TECHNICAL TRANSACTIONS | **CZASOPISMO TECHNICZNE**
CIVIL ENGINEERING | BUDOWNICTWO
2-B/2014

BEATA GRZYL, ADAM KRISTOWSKI*

A CALCULATION PROPOSAL OF LABOUR TIME INPUT WHEN CONCRETING IN DIFFICULT ATMOSPHERIC CONDITIONS

PROPOZYCJA WYZNACZENIA NAKŁADÓW CZASU PRACY PODCZAS BETONOWANIA W TRUDNYCH WARUNKACH ATMOSFERYCZNYCH

A b s t r a c t

The paper presents a selected proposal of establishing labour input in concreting jobs carried out in difficult atmospheric conditions. The author aims to answer the following question: is there a common-sense limit, e.g. defined by temperature, to which concreting works can be performed safely and efficiently and beyond which it is more reasonable to stop the work and wait for more favourable weather conditions.

Keywords: construction, planning

S t r e s z c z e n i e

W artykule przedstawiono wybraną propozycję wyznaczenia robocizny robót betonowych wykonywanych w trudnych warunkach atmosferycznych. W tym zakresie autor stara się odpowiedzieć na pytanie: czy jest granica określona np. przez temperaturę, do której możemy w sposób bezpieczny i ekonomiczny prowadzić roboty betonowe, a powyżej której lepiej jest je przerwać i poczekać na sprzyjającą pogodę.

Słowa kluczowe:

* Ph.D. Beata Grzyl, Ph.D. Adam Kristowski, Faculty of Civil and Environmental Engineering, Gdansk University of Technology.

1. Introduction

When undertaking concreting works in lower temperatures, one has to consider the need for technological steps which will allow the freshly poured concrete to cure in conditions as close as possible to the norm, for its durability to increase steadily and for the concrete to obtain that required durability before freezing. In order that the above conditions are met, four methods are generally used to cure and protect young concrete [1]:

– mix modification method,
– heat treatment method,
– heat preservation method,
– heated shelters method.

Among the mix modification methods, the following can be distinguished: chemical admixtures which speed up the process of binding, hardening, those which reduce batch water, air-entraining admixtures, chemicals enhancing plasticity, using higher brand cements or higher hydration cements, increasing the amount of cement, reducing the water-cement ratio to the lowest possible value, re vibration, introduction of improvements to eliminate the cooling of concrete during transport. The heat treatment method means providing additional heat by warming with hot air, steam, or with electrical devices. The heat preservation method involves using foil plastic insulation covers, Styrofoam or mineral wool, etc., in order to retain cement hydration heat. The heated shelter method requires complete insulation of the site from external factors.

Even though protection methods have been known and used for many years, the construction market lacks industry standards which would allow one to estimate the extent of labour input in difficult weather conditions. The Instruction [1], widely known in the construction community in Poland, lists some techniques to protect concreting works in high or low temperatures, but realistically speaking, nobody is able to calculate the exact cost of these protective measures. According to [1] – among others – low temperatures are assumed to be temperatures below 10°C while high temperatures are those that exceed 25°C. On the basis of his own professional experience in this respect, the author attempts to answer this question: is there a common-sense limit, e.g. defined by temperature, up to which concreting works can be performed safely and effectively, and above or below which it is more advisable to stop the work and wait for better weather. One has to be prepared for this kind of situation as a prerequisite of construction work planning [2]. Such readiness is costly and usually affects the contractor's profits. That is probably why many contractors take the risk and perform concreting works in unfavourable weather, counting on their good luck. Unfortunately, good luck is not something to be relied on and the consequences of failure are acute and concern mainly poor quality of the construction made, which in turn results in an avalanche of claims from investor supervisors and further financial problems.

2. Establishing the extent of the change of concreting labour time according to ambient temperature

Concreting works carried out at lower temperatures require an increased labour input and are additionally charged with the risk of compromising the quality of the elements

produced. One ought to remember that it is relatively difficult to protect a construction from the cold on site since techniques successfully employed in prefabrication plants cannot be used out of doors. Therefore, it seems advisable to carry out an analysis of possible protection methods for selected construction elements. The analyses made by the author are based on individual calculations or research carried out on the natural scale, concerning concreting labour time and costs. For the purpose of this paper, the author presents results concerning two selected construction elements, typical solutions in monolithic building construction. Calculations for a reinforced concrete partition (Tab. 1) and reinforced concrete roof slab (Tab. 2).

2.1. Calculation for making a reinforced concrete partition

The main assumptions made for the purpose of calculating the cost of producing a reinforced concrete partition in low temperatures:
- partition capacity 17 m^3, surface area 55 m^2,
- Portland cement-based concrete, class C20/25,
- cost assessment for using a given method in air temperature of –10°C so that the concrete obtains sufficient durability and the construction can be used safely.

Table 1

Cost calculation results for producing 1 m^3 of concrete construction in –10°C

Method description	Cost of protection for 1 m^3 of mix [PLN]	Cost of protection with traditional formwork for 1 m^3 of mix [PLN]	Cost of protection with proprietary formwork for 1 m^3 of mix [PLN]
Concrete admixtures	PLN 47,23	PLN 673,21	PLN 1.229,43
Hot concrete mix	PLN 39,84	PLN 635,23	PLN 1.182,20
Hot mix and thermal insulation Styrofoam 10 cm	PLN 157,41	PLN 853,24	PLN 1.400,00
Hot mix and heated shelter	heater PLN 37,14 heated shelter PLN 105,73	PLN 1.236,24	PLN 1.721,15
Hot mix and heating mats	heating mats PLN 1.795,43	PLN 2.385,72	PLN 2.730,23

2.2. Calculation for making a reinforced concrete roof slab

Concreting labour cost calculations for building a monolithic 100 m^2 roof slab of C20/25 concrete where the slab thickness is 18 cm. The total amount of concrete used will be 25 m^3, while the amount of cast reinforcement has been omitted from the analysis.

Table 2

Cost calculation results for producing 100 m^2 of concrete roof slab

Atmospheric conditions	Suggested method	Additional input	Total cost of concreting labour [PLN]
ambient temperature above 25°C	using cement with lower heat of hydration, intensive moisture care	pouring water on concrete while it cures	PLN 29.517,11
temperature from 10 to 25°C	no additional labour input	none	PLN 24.367,31
ambient temperature 10 to 5°C	using a typical mix according to the project, extending the time in which elements are kept in the formwork	none	PLN 30.305,21
ambient temperature –3 to –10°C	using a concrete mix heated to 20°C with plastificator, making thermal insulation of 10cm thick Styrofoam for the concrete surface	C20/25 concrete with plastificator, heated to 20°C, Styrofoam sheets	PLN 34.277,98
ambient temperature below –20°C	using a concrete mix heated to 20°C, heating concrete with electricity, concreting works carried out in a heated shelter	C20/*25* concrete with plastificator, heated to 20°C, heated shelters construction, heater, insulated heating core, electricity	PLN 70.484,32

3. Summary

The methods presented were based on assumptions which allow one to calculate a mix temperature decrease during the curing process depending on the outdoor temperature and the type of formwork and insulation used, etc. On the basis of these calculations and research it can be said that making reinforced concrete constructions in winter at mean air temperatures below –10°C is uneconomical. In such cases, the thermal properties of the formwork are such that they lead to relatively quick heat loss from the concrete. When it comes to expenses, using

construction chemicals alone is an advantageous solution as it is slightly more expensive than, for example, heating the concrete mix. Using formwork with additional Styrofoam insulation on the outside [4] is undoubtedly cost-effective for contractors who own this sort of construction; otherwise mounting and dismounting heating constructions each time may prove unprofitable [3]. A cost analysis for using heated shelters with a heating system shows this method is the least economical and is also expensive. The presented in Table 1 do not include the price of purchasing the heating system. The author is inclined to state that the traditional heated shelter method is justifiable for repetitive construction projects. The method which involves the use of warming mats may, in the author's opinion, be the most profitable among the methods presented in this paper, possibly resulting from the fact that warming mats lend themselves to repeated use, which is not accounted for in Table 2.

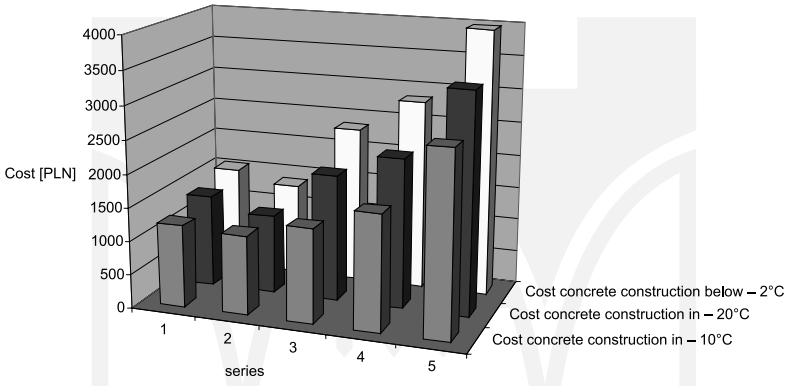

Fig. 1 Cost calculation results for producing 1 m^3 of concrete construction in –10°C, –20°C and below –20°C (series: 1– Concrete admixtures, 2 – Hot concrete mix, 3 – Hot mix and thermal insulation, 4 – Hot mix and heated shelter, 5 – Hot mix and heating mats)

4. Conclusions

The author has presented selected methods employed during concreting works, mainly used in wintertime. The availability and accessibility of the construction materials market enables the contractor to choose solutions best suited to expected weather conditions, according to the extent of the work to be carried out, expectations and financial resources. A definite limit of concreting works profitability cannot be established since they have to be calculated separately each time and an attempt should be made to choose methods which will prove best in each particular case, e.g. depending on the distance from a batching plant, repetitiveness of concrete elements, etc. While solutions which enable the curing of concrete in low temperatures exist, it may well appear that the profitability limit is set e.g. by the factor of human tolerance of low temperatures rather than technology. However, it can be said that in the case of meteorological conditions suitable for carrying out concreting works, a decrease in temperature will involve an increase of labour input at the following rates (based on Fig. 1): up to 30% for temperatures of 0 to –10°C, up to 150% for temperatures of –10 to –20°C, up to 250% for temperatures –20°C and below.

References

[1] Instrukcja ITB nr 282: *Wykonywanie robót budowlano-montażowych w okresie obniżonej temperatury*, Instytut Techniki Budowlanej, Warszawa 1995 i 2011.
[2] Dyżewski A., *Technologia i organizacja budowy*, Tom 2, Warszawa 1990.
[3] Grzyl B., Kristowski A., *Kontrola budżetu jako element efektywnego planowania i realizacji inwestycji budowlanej*, Technika Transportu Szynowego 10/2013.
[4] Kristowski A., Majkowski Ł., *Organizacja badań poligonowych budowy wybranych systemów deskowań*, Zeszyty Naukowe Politechniki Rzeszowskiej, z. 58, nr 3, 2011, 241-248.