and research

The complex program of researching of non axial pressed reinforced concrete elements under local heating were performed (Fig.1). According to the program the following cases were investigated: 40% loading and pressed elements side heating, 40% loading and stretched elements side heating, 60% loading and pressed elements side heating, 60% loading and stretched elements side heating. This test was conducted in two stages. At the first stage columns were loaded to the necessary level step by step. Thereafter at longitudinal deformations of concrete and steel reinforcement, curvature, appearance and opening of cracks on each step were fixed. At the second stage to the column through reducer was joined a stove which was preliminary warmed-up to the temperature of 900^0C-1000^0C. The source of heating was placed near the stretched or compressed element’s side, in obedience to the program of researches. Longitudinal deformations of concrete and steel reinforcement, curvature of element were fixed each 10 min. during the local heating. The temperature was taken with the measuring transformer PVI-0289, which archived information in computer memory. Elements were destroyed immediately at the end of heating (90 min) by gradually – growing loading. Thus the maximum load was fixed. Patterns were designed with such characteristics: length -1200 mm, crosscut – 200x140, eccentricity of force – 14 cm, class of concrete –C25, class of steel reinforcement – A400, Bp-I.

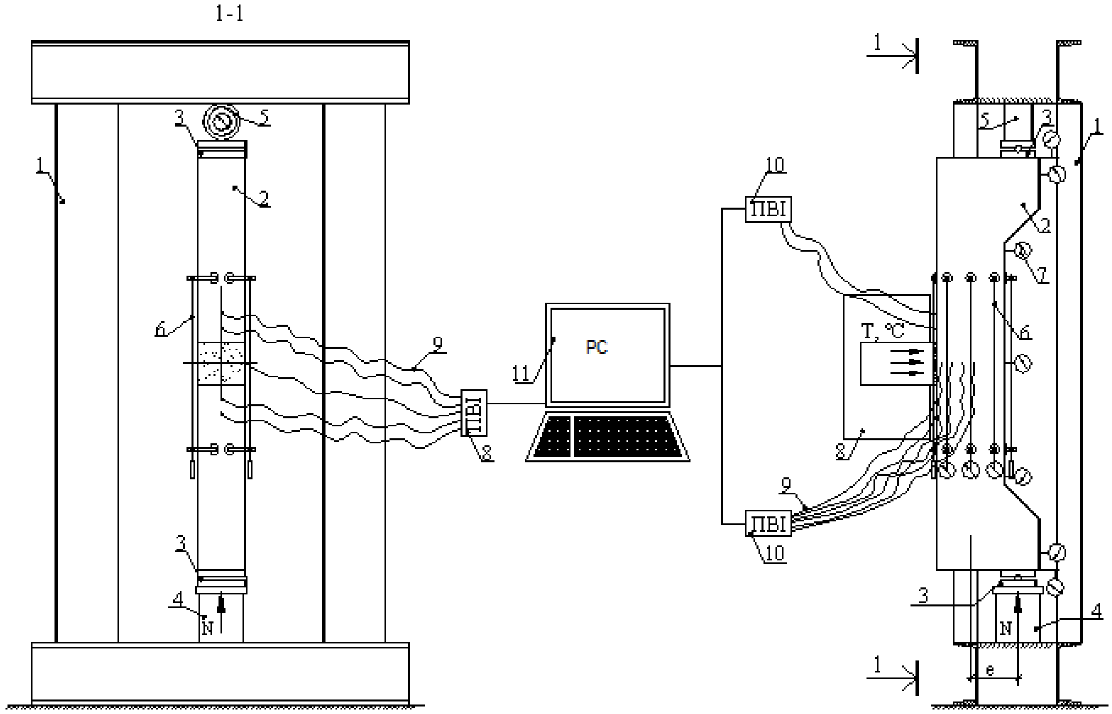

Figure 1. The scheme of investigation: 1- test bench, 2- reinforced concrete column (1200x200x140), 3-supporting hinge, 4 - hydraulic jack , 5- dynamometer, 6,7 - indicator, 8- stove, 9- thermocouple, 10- measuring transformer PVI-0289, 11-computer.

Theoretical analysis

The ultimate load for non axial pressed element under heating is determined from well-known dependence [2,3,5]:

$$N_{f,u} = f_{cd}(\theta_m)bx_t + f_{csd,fi}(\theta_m)A_s^{'} - f_{cd,fi}(\theta_m)A_s \text{,(1)}$$

$$x_t = h_0 - e + \sqrt{(e-h_0)^2 + 2(f_{cd,fi}(\theta_m)A_s e - f_{csd,fi}(\theta_m)A_s^{'}(e-h_0+a_s^{'}))/f_{cd}(\theta_m)b} \quad (2)$$

When temperature longitudinal deformations are impossible or limited (in case of heating already loaded column), temperature force N_t has the influence on ultimate load:

$$N_{f,u} = f_{cd}(\theta_m)bx_t + f_{csd,fi}(\theta_m)A_s^{'} - f_{cd,fi}(\theta_m)A_s - N_t \text{ ,(3)}$$

$$N_t = \frac{\varepsilon_{tx}^{loc}}{\left(\frac{e_s\psi_s}{zA_sE_s\beta_s\nu_s} - \frac{\varphi_s}{A_sE_s\beta_s\nu_s}\right)\left(\frac{y_s}{h_0-x_t} - 1\right)} \text{ , (4)}$$

ψ_s,φ_s, x_t, y_s, z, e_s, β_s, υ_s – values, which are determined from [4], ε_{tx}^{loc} - axial temperature extending of pressed and localy hetated elements zone.

Thus, temperature internal force N_t is caused by axial temperature deformation of pressed element's zone ε_{tx}^{loc} , which can occur, but is limited by supports. Axial temperature deformation ε_{tx}^{loc} in case of local heating is defined from equations:

$$\varepsilon_{tx}^{loc} = \frac{\Sigma A_{red,i}\varepsilon_{ti}^{loc} + A'_{s,red}\,\varepsilon_s'^{loc}}{A_{red}} \quad (5)$$

The values from equations (5-7) are received from [2], taking into account the peculiarities of temperature distribution in case of local heating (Fig.2).

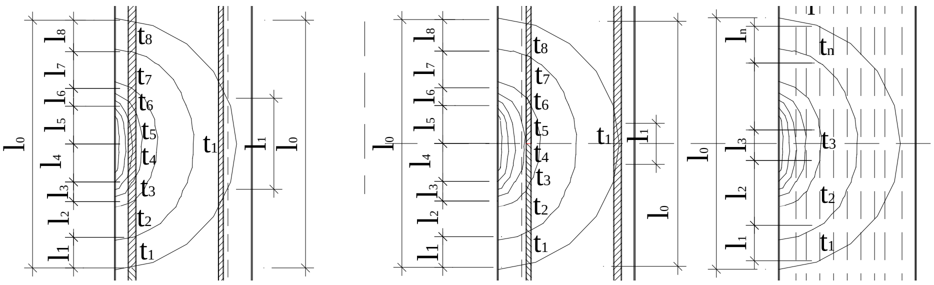

Figure 2. Temperature distribution in case of local heating

$$\varepsilon_{ti}^{loc} = \varepsilon_{t_1 i}\frac{l_1}{l_0} + \varepsilon_{t_2 i}\frac{l_2}{l_0} + \varepsilon_{t_3 i}\frac{l_3}{l_0} + ... + \varepsilon_{t_n i}\frac{l_n}{l_0} \qquad (6)$$

$$\varepsilon'^{loc}_{s} = \varepsilon'_{st_1}\frac{l_1}{l_0} + \varepsilon'_{st_2}\frac{l_2}{l_0} + \varepsilon'_{st_3}\frac{l_3}{l_0} + ... + \varepsilon'_{st_n}\frac{l_n}{l_0} \qquad (7)$$

Columns crosscut should be divided into elementary parts (Fig. 3a), with their own parameters (Fig. 3b, 3d). Heated reinforced concrete crosscut is reduced to free of damage crosscut (Fig. 3c).

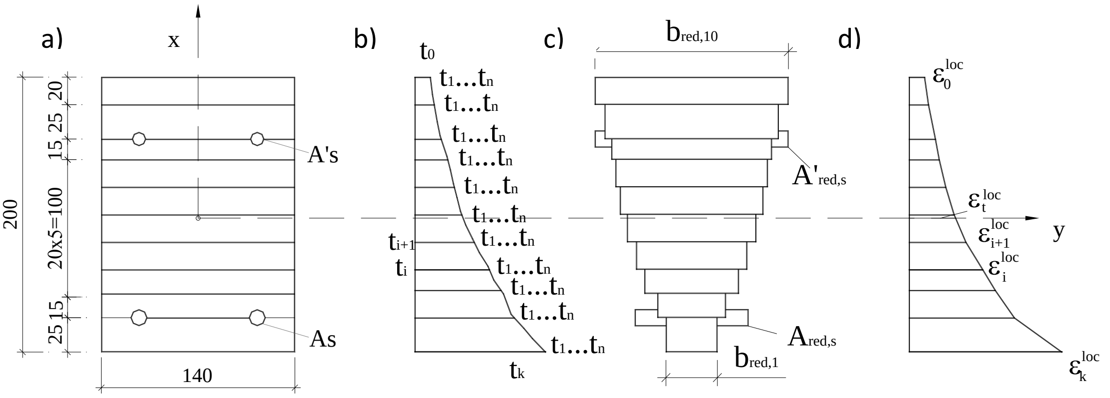

Figure 3. The scheme of: a) crosscut distribution, b) temperatures distribution, c) reduced crosscut, d) deformations distribution

Results of researches of non axial pressed elements durability under local heating and synchronous service loading are presented in a Table 1. Elements appearance after investigations is shown in the Fig. 4.

Table 1. Results of experimental and theoretical researches

Elements mark	Synchronous loading, %	Heating place	N^m_s kN	$N^m_{2,}$ kN	$N_{3,}$ kN	$N^T_{t,}$ kN	$\Delta_{3,}$ %
1	2	3	4	5	6	7	9
К1.2р	60	s/s	60 min. of heating	151.4	163.4	5.2	7.3
К2.2р	60	s/s					
К1.2с	60	p/s	121.5	162.5	168.7	33.6	3.7
К2.2с	60	p/s					
К1.1с	40	p/s	145.8	173.1	166.7	35.6	-3.9
К2.1с	40	p/s					

K1.1p	40	s/s	90 min. of heating	160.2	162.9	5.7	1.7
K2.1p	40	s/s					

Note: N_s^m- mean value of experimental ultimate load (fluidity of steel reinforcement); N_2^m – mean value of experimental ultimate load (total destruction); N_3 – theoretical value of ultimate load ; N^{τ}_{t} – theoretical value of temperature force; s/s – heating of stretched elements side, p/s – heating of pressed elements side; value deviation -$\Delta_3=(N_3- N^m{}_2)/ N_3$.

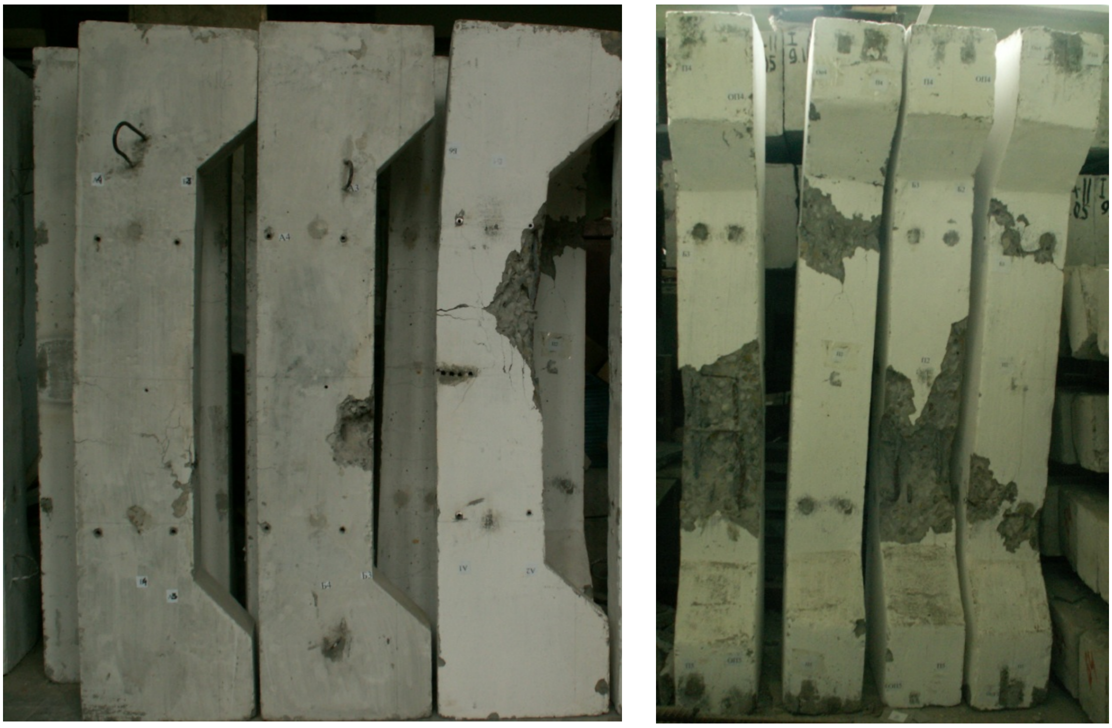

Figure 4. Elements appearance after investigations

Conclusions

The results of experiments show the influence of local heating on pressed reinforced concrete building constructions. Durability of non-axially pressed reinforced concrete elements under loading and local heating depends on value of internal temperature force N_t. The value of internal temperature force N_t is suggested to find from equation (4). The comparative analysis of the theoretical and experimental quantities confirms the acceptance of the proposed improvements.

Presented analysis was done on the base of normative documents (SNiP). Some of them were abolished [3,4] and substituted national standarts (DSTU), some of them are still valid [2]. Consequently, it makes huge difficulties in analysis of heated reinforced concrete structures. National standarts, especially in this branch, should be harmonized with each other and with European norms.

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