INFLUENCE OF ADDING WATER TO READY-MIX CONCRETE ON COMPRESSIVE STRENGTH

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ABSTRAKT

Tento příspěvek se věnuje tématu dodatečného přidávání vody do betonu na staveništi. Bohužel i v dnešní době dochází k této neodborné úpravě betonové směsi. Hlavním záměrem je zpravidla dosažení řidší konzistence betonu, snadnějšího ukládání a jednoduššího probetonování konstrukce. Přidáním vody se však zvyšuje riziko segregace kameniva a také se zhoršují vlastnosti ztvrdlého betonu včetně nejčastěji sledované pevnosti betonu v tlaku. Prezentované výsledky porovnávají vliv správně provedené úpravy konzistence na staveništi pomocí doporučené vhodné dávky superplastifikátoru a neodborným přidáním většího množství vody do autodomíchávače. Sledován byl zejména vliv na konzistenci a pevnost betonu v tlaku jak v raném stáří, tak i po 28 dnech.

KLÍČOVÁ SLOVA

Vodní součinitel • Superplastifikátor • Přidávání vody do betonu • Pevnost v tlaku • Konzistence

ABSTRACT

This paper deals with additionally added water into the concrete mix on the construction site. Unfortunately, this unprofessional adaption of concrete mix still happens. The main goal is usually reaching a more fluid consistency of concrete, easier pouring, and successful formwork filling. Added water increases the segregation risk of aggregates in concrete mix and worsens the properties of hardened concrete, including very often monitored compressive strength. The presented results compare the influence of well-performed adaption of consistency on the construction site by adding a recommended suitable superplasticiser dosage and the unprofessional addition of a more considerable amount of water to the concrete truck. The influence on consistency and compressive strength was observed at an early age and later age.

KEYWORDS

Water-cement ratio • Superplasticiser • Adding water to concrete • Compressive strength • Consistency

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1. INTRODUCTION

Adding water to ready-mix concrete at the construction site is often discussed. The motivation of workers to ask concrete truck drivers to add water to the concrete mix is the more effortless workability of concrete. Additional water in concrete changes the consistency and makes the concrete mixture more liquid. It makes pouring easier and increases the probability of successfully filling complicated shapes. It could be the easiest and cheapest way to modify concrete consistency, but only from the worker or foreman’s point of view.

However, this adaptation of the concrete mix does more harm than good. Additional water in the concrete mix makes the hardened concrete more porous and make the properties (such as compressive strength, water tightness, carbonation resistance, and others) worse. Higher water content also increases the risk of segregation. This procedure is not correct, and another approach should be taken.

1.1. Recommended procedure

At first, suitable concrete consistency should be ordered considering the type of structure, its shape, reinforcement ratio, and the used procedure pouring. It means ordering concrete mix with consistency class (e.g. S4) rather than trying to save some euros by ordering (e.g. S3), which will be later adapted on the job site with additional water.

If the consistency of the delivered concrete does not comply with the ordered one, the following procedure should be taken. The actual consistency should be tested, e.g. by performing a slump test. If the concrete is less fluid than it should be and the tested value confirms that (e.g. S3 instead of S4), consistency could be adapted using recommended superplasticiser from the concrete supplier. Before using superplasticiser, the person who doses superplasticiser should climb up the ladder on a concrete truck to see the inside of a concrete drum. Concrete should be „unscrewed“ as close as possible to the feed opening. After applying the recommended dosage of suitable superplasticiser, the spot where the superplasticiser was poured should be shortly washed with a small batch of water (e.g. 5 litres). It will later support the distribution of superplasticiser within the concrete batch. Concrete should be mixed for several minutes by turning the concrete drum of the concrete truck. After the mixing, consistency should be tested again. If the consistency complies with the delivery sheet, concrete pouring can start. The above-described procedure allows the adaption of concrete consistency without significantly impacting concrete quality.

1.2. Aim of the paper

This paper answers the following questions. Can adding 80 or 160 litres of water to the 8 m^3 big concrete truck dramatically decrease the compressive strength of concrete? How additionally used superplasticisers or water affect selected concrete properties – consistency, compressive strength, and concrete density?

2. MOTIVATION

The primary motivation was the result of the previous experiment on the construction site, where the addition of water and lower strength results were observed. The previous experiment's main goal was to validate the maturity method for use on the construction site. The calibration curves of two concrete mixes were determined, and early-age samples were regularly created on the construction site and tested in the lab. All test samples were monitored with the maturity method and destructively tested in the lab. This investigation allowed the author to see standard practices on the construction site and the deviations. The goal of this chapter is not to introduce mentioned experiment in detail but to point out the connection between added water and lower early-age strength. This experiment was presented in detail at the CCC conference in Zakopane or the fib Symposium in Rome. [1; 2]

2.1. First observation

Figure 1 and Figure 2 present the results of deviations; the reference is always the calibration curve determined before regular testing on the job site. The aim was to prove if a higher variation than the safety factor can occur in practice. Regularly tested validation samples are given as circular points. The results of calibration samples are shown as orange triangles. The orange line represents the calibration curve, and the dashed red lines show the safety factor value subtracted and added to the calibration curve. The safety factors for those specific calibration curves were 2,7 MPa and 2,9 MPa. It was calculated based on a determined standard deviation of the calibration curve according to the standard NEN 5970. A calibration curve with substracted safety factor should be used in the construction projects of reinforced structures. In the presented case, it would be the dashed red curve below.
The maturity method would overestimate every result below the lower red dashed line for this experimental part because the negative deviation is higher than the safety factor. The presented results did not evidence higher variations than the safety factor. The only exceptions are validations five and twelve (Figure 2), where approximately 50 litres of water was added to the concrete truck on the job site. That is the main message of those figures. The details about that experimental analysis can be found in the two mentioned papers. [3]

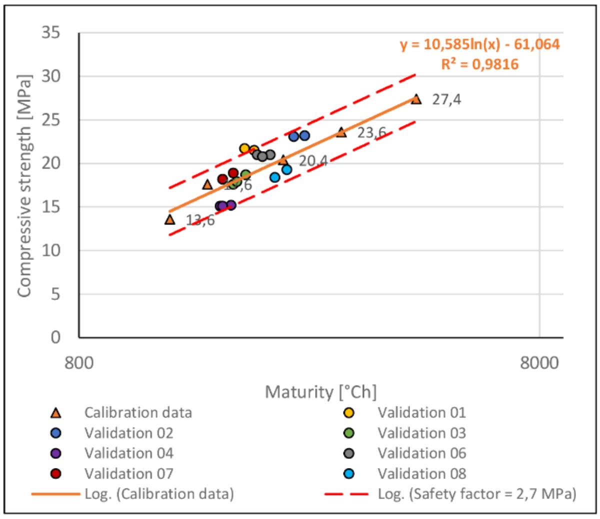

Figure 1 - Results of validation samples 12/2021 - 04/2022

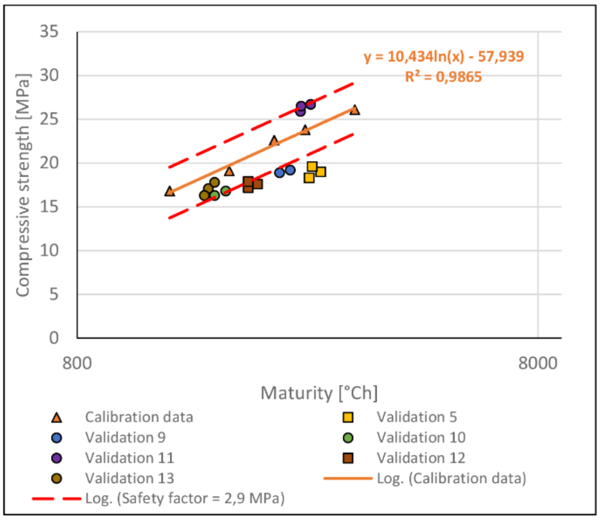

Figure 2 - Results of validation samples 03/2022 - 05/2022

3. METHODOLOGY

Based on the observation on the construction site described in the previous chapter, following experimental analysis was performed.

Figure 3 - Execution of experiment at the batching plant [photo: author]

The experiment took place at the concrete plant to gain valid results from practice. First, one cubic meter of the selected concrete mix was mixed and poured into the concrete truck following the standard procedure. Then concrete was poured from the concrete truck into four tanks with a volume of 0,2 m^3. The concrete mix in the first tank was not adapted and used as a reference for mixed concrete. Concrete batches in the remaining three tanks were adjusted in order to reach better consistency. Water was added into the second and third concrete tanks, which should represent a wrong way of consistency improvement on the construction site. Two litres of water added were added into the second concrete tank (10 l/m^3 additionally) and four litres of water into the third concrete tank (20 l/m^3 additionally). The consistency of concrete in the fourth tank was adapted following the recommended procedure – the addition of superplasticiser mixed with a small amount of water for better distribution of superplasticiser within the concrete batch. After those adaptions of concrete mixes, concrete was properly mixed using an electric concrete mixer and a showel.

Figure 4 - Three concrete batches before adaption of consistency [photo: author]

Right after the mixing, the following tests were performed by the author of the paper, and samples were prepared:

- Slump test
- Density
- Air content
- Samples for determination of the water-cement ratio
- Early-age compressive strength samples
- 28-day compressive strength samples

Consistency (EN 12350-2), density (EN 12350-6), and air content (EN 12350-7) were determined according to the standard procedure described in mentioned standards. The water-cement ratio was determined by drying an approximately 3,5 kg concrete batch. Early-age and 28-day samples were created and cured according to EN 12350-1 and EN 12390-2. The calibration curves of all four differently adapted recipes (acc. NEN 5970) were determined based on sequential testing of early-age compressive strength samples and continuous temperature monitoring. [3; 4; 5; 6; 7; 8]

Figure 5 - Early-age compressive strength samples [photo: author]

4. RESULTS

Concrete of the following specification was used.

C30/37 – XC4, XD2, XF1, XA1 – Cl 0,2 – D_{max} 16 – S4

The mixed recipe (reference) demonstrated a delivered concrete with the wrong consistency class. The tested consistency was S2. Table 1 shows the results of the slump tests. Adding 0,4 l/m^3 superplasticiser and 1,0 l/m^3 water improved concrete consistency equally as 10 l/m^3 of water. In both cases, the slump test result was 14 cm (S3). Adding 20 l/m^3 of water to the concrete resulted in an 18 cm slump (S4).

Table 1 - Consistency of tested concrete

Description	Air content [%]	Density [kg/m^3]	Slump [cm]	Consistency
Reference	2,7	2328	5	S2
Added 10l/m^3	-	-	14	S3
Added 20l/m^3	-	-	18	S4
Superplasticizer	-	-	14	S3

Table 2 presents the results of tested water-cement ratios by drying the sample of concrete.

Table 2 - Water cement ratio of tested concrete

Description	m_{water} [kg/m^3]	w/c	Δ w/c
Reference	172,3	0,45	0,00
Added 10l/m^3	177,6	0,46	0,01
Added 20l/m^3	179,2	0,47	0,02
Superplasticizer	171,6	0,45	0,00

Table 3 shows concrete density and 28-day compressive strength determined using standard cube samples. Presented 28-day strength values are the average results of three samples. The results confirm that added superplasticiser does not significantly reduced 28-day compressive strength. However, added water caused a drop in compressive strength value of about 6 – 7 MPa.

Table 3 - Density and 28-day compressive strength of tested concrete

Description	Density [kg/m^3]	28-day compressive strength [MPa]
Reference	2328	51,3
Added 10l/m^3	2313	45,2
Added 20l/m^3	2300	44,0
Superplasticizer	2312	50,6

Similar behaviour is observed in the early-age compressive strength samples. Figure 3 presents calibration curves of all concrete mixes. Compressive strength development of concrete mix with an added superplasticiser evinces even faster strength development (approx. + 1 MPa) than the reference recipe. Concrete samples with added water reached significantly lower values (approx. – 2 MPa or – 4 MPa).

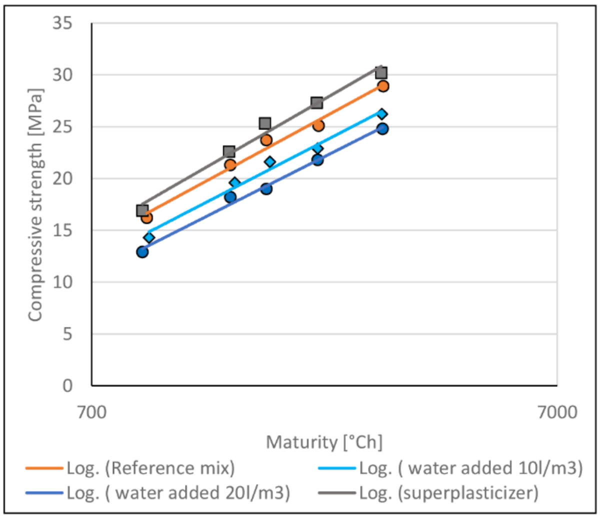

Figure 6 - Calibration curve of tested concrete

5. CONCLUSION

The results show the negative impact of adding water to ready-mix concrete at the construction site and confirm the negligible effect of the adaption of concrete mix following the recommended procedure with a superplasticiser. In the case of added water, compressive strength values are affected at an early age and later age.

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