Perfecting technology of winter concreting of cast-in-situ columns

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Abstract. The article deals with an analysis of the existing systems of the heating method of reinforced concrete structures. It is demonstrated that, concreting of rectangular columns, the area of angles is characterized by a lower concrete quality than in other areas, which causes extensive damage in indicated zones. To remove the existing limitations, the formwork design for concreting of cast-in-situ columns is offered in the article. It was established that during the removal of column formwork one can often observe palled angles with reinforcement uncovering. Corners are the most vulnerable parts under impact forces or static loads during the exploitation. Repair and restoration of the exterior view and protective properties of concrete in column corners often require using materials or repair methods, which increase the cost of construction. The reasons of concrete lower quality are in the incompact joints of formwork elements and the chilled temperature of concrete hardening. Furthermore, the reason is in low temperature in columns corners. It is the consequence of the deficiency of existing heating systems ignores the irregularity of heating proper emission of the heat and increased heat loss in the corners of the columns.

1. Introduction
Construction of reinforced-concrete columns experience of chemical productions shows that the most “problematic” place are corners. During the removal of column formwork there is often occurred spalled angles with the uncovering of the reinforcement. While in operation of columns corners are the most vulnerable parts under impact forces or static loads [1]. Repair and restoration of the exterior view and protective properties of concrete in column corners often generate a need for using special materials (repair, organic concrete and etc.) or repair methods (pneumatic concrete placing and etc.), which significantly increase the cost of construction [2]. In most cases the reasons for this rather high columns corners damage are two factors:

1) less qualitative concrete in the corners than in the main "body" of the structure, in particular - lower strength properties;
2) Salient corner creates under external mechanical loads large stresses in the area of the protective layer of reinforcement.

One of the reasons of low quality of concrete are technological reasons - in the majority of cases the thickness of a protective layer does not allow a coarse aggregate to penetrate into corner zones and a body of concrete in it consists of a fine filler and knitting [3]. To create conditions of filling corners with high-quality concrete it is necessary to increase the pressure or the number of a coarse aggregate, which can negatively affect on the strength of concrete in the middle part of the column [4]. Devices
for fixing a certain thickness of the protective layer also has a negative effect, installed on the reinforcing frame and making obstacles for penetration of the coarse aggregate in the local areas of the corners [5-6].

Today columns formworks consisting of separate form panels are commonly used. There are inventory panels, designed for building standard size columns, and universal – for the manufacture of different monolithic concrete structures (beams, slabs, foundations, etc.) For a relatively small volumes of works builders often made a formwork by a handicraft way with available locally improvised materials – plywood, boards, defective finishing plates, etc. The similarity of all these types of formwork is that the joints of formwork panels at concreting of columns fall on corners of a structure. Substandard production of formwork panels leads occurrence of considerable insoluations and cracks in places of joints, that is the cause of two unpleasant consequences: 1) outflow of laitance layer with a small aggregate through them, which causes the appearance of caverns in the corners, exposed reinforcing bars, irregularities and poor quality of the concrete surface; 2) concrete, hardened in slits and infertiles of formwork, contribute appearing additional stresses at the form removal, deteriorate surface appearance of a column, an opportunity of people damages, etc. Also pressure of concrete during the filling of a formwork and a sealing promotes additional disclosure of joints between panels [7-9].

Also one of the reasons of low quality of concrete in columns corners is the lower temperature of concrete hardening, than the whole concrete. This is caused by two main factors: 1) hardening concrete provides the heat, which is distributed irregularly among the structure - the largest amount of heat is located in the center, and the smallest- on the periphery. Besides, the temperature in the corners is lower than in the middle face of the structure [10]. This fact is most evident for massive constructions – dams, foundations, etc. In particular, the work shows the distribution scheme of temperatures in the body of concrete pylons; 2) in the corners of structures, especially those that are operated outdoors, there are more intense heat losses caused by the effect of "blown" by the wind, as well as through the looseness of the joints of the formwork shields. This fact was established in the works [11-14]. It is established that the value of temperature reduction in the corners makes no difference on distribution of heat.

Based on all the above, it is possible to conclude that the creation of a formwork, the construction of which will contribute to a better concrete column corners, is a very urgent task for increasing the energy efficiency of construction production, improving the quality of construction products, both columns and other monolithic concrete structures.

At the same time it is necessary to solve two basic questions: 1) the design of formwork surface directly contacting with concrete, should exclude occurrence of the above disadvantages of concreting of corners; 2) conditions for sufficient warming of the columns of columns at negative external air temperatures should be created.

To create a dense joint of formwork shields some manufacturers offer formwork in which connections of shields is made through special angular elements on the principle of flange connections. These constructions create much more qualitative concrete constructions, but they solve it by the manufacture and use of additional connecting elements and complication of design of panels, which ultimately leads to the inability to use shields for one type of columns in the manufacture of columns of other sizes and a significant rise in the price of construction. To solve this problem can be applied non-removable formwork of box section, but their application creates considerable difficulties in reinforcing columns, for uniform filling of the formwork with concrete and its sealing [15-18].

2. Research methods
In order to measure the necessary power of heating elements, we conducted an experiment to determine the temperature of the concrete from the heating element at various distances. Composition and content of free water have an influence on temperature gradient. The experimental installation is described in Figure 1.
A mixture of coarse-grained and fine sand and a thin ground slag of the convertory steel, imitating cement were used as a specimen. The ratio of sand and slag in weight was 5:1. The research was carried out on samples with different water content: water-cement treatment \((V/C)\) was 1:5, 1:3, 1:1.5. The temperature of the heating element was maintained at the level of +80º C – the maximum possible temperature of the concrete heating. Thermoparames in the quantity of 7 was measured the temperature in the concrete at distances from the heating element 0.005 m, 0.05 m, 0.1 m and was written on the recorder.

![Figure 1. Instrument diagrammatic sketch for determination the temperature of heated concrete: 1 – contact thermometer; 2 – recorder; 3 – thermocouples; 4 – concrete; 5 – copper tube; 6 – water container; 7 – electronic block; 8 – heating element.](image)

3. Results and discussion

The influence of temperature in fine-grained concrete depending on the distance of thermocouples and water-cement relations is established (table 1).

The distribution of temperatures in the concrete also depends on the level of heat isolation of the surface, touching the surface of the formwork. The experiments of the distribution of temperatures in the concrete, connecting formwork panel were conducted for various materials of formwork. Used materials: 1 – steel galvanized sheet thickness 7 \(*\) 10-4 m; 2 – wooden panel with boards thickness 0.025 m; 3 – steel galvanized sheet with thickness of 7*10-4 m with glued sheet of foam plastic thickness 0.05 m. The dimensions of the boards were 1.8 m wide, 0.6 m in height, the thickness of the material layer imitating the concrete was 0.4 m. The heating element was located in direct contact with the formwork. The surface warming from the single heater was simulated. Temperature fixing sensors were located on the same distances from the heater in contact with the formwork spanel. The heating temperature was maintained at 80 ºC. Measurements were conducted in 15 minutes after the heating starts. The results of the studies are presented in table 2.

| Distance,m | Temperature in concrete, ºC depending on water-cement ratio: |
|------------|-------------------------------------------------------------|
|            | 1/5 | 1/3 | 1/1.5 |
| 0.005      | 77.2 | 76.4 | 76.2 |
| 0.05       | 64.2 | 57.2 | 53.6 |
| 0.1        | 59.3 | 52.7 | 42.1 |

In the works [19-20] it has been found that the temperature of the concrete in the corners of the structure is lower than in the middle part of the faces, by a uniform heating of the entire surface of the columns.

To eliminate the above defects we offered the following construction of the formwork for concreting of cast-in-situ columns (Fig. 2).
**Table 2.** Results of temperature measurements in the body of concrete depending on the formwork material.

| Formwork material             | Temperature in concrete, °C depending distance from the heater, m |
|------------------------------|---------------------------------------------------------------|
|                              | 0,005 | 0,05 | 0,1  |
| Metal sheet                  | 74,1  | 61,5 | 49,2 |
| Wooden shield                | 77,4  | 66,2 | 52,8 |
| Metal sheet with foam plastic| 77,8  | 69,1 | 63,7 |

**Figure 2.** Proposed formwork construction: 1 - angular unit; 2 – non-standard precast component; 3 - connecting bar; 4 – heat insulation material; 5 - heating element.

Angular units are the main elements of the formwork system. They are made of steel sheet, bent accordingly, or other material (for example, fiberglass plastic). These elements have the following differential peculiarities:

1) The sheet bend has an assigned radius of rounding, which has an equal length from the center of the reinforcement to the outside surface of the column, making the same thickness of the protective layer on the corners of the structure. It helps to improve appearance of the structure, to decrease a chance of crack development during formwork removal, also to decrease the removal labor intensity.

2) The sheet bend zone is supplied with heating elements for local warming of column angle, and also insulated to reduce heat loss. This allows decreasing the energy consumption and eliminating the heating irregularity on different areas of the surface.

Non-standard precast components took place between the corner elements and allow to made columns of suitable sizes.

**4. Conclusions**

1. The analysis of scientific and technical literature and on-site investigations have shown that at concreting of columns of a rectangular section the area of corners is characterized by the lower quality of concrete, than in other areas, that causes the increased damage in the specified zones.

2. The reasons of lower quality concrete are in the incompact of the joints of formwork elements and the chilled temperature of concrete hardening

3. Chilled temperature in column corners is the result of deficiency in existing heating systems, which don’t consider the irregularity of heating from the concrete emission of heat, as well as increased heat loss in the corners of the columns.

4. The proposed type of formwork consists of separate angular elements with a curve form in a corner of a column. This formwork allows creating an aesthetic appearance of columns, reducing the damage in the corners of columns and the labor capacity of formwork in cast-in-situ concreting of rectangular columns.
5. The proposed system of local heating of concrete columns surfaces in angular zones allows to reduce the irregularity of heating of different zones of a surface, and so to reduce energy consumption on heating of concrete.

6. The proposed principle of local heating of concrete structures allows to realize its large quantity of technical means, that allows it to apply for a various constructions and conditions of concreting and exploitation of constructions.

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