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The e& ect of a starch-based stabilizing admixture on a change in the consistency of a concrete mix

Abstract: The article presents the research results into the influence of the content of a chemical-based stabilizing admixture in the form of starch on the change in the consistency of the concrete mix. The assessment of the impact of the stabilizing admixture dosed in the amount of 0.2%, 0.4%, and 0.6% in relation to the mass of cement on the change in consistency was made based on the cone drop test according to PN-EN 12350-2:2019-07. From the prepared concrete mixes, samples were also made for testing concrete density according to PN-EN 12390-7:2019-08 and compressive strength according to PN-EN 12390-3:2019-07. For the developed composition of the concrete mix, a standard (reference) mix was prepared, which was used to compare the test results from samples containing admixture in different amounts. Based on the tests carried out, it was found that the applied stabilizing admixture based on starch with a different percentage share concerning the mass of cement significantly reduces the consistency. The use of an admixture in the case of a concrete mix with too high consistency gives the possibility of changing its purpose without affecting the other parameters.

Keywords: Concrete mix; Starch; Concrete consistency

Introduction

The parameters of the concrete mix and cement concrete are strictly matched to the element being made. For example, cement concretes for the construction of road engineering structures require the use of a concrete mix of S3-S4 consistency. Consistency is the degree of liquidity of the concrete mix and is one of the factors shaping the workability of the mix [1]. In the case of concrete road surfaces and road linear elements in sliding formwork, the concrete mix used should have the consistency of S1. Very similar requirements for cement concrete for engineering structures and road surfaces make it possible to use one type of concrete mix. The problem, however, is in the consistency of the concrete mix, which differs by three classes. For this reason, the authors of the work undertook an attempt to check the

effect of the stabilizing admixture on the consistency of the concrete mix. In the case of the positive effectiveness of the admixture, it would be possible to change its intended use without affecting the other parameters of the concrete mix and hardened concrete. Such a solution would make it possible, for example, to reduce the costs associated with the production of a new mix if the mix available at the construction site would not meet the consistency requirements.

Based on the review of the literature, it was found that an admixture prepared on a chemical basis in the form of starch may have an impact on the change in the consistency of the concrete mix in the searched range. The authors of papers [2, 3] noticed that the starch-modified concrete mix is characterized by reduced consistency while maintaining the parameters of cement concrete made from the reference mix. In addition, in the work [4], the author noticed that cement concretes made with starch admixture show significantly lower deformations in the creep test compared to reference samples without modification. As noted by the author of [5], the admixture in the form of starch increases the setting time of cement concrete.

Purpose and scope of research

The research aimed to determine the effect of the starch-based stabilizing admixture on the change in the consistency of the concrete mix.

The scope of the tests included the preparation of four batches of concrete mixes, i.e. one standard (reference) according to a previously selected recipe and three with a variable percentage of stabilizing admixture. The next stage concerned the testing of the consistency of concrete mixes using the cone drop method according to the PN-EN 12350-2 standard. The last part consisted of density tests according to PN-EN 12390-7:2019-08 and compressive strength tests according to PN-EN 12390-3:2019-07 of cement concrete samples made of four different concrete mixes.

Materials and research methodology

Concrete mix recipe

In the tests, a concrete mix recipe was used as a model (reference) for the preparation of rope drainage elements and curbs made using the sliding method. The designed class of cement concrete for this mix is C30/37 and meets the requirements of exposure classes following the standards PN-EN 206+A1: 2016-12, PN-B-06265:2018-10+Ap1:2019-05. The consistency class of the concrete mix tested by the cone drop method according to the PN-EN 12350-2 standard is S2 (50-90 ± 20 mm). The water-cement W/C ratio is 0.43 and the air content in the concrete mix is between 4.5% and 6.5%. The composition of the recipe calculated per 1 m3 is to the mass of cement: natural sand 0/2 (main component quartz - 88%) - 39%, granite aggregate 2/8 - 28.8%, granite aggregate 8/16 - 32.2 %, cement 12.4%, water 42.56%, plasticizer and water-reducing/plasticizing superplasticizer and air-entraining admixture - 1.35% of total. Due to the influence of the air content in the concrete mix on its consistency (air bubbles act as shock absorbers and increase the liquidity of the concrete mix [6]), no air-entraining admixture was added to all mixes. The cement according to the recipe is CEM I 42.5 N-NA characterized by early strength after two days above 10.0 MPa and low alkali content (NA) below 0.6%. In the tests, a ready-made chemical-based stabilizing admixture in the form of starch was used, which increases the stability and cohesion of the concrete mix and is intended primarily for the production of self-compacting concrete (SCC). Thanks to the use of admixture, it is possible to obtain a greater homogeneity of the concrete mix and reduce the phenomenon of water drainage, thus reducing the phenomenon of aggregate segregation.

The internal cohesion is also increased, however, too much may delay the setting process of cement concrete.

Research methodology

After making the trial mixes to check whether the mix and cement concrete prepared according to the adopted recipe meets the adopted requirements, the first stage of testing was started. Concrete mixes with a volume of 30 dm3 were prepared: standard (reference) and three with different percentages of the stabilizing admixture, namely 0.2%, 0.4%, and 0.6% about the mass of cement (in short, bw). After mixing all the ingredients, aggregate, water, cement, and admixtures, consistency measurements were made using the slump method per the PN-EN 12350-2: 2019-07 standard "Part 2 Consistency testing by slump method". The cone drop method consists in filling a cone-shaped form with three layers of concrete mix, where each layer is equal to 1/3 of the height of the cone. Each layer is compacted with 25 bar strokes. After compaction of the top layer, the surface of the mix is leveled, the mold is removed and the cone slump is measured by determining the height difference between the mold and the highest point of the cone. There are 5 consistency classes according to the cone drop method according to Table **1**. In the case of the reference mix, two measurements were made: the first one was 10 minutes after the cement came into contact with water, which is the determinant of the initial consistency. The second measurement took place 60 minutes after the cement came into contact with water, which represented the delivery time of the concrete mix to the construction site. In the case of mixes containing a stabilizing admixture, three consistency tests were performed. The first is after 10 minutes from the moment of contact of cement with water. Then, a stabilizing admixture was added to the mix in the amount of 0.2%, 0.4%, or 0.6% of the cement mass, and the whole was mixed for another 2 minutes. Then, the second consistency measurement was made 15 minutes after the cement came into contact with water and 5 minutes after adding the stabilizing admixture. The third measurement of the consistency of the concrete mix was made 60 minutes after the cement came into contact with water (50 minutes after adding the stabilizing admixture).

Tab. **1**. Consistency classes according to the cone drop method

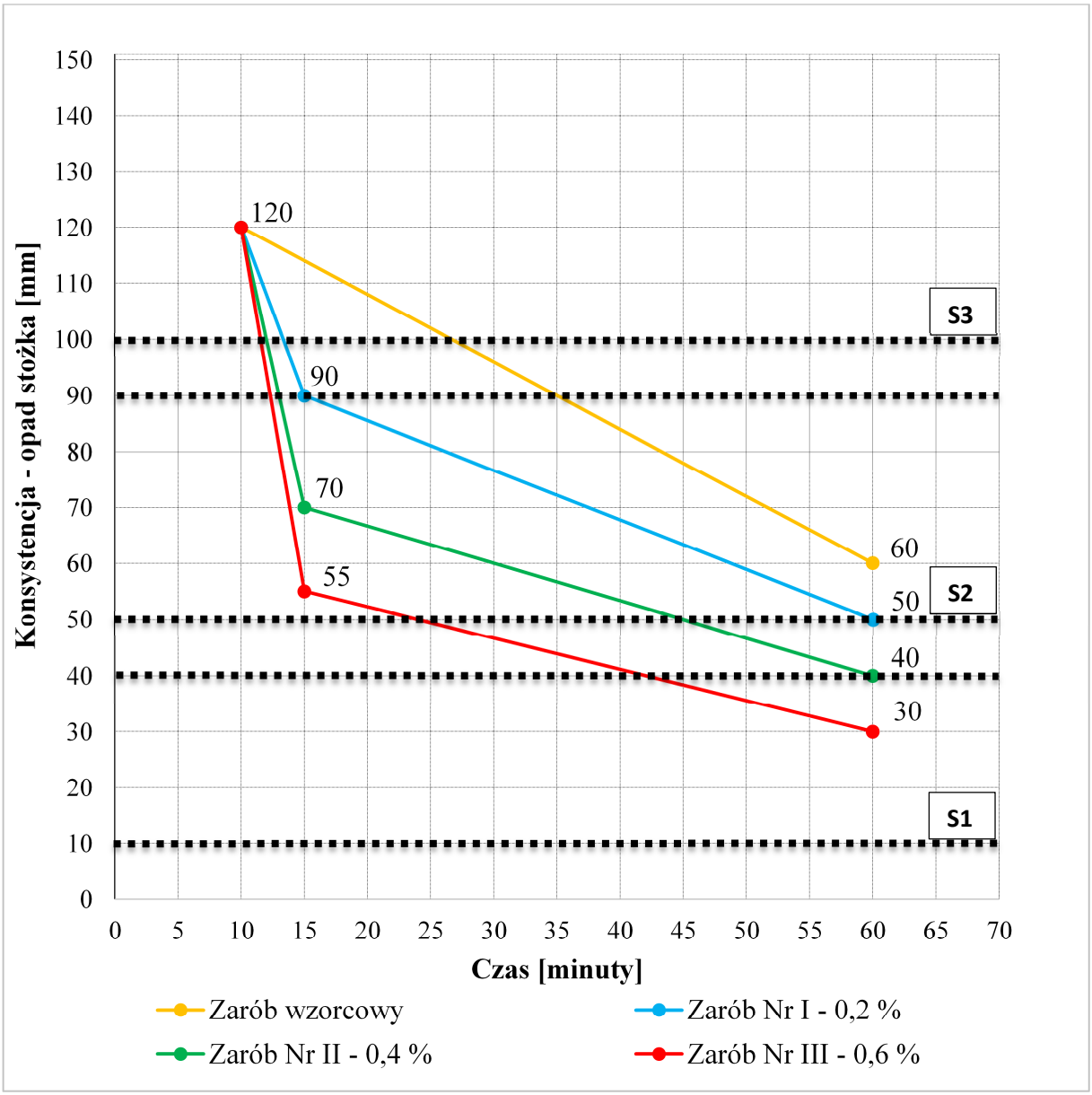
Class	Cone drop tested in accordance with PN-EN 12350-2 [mm]
S1	from 10 to 40
S2	from 50 to 90
S3	from 100 to 150
S4	from 160 to 210
S5	≥220

The second stage of the research consisted in taking from each concrete mix a batch for the preparation of cubic samples (3 pieces from each batch) with dimensions of 150x150x150 mm in order to test the density and compressive strength of cement concrete. The collected samples were made and maintained in accordance with the PN-EN 12390-2:2019-07 standard "Concrete tests Part 2: Preparation and care of samples for strength tests". The density test was carried out on three samples using a hydrostatic balance in accordance with the PN-EN 12390-7:2019-08 standard "Parts 7 Concrete density" point 6.5 Volume determined by displaced water. The compressive strength test was carried out using a hydraulic press for three samples per the PN-EN 12390-3:2019-07 standard "Concrete tests Part 3: Compressive strength of test specimens". The result of determining the compressive strength *fc* [MPa] is the ratio of the maximum measured load [N] to the surface area of the sample [m^2].

Research results and their analysis

Thr consistency of the concrete mix

Figure **1** shows the results of determining the consistency of the concrete mix by the cone drop method in the form of a cone height versus time graph. Analyzing the test results, it can be seen that the drop of the cone is smaller with the increase in the amount of admixture. The initial consistency of the concrete mix is 120 mm (class S3). When a stabilizing admixture based on chemical starch is added to the concrete mix, the drop of the cone is reduced (after 15 minutes from the moment of contact of the cement with water) to class S2. Namely, the decrease in consistency was 30 mm when the stabilizer was used in the amount of 0.2% b.w., and by 50 mm when using 0.4% b.w. stabilizer and 65 mm for the content of 0.6% m.c. stabilizer. After 60 minutes, i.e. mapping the time of delivery of the concrete mix to the construction site, the consistency of the standard (reference) mix is S2 (60 mm cone drop), and similarly in the case of a mix with a stabilizing admixture content of 0.2% m.c. (cone drops 70 mm). For higher admixture contents, mix with the amount of stabilizer in the amount of 0.4% b.w. and 0.6% b.w. consistency class S1 is obtained (respectively, for 0.4% b.w. the drop of the cone is 80 mm, and for 0.6% b.w. it is equal to 90 mm). The greatest decrease in consistency was recorded immediately after the application (ie mixing in the concrete mix) of the stabilizing admixture based on chemical starch. After 50 minutes from the application of the admixture, the results of testing the consistency of the concrete mix differ to a much lesser extent. Figure **2** shows the concrete mix cones obtained.



1. Influence of the amount of stabilizing admixture on the consistency of concrete mix over time according to the cone drop method following PN-EN 12350-2

Time from the moment of the first water-cement contact		
0 min	15 min	60 min
Model Grout		
		
Grout No. I - 0.2% m.c. stabilizing admixture		
		
Grout No. II - 0.4% m.c. stabilizing admixture		
		
Grout No. III - 0.6% m.c. stabilizing admixture		
		

2. Photographs showing the measurement of the tested concrete mix cone drop

Concrete density

Table **2** summarizes the results of the density determination of cement concrete samples obtained from individual partitions according to the PN-EN 12390-7:2019-08 standard. For all samples, the value of the standard deviation does not exceed 10 kg/m3, i.e. the accuracy with which the standard requires the determination of results. There is a tendency to decrease the density of cement concrete with increasing content of the stabilizing admixture. In the case of an admixture content of 0.2% m.c. densities are practically at the same level, while in the case of the content of 0.4% and 0.6% m.c. density is less by about 10 kg/m^3.

Tab. **2**. List of results of cement concrete density tests according to PN-EN 12390-7:2019-08

Grout (concrete mix)	Average concrete density [kg/m^3]
Model Grout	2329±10
Grout No. I - 0.2% m.c. stabilizing admixture	2328±10
Grout No. II - 0.4% m.c. stabilizing admixture	2320±6
Grout No. III - 0.6% m.c. stabilizing admixture	2319±9

Compressive strength

The results of the compressive strength tests are presented in Table **3**. Analyzing the data, it can be seen that the use of a stabilizing admixture does not change the average value of the cement concrete compressive strength f_{cm}. Taking into account the standard deviation values, the f_{cm} value for all samples is in the range of 57-62 MPa. Due to the obtained values of the average and minimum compressive strength at the border of the ranges, the cement concretes obtained from the mixtures belong to the C40/50 or C45/55 class. Compressive strength classes for each of the mixes determined following the rules set out in the PN-EN 206+A2:2021-8 standard are listed in Table **4**. Cement concrete samples with a stabilizing admixture content of 0.2% and 0.6% m.c. are characterized by one strength class higher than samples from the reference batch).

Tab.**3**. List of compressive strength test results according to PN-EN 12390-3:2019-07

Grout (concrete mix)	Average compressive strength of concrete f_{cm} [MPa]	Minimum value of compressive strength $f_{ci\ \min}$ [MPa]
Model Grout	58,2±0,7	57,4
Grout No. I - 0.2% m.c. stabilizing admixture	60,5±1,2	59,5
Grout No. II - 0.4% m.c. stabilizing admixture	58,4±1,4	57,6
Grout No. III - 0.6% m.c. stabilizing admixture	60,0±1,9	58,8

Tab. **4**. Compressive strength classes of tested cement concretes according to PN-EN 206+A2:2021-8.

Grout (concrete mix)	Compressive strength class
Model Grout	C40/50
Grout No. I - 0.2% m.c. stabilizing admixture	C45/55
Grout No. II - 0.4% m.c. stabilizing admixture	C40/50
Grout No. III - 0.6% m.c. stabilizing admixture	C45/50

Summary and Conclusions

The tests carried out showed that through the appropriate use of a stabilizing admixture, the consistency of the concrete mix can be controlled with no negative impact on the parameters of cement concrete, such as density and average compressive strength.

In the case of problems with the appropriate consistency of the concrete mix, the use of a stabilizing admixture (reducing consistency) can be a way to reduce the costs associated with the need to make a new mix and thus downtime at the construction site. The conducted pilot studies should be extended to the study of air-entrained concrete mix, because air bubbles in the concrete mix have a significant impact on the consistency of the mix, and in hardened concrete, they improve durability parameters. In addition, tests of frost resistance and the depth of water penetration under pressure should be carried out and, of course, the scope of the test should be extended to include cement concrete of a different class, e.g. C30/37.

From the conducted research on the effect of a stabilizing additive based on chemical starch, it was found that:

- stabilizing admixture in the amount of 0.2%, 0.4%, and 0.6% b.w. reduces the consistency of the concrete mix,
- the greatest reduction in consistency can be noticed immediately after the use of a stabilizing admixture,
- after 50 minutes from the application of the admixture, the results of testing the consistency of the concrete mix differ to a much lesser extent,
- use of an admixture in the amount of 0.6% m.c. allows you to change the consistency of the concrete mix by two classes from S3 to S1 (after 60 minutes of contact of cement with water),
- use of an admixture in amounts from 0.2% to 0.6% b.w. enables an immediate change in the consistency of the concrete mix by one class from S3 to S2, and the case of larger quantities, probably even by 2 classes,
- the results of density tests of cement concrete showed that the stabilizing admixture had a slight effect on its density,
- the results of compressive strength tests confirm that the stabilizing admixture has no negative effect on the change in the compressive strength of concrete.

Source materials

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