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HOMOGENEITY CHANGE OF THE CONCRETE STRENGTH IN MONOLITHIC CONSTRUCTION

ABSTRACT

There is a comparative analysis of 28 days compressive strength of grade C50/60 concrete made either of a mix at a concrete plant or of a mix after delivery to the construction site or after hardening in concrete columns of cast-in-place concrete frame building.

It is established that while designing composition of concrete it is necessary to take into account the variation coefficient of concrete produced at a particular plant. The variation coefficient of concrete plays an important role in structural design, because this value depends on value of the minimum required strength of concrete.

The paper investigates changes in variation coefficient and average strength of concrete

molded and cured in different conditions and from different manufacturers in Kyiv.

The method of analysis of statistical data obtained for a certain period revealed the difference in compressive strength of concrete from different concrete plants in Kyiv, which supplied the concrete mix to construction site. The results are influenced by many factors including practices of workflow when producing concrete mix and calculating the minimum required strength of ready-mix concrete.

Based on the obtained results and observations, recommendations are given regarding the care of high-strength concrete during the hardening in monolithic reinforced concrete structures of residential or industrial buildings as well as attention is drawn to the details of concrete hardening due to concreting conditions in summer and winter. The identity of pouring the concrete mix in the formwork and compaction in all structures was also monitored.

Experimental data of a number of concrete plants in Kyiv were obtained to determine the intra-batch index of compressive strength of concrete and variation coefficient in accordance with current regulations of Ukraine regarding summer and winter construction at all stages of concrete production.

KEYWORDS: high strength concrete, variation coefficient, compression strength, statistical control, concrete mix

ЗМІНА ОДНОРІДНОСТІ МІЦНОСТІ БЕТОНУ В МОНОЛІТНОМУ БУДІВНИЦТВІ

АНОТАЦІЯ

Проведено порівняльний аналіз визначення міцності при стиску на 28 добу твердненя високоміцних бетонів класу С50/60 на зразках, виготовлених на бетонному заводі, а також виготовлених на будівельному майданчику та вибурених із конструкції залізобетонних колон монолітно-каркасного житлового будинку.

Встановлено, що при проектуванні складу бетонів необхідно враховувати коефіцієнт варіації бетону, що виготовляється на певному заводі. Коефіцієнт варіації бетону відіграє важливу роль при виконанні розрахунків конструкцій, оскільки від його значення залежить величина мінімально необхідної міцності бетону.

В статті досліджуються зміни коефіцієнта варіації та середньої міцності бетону заформованого і витриманого в різних умовах та від різних заводів-виробників м. Києва.

Методом аналізу статистичних даних, отриманих за певний період, виявлена різниця за міцністю при стиску бетону різних бетонних заводів м. Києва, які постачали бетонну суміш на будівельний об'єкт. На результати вливають безліч факторів серед яких і культура технологічного процесу під час виготовлення бетонної суміші та закладення мінімально необхідної міцності готового бетону.

За отриманими результатами і спостереженнями розроблено рекомендації щодо догляду за високоміцним бетоном під час його твердненя в монолітних залізобетонних конструкціях житлового або промислового будівництва з врахуванням особливостей твердненя бетону, зумовлених умовами бетонування в літній та зимовий час. Також, контролювались ідентичність проведення укладання бетонної суміші в опалубку та її ущільнення у всіх конструкціях.

Отримані експериментальні дані ряду бетонних заводів м. Києва для визначення показника внутрішньосерійної міцності, при стиску бетону та її коефіцієнта варіації згідно з чинними в Україні нормативними документами у літній та зимовий період будівництва на всіх етапах виготовлення бетону.

КЛЮЧОВІ СЛОВА: високоміцний бетон, коефіцієнт варіації, міцність при стиску, статистичний контроль, суміш бетонна

INTRODUCTION

Today, the use of high-strength concrete in the construction of high-rise buildings of residential buildings and office centers becomes widespread. When designing proportions of these concretes, it is necessary to take into account variation coefficient of concrete produced at a particular plant. When erecting reinforced concrete structures with responsibility category A, the variation coefficient of concrete is relevant because its value depends on the value of the minimum required strength of concrete.

Thus, a number of Kyiv manufacturing plants of ready-mixed concrete was selected with the aim to study the change of variation coefficient and average strength of concrete which was formed and aged in different conditions.

For the analyzed period, some patterns of experimental data obtained in summer and winter conditions were revealed and were the result of calculation of intra-batch compressive strength and its variation coefficient measured for any sequences of 30 series of C50 / 60 concrete samples. The tests revealed a difference in the compressive strength of concrete manufactured by different Kyiv concrete plants, which supplied the concrete mix to construction site. This may be due to the culture of the technological process during the manufacture of the concrete mix and the required strength of concrete according to the regulation of quality of concrete mix.

The results of the search brought to the need to develop recommendations for the care of high-grade concrete during its hardening in

monolithic reinforced concrete residential or industrial structures taking into account the details of concrete hardening caused by concreting conditions in summer and winter.

ANALYSIS OF RECENT RESEARCH AND PUBLICATIONS

It is known that the intra-batch coefficient of variation of concrete strength is an indicator of the quality of ready-mixed concrete of a certain class and characterizes its homogeneity [1-3]. As a rule, this indicator should correspond to values from 6 to 16% [4]. If the figure exceeds 16%, the concrete mix is made in unsatisfactory condition. For monolithic structures, the strength of concrete at the design age must be accepted at a group variation coefficient of not more than 13.5%.

The data say [6] there is a need to normalize compressive strength of concrete for load-bearing reinforced concrete structures. In addition, the authors of the source who studied the physical and mechanical characteristics of different concretes state that over time the actual deviations in the strength of lightweight concrete are slightly higher than for heavy and high-strength concrete. It is also noted that the variation coefficient of concrete strength decreases with increasing average strength.

SETTING OBJECTIVES

Today, Ukrainian enterprises manufacturing ready-mixed concrete mostly indicate a variation coefficient being equal to 8% in the certificate. Experience shows that every enterprise does not confirm this indicator experimentally, or concrete manufacturers use a variation coefficient once set for all classes of ready-mixed concrete. There is also a problem with the conformity of one class of concrete to control samples made in the factory and samples of the same concrete taken from monolithic structures.

An urgent task is to conduct a comparative analysis to determine the compressive strength of concrete made from ready-mixed concrete at the concrete plant, concrete made from mix after delivery to the construction site and concrete after hardening in vertical structures such as columns on the construction site. The result of the analysis is statistical processing of test results of grade C50/60 concrete on the 28th day of hardening in different manufacturing conditions and determination of variation coefficient of a concrete batch.

FINDINGS AND RESULTS

For the purpose of studying compression and homogeneity compliance of concrete, it was selected two Kiev concrete manufacturing plants “ASTOR & CO” LLC and LLC “BETON KOMPLEKS”. The studied batches of grade C50/60 concrete were supplied for the production of vertical elements of a residential building on the site: "Construction of a residential and office center with trade and entertainment, market and municipal facilities and parking on the street Khokhlov family, 8 in the Shevchenkivskyi district of Kyiv ” which is shown in Figure 1.

Reinforced concrete columns with a cross section of 600 mm x 600 mm are selected as the object of concreting and located at the following marks: -3,000; +6,050; +9,350 residential cast-in-place concrete frame building.with geometry along the axes: length 31.8 m and width 18.7 m. From 3 to 9 columns were concreted in one shift, depending on the volume of concrete mix in the concrete mixer. One floor was concreted within 4-5 days. In winter (air temperature did not exceed 50C) concrete in columns was cured electrically. Additional insulation of reinforced concrete columns on the construction site is not provided.

Temperature within the body of monolithic columns was followed using the online monitoring system "Maturix" by «ASTOR & CO” LLC. This system make it possible to monitor the temperature within body of concrete at intervals of five minutes at the time development of strength in concrete. The results of heat release shown in Fig. 2 indicate that the temperature curves of separately located vertical structures which were concreted with a difference of less than one hour have the same character

Figure 1 - General view of the formed vertical structures

i.e. gain temperature to the maximum and cool to the minimum (15.2 ° C) equally with a maximum temperature difference not exceeding 10.2 ° C.

For the research, it was decided to monitor the strength of concrete in the following conditions:

- test samples manufactured and stored on site of concrete mix manufacturing plant;
- test samples made on the construction site but stored in normal conditions according to [5];
- test samples taken from the structures according to [7];

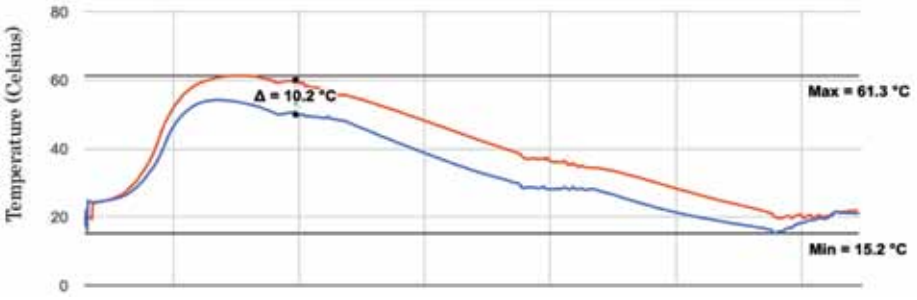

Figure 2 - Concrete temperature indicators according to the online monitoring system "Maturix"

For quality monitoring of concrete mix, cube samples with an edge of 100 mm were molded from each mixer at the construction site. During one shift the number of cubes ranged from 12 to 36 pieces depending on the mixer volume The laboratory of concrete plant also took concrete mix to make cubes in metal molds 2FK-100. The total number of molded samples for each of the above conditions was 90 pieces, which meets the requirements of DSTU B V.2.7-224 [4] where the number of unit values of strength should be not less than 30. It was generally accepted that each batch consisted of three samples, and the entire batch included 90 samples.

Test samples were manufactured and prepared in accordance with

DSTU B V.2.7-214 [5] taking into account the requirements of DSTU B V.2.7-224 [4], which establishes the rules for assessing the strength of concrete based on the test results of samples.

The cube samples on the construction site were molded in a specially equipped metal container, in which the horizontal position of the floor and air heating were provided to maintain the required temperature. The temperature and humidity in the container were monitored by a psychrometer. The samples were stored at a temperature of 20 ± 4 ºC. Molded cube samples in metal molds 2FK-100 were covered with burlap moistened with water to retain moisture on the surface. When making samples from winter concrete, they were covered with foamed polyethylene. The samples were stripped off a day after curing followed by transportation to concrete mix manufacturing plants for further storage under normal conditions.

The next stage of experimental work involved drilling core samples from reinforced concrete columns and testing those on the 28th day of curing. In the central part of the column, regardless of the face, one core (Fig. 3) with a diameter of 100 mm was drilled at a height of approximately 1.3-1.5 m from the floor level. The length of the cores was 600 mm.

Cylindrical specimens with a height of 95 to 105 mm were made of drilled cores and the supporting surfaces were leveled with cement-sand mortar according to [5].

Definition of the characteristics of concrete homogeneity in strength was carried out according to the method of section 6, DSTU B V.2.7-224 [4]. When monitoring the samples, the average concrete strength of samples from one batch was taken as a single value of concrete strength. After sampling which was made in different conditions,

Figure 3 - General view of the core samples drilled from columns

according to the results of tests of any sequences of 30 batches of concrete samples of one class (C50 / 60), determined the intra-batch compressive strength and the variation coefficient (table 1).

Based on the results of analysis of the experimental data, it was established that a concrete mix supplied to the construction site was used in order to get grade C50/60 concrete with a variation coefficient of compressive strength of 8%.

Table 1 – AAverage strength and variation coefficient of concrete from different manufacturing plants

Place of sampling	Type of sample	Concrete mix manufacturing plant in Kyiv			
		"ASTOR & CO" LLC		**LLC "Beton Kompleks"**	
		Compressive strength in MPa	Variation coefficient in %	Compressive strength in MPa	Variation coefficient in %
Concrete plant	Cube samples with an edge of 100 mm	74.2	2.1	73.7	5.2
Construction site		73.5	5.2	71.4	5.4
	Cores	65.7	7.9	69.0	7.7

Analyzing the obtained data, we can see that the compressive strength of concrete manufactured at the plant and on the construction site does not differ considerably i.e. the difference is 1-2 MPa, but this difference may indicate the impact of transporting the concrete mix on the quality. The strength of concrete poured in the structure was lower by 5-10%.

Variation coefficient:

- ranges from 2 to 5% manufactured and cured in the factory laboratory under normal conditions;
- is about 5% for concrete samples molded on the construction site and cured in normal conditions.

Such changes in strength of concrete show that concrete, from the moment of it is manufactured until it is placed in the structure, is influenced by many factors that determine the final strength of concrete: time of transportation of concrete mix, parameters of truck concrete mixer, technology of laying of concrete in a timbering, way of vibrocompaction, correctness and relevance of this or that way of care of concrete. Also, the homogeneity of strength indicators on the construction site is influenced by the human factor and meteorological conditions i.e. structures are concreted in different periods of construction.

CONCLUSIONS

1. There is a difference in the average strength of concrete of one batch of the same mix and grade of the samples manufactured in the concrete plant, on the construction site and taken from the structures. There is an influence of conditions of manufacturing, placing and hardening on homogeneity of concrete strength. With the removal of the concrete mixture from the place of its manufacture, the final strength of concrete, at the design age, decreases.
2. The value of variation coefficient almost coincide for concrete manufactured in different Kyiv plants but in same conditions. That is, the quality of the technological process of manufacturing ready-mixed concrete does not differ significantly.
3. The variation coefficient of concrete defined by the plant for one grade of concrete made from the same raw materials and manufactured on the same production line affects the value of the minimum required strength of concrete for a specific grade. In case if the variation coefficient of concrete of a given grade is known, for example C50 / 60, it is possible to calculate the required strength in accordance with DSTU B V.2.7-224 [4] and DSTU B V.2.7-43 [8].
4. Since it is desirable to take the real characteristics of the concrete placed in the structure as a basis for the design of buildings and structures, in general, the value of variation coefficient of concrete being equal to 8% set at the Kyiv plants is confirmed experimentally.

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