THE INFLUENCE OF AIR ENTRAINING ADMIXTURES ON CONCRETE PROPERTIES

Ksenija Janković[1]
Marko Stojanović[2]
Dragan Bojović[3]
Ljiljana Lončar[4]
Lana Antić[5]

UDK: 666.972.168
DOI:10.14415/konferencijaGFS2017.049

Summary: Concrete exposed to frost and de-icing salts have to be protected by aeration. This is achieved by adding chemical additives to draw air into the fresh concrete. These concretes have resulted in a decrease of compressive strength of concrete by 5% for each percent of entrained air in comparison to the conventional concrete. Three concrete mixtures with different types of air entraining admixtures was done were made. A testing of properties of fresh concrete and the influence of different types of air entraining admixtures to fresh concrete was conducted. The results obtained in the fresh concrete as well as the compressive strength at the age of 3, 7 and 28 days are shown.

Keywords: *air entraining admixtures, fresh concrete, compressive strength*

1. INTRODUCTION

In cold climate countries, concrete damage due to the combined action of frost and de-icing salts provides a major contribution to repair costs for transportation infrastructure. Such damage consists of the removal of small chips or flakes of material at the exposed surface of concrete elements. This phenomenon is usually called “frost-salt scaling”. Numerous field evidences and laboratory test results show that air entrainment reduces frost-salt scaling damage, e.g. [1]

By deliberately introducing many, small and closely spaced air voids in the cement paste the durability of concrete subjected to wetting and cycles of freezing and thawing can be enhanced. During the freezing, if the air-void spacing and the size distribution of the air voids are within certain limits, the ice formed in the capillary pores of the paste expands into adjacent air voids without damaging the paste. Concrete specifications for frost resistant concrete need to have the air-void system parameters incorporated into them. The air void system protects the paste portion of the concrete by providing relief

[1]Ksenija Janković, PhD, Institute IMS, Bulevar vojvode Mišića 43, Belgrade, Serbia, tel: +381 11 2653645, e-mail: ksenija.jankovic@institutims.rs
[2]Marko Stojanović, MSc, Institute IMS, e-mail: marko.stojanovic@institutims.rs
[3]Dragan Bojović, MSc, Institute IMS, e-mail: dragan.bojovic@institutims.rs
[4]Ljiljana Lončar, BSc, Institute IMS, e-mail: ljiljana.loncar@institutims.rs
[5]Lana Antić, MSc, Institute IMS, e-mail: lana.antic@institutims.rs

from hydraulic pressures which are generated as a result of freezing and migrating water in the paste. When developing durable concrete it is important to develop the proper air void system [2]. The pressure developed by water as it expands during freezing is dependent on the distance the water must travel to the nearest air void. The voids must be spaced close enough in order to relieve the pressure. Thus smaller, closely spaced voids provide more protection than larger, more distant void spacing [3].

2. EXPERIMENTAL WORK

The aim of the research was to determine the differences in the use of different types of air entraining admixtures on the properties and rheology of fresh concrete and the impact on the compressive strength at the age of 3, 7 and 28 days. A testing of consistency, air content, bulk density and temperature of the fresh concrete was performed.

2.1. The composition of concrete

Concrete mix is designed in such a way that concrete surface is exposed to frost and de-icing salts. The recommended values according to the SRPS U.M1.206/2013 standard, class of concrete, max w/c, the minimum quantity of cement, the minimum air content were adopted.

2.1.1. Cement

Portland - composite cement CEM II / A-M (S-L) 42.5 R, producer Lafarge BFC – Beocin was used. The chemical properties of the cement are shown in Table 1.

Table 1. Composition of cement (%)

	Cement
SiO_2	20.88
Al_2O_3	5.68
Fe_2O_3	3.32
CaO	59.69
MgO	1.92
Na_2O	0.36
K_2O	0.60
SO_3	3.70

2.1.2. Aggregate

Natural, river aggregate in fractions 0/4, 4/8, 8/16 mm was used. Aggregate was of limestone origin, the average specific mass of 2650 kg/m3. Water absorption of aggregate for each fraction is 0/4 mm - 1.2%, 4/8 mm - 0.6% and 8/16 mm - 0.8%. Particle size distribution of aggregates is shown in Figure 1.

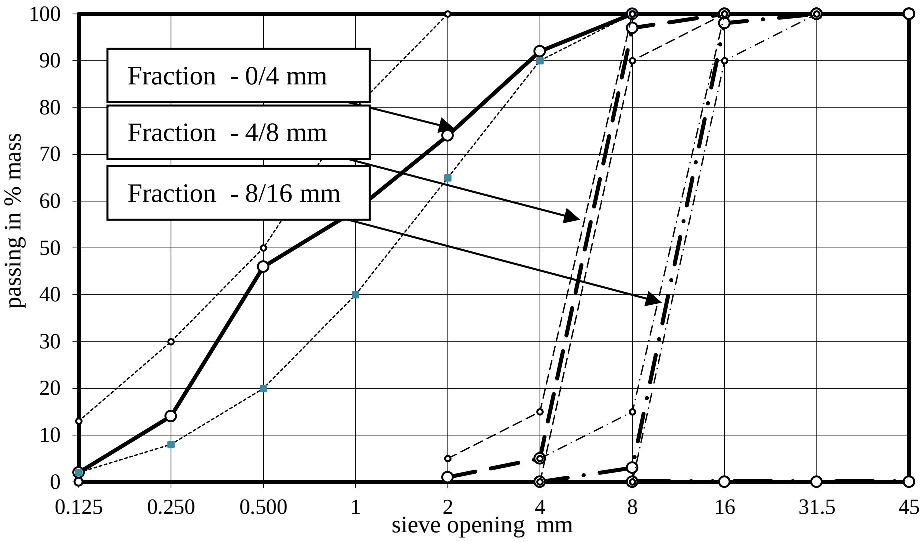

Figure 1. Aggregate grain size distribution

2.1.3. Chemical additives

2.1.3.1. Superplasticizer

Superplasticiser Sika Viscocrete 1020 x (polycarboxylate ether), manufacturer Sika doo Serbia - Belgrade was used. Specific mass of the additive is 1.04 kg/l. Superplasticizer was used in all concretes in the amount of 1.8 kg/m^3.

2.1.3.2. Additives for concrete protection from the influence of frost

In concrete making, different concrete admixtures for protection against frost were used:

- Sika Aer - liquid admixtures that is mixed with water and entraining air bubbles up to 300μ in size,
- Sika Control Aer P 200 - admixtures for entraining air bubbles in fresh concrete, in powder form is added to the aggregate during the preparation of concrete,
- Sika Aer Solid - very tiny white plastic beads, which physically remain in the cement matrix, are added to the aggregate during the preparation of concrete.

A picture of the admixtures is shown in Figure 2.

a) Sika Aer *b) Sika Control Aer 200 P* *c) Sika Aer Solid*

Figure 2. Different types of air entraining admixtures

Four types of concrete were made. Compositions of concrete mixtures are shown in Table 2.

Table 2. Concrete mixture composition (kg/m^3)

Mix Nº	C	A	VSC 1020x	Water	Sika Aer	Sika Control Aer 200P	Sika Aer Solid
Mix 1	360	1870	1.8	158	-	-	-
Mix 2	360	1780	1.8	158	0.036	-	-
Mix 3	360	1780	1.8	158	-	3.6	-
Mix 4	360	1870	1.8	158	-	-	3.5

w/c =0.439

2.2. Results of fresh concrete testing

2.2.1. Slump - test

Determination of the concrete consistency was performed by the slump method. For this testing, the Abrams cone was used. Concrete slump is measured after the preparation of concrete and on every 15 minutes after that according to the SRPS EN 12350-2:2010. The measurement results are shown in Figure 3.

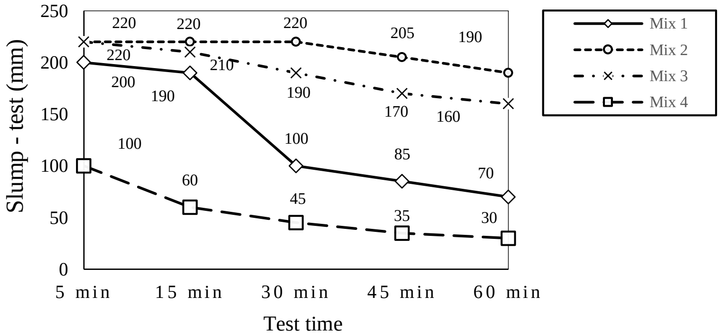

Figure 3. Slump – test in time

2.2.2. Density

Determination of bulk density of concrete is done in a container with a volume of 0.008m^3. Determination of bulk density of fresh concrete was done on every 15 minutes from the moment of completion of the concrete preparation according to SRPS EN 12350-6:2010. The measurement results are shown in Table 4.

Table 4. Density (mm)

Mix Nº	5 min	15 min	30 min	45 min	60 min
Mix 1	2370	2355	2370	2370	2340
Mix 2	2290	2270	2250	2230	2220
Mix 3	2350	2360	2350	2330	2320
Mix 4	2410	2400	2380	2380	2370

2.2.3. Air content

Measurement of the air content of fresh concrete was done on every 15 minutes according to SRPS EN 12350-7:2010. The measurement results are shown in Table 5.

Table 5. Air content (%)

Mix N°	5 min	15 min	30 min	45 min	60 min
Mix 1	2.2	2.2	2.3	2.4	2.4
Mix 2	6.8	7.7	8.5	10.0	11.0
Mix 3	3.8	4.0	4.2	5.0	5.3
Mix 4	2.2	2.5	2.6	3.0	3.8

2.3. Results of hardened concrete testing

2.3.1. Compressive strength

Samples for testing compressive strength of concrete were made. Concrete was compacted on the vibrating table in cube shaped metal molds, edge d = 150 mm, which were cured in water at a temperature of + 20 ° C until the moment of testing according to SRPS EN 12390-2 standard. Testing of compressive strength of concrete at the age of 3, 7 and 28 days was carried out according to SRPS EN 12390-3 standard. The test results are shown in Figure 3.

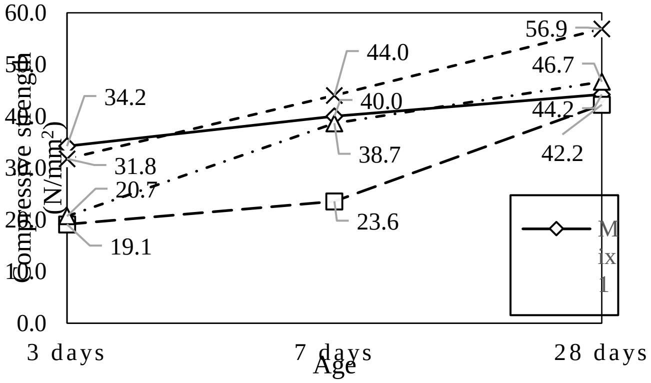

Figure 3. Compressive strength at the age of 3, 7 and 28 days

3. CONCLUSION

Based on the obtained results of concrete slump test it can be established that all concrete mixes belong to the class of consistency S4, except Mix 4, which belongs to the class of consistency S2. Concrete Mix 2 after 60 minutes had a consistency less than 30 mm, Mix 1 - 130 mm, Mix 3 - 60 mm and Mix 4 -70 mm, in relation to the initial value (5 min).
The results of bulk density indicate that the concrete Mix 2 has a reduction of bulk density by as much as 70 kg/m^3 after 60 minutes of measurement in relation to the measurement value after the completion of the concrete preparation. Mix 4 had the best results of

compactness. It is evident that over time bulk density of concrete decreases for all concrete mixes. Air content in all concrete mixes increase over time. Increasing the air content over time is the highest in concrete Mix 2 which reached a value of 11% after 60 minutes. Concrete Mix 3 is more constant compared to the concrete Mix 2. The results of air in concrete Mix 4 indicate that the matrix is very compact and exhibits the characteristics of concrete without the entrained air content. The test results of compressive strength at age of 3 days are the best in concrete without the entrained air content Mix 1 - 34.2 MPa. After 7 days, the best result was achieved in concrete Mix 4 - 44.0 MPa, and at 28 days Mix 4 - 56.9 MPa. In concrete Mix 2, which had the highest air content the lowest results of compressive strength were achieved. By using different types of air entraining agents, we found that the best results of hardened concrete was achieved in concrete Mix 4 ie. Sika Aer Solid. In addition to the good mechanical properties that this concrete proved in further research, its durability needs to be proven through testing the resistance of concrete surface to the action of frost and de-icing salts.

ACKNOWLEDGMENTS

The work reported in this paper is a part of the investigation within the research project TR 36017 "Utilization of by-products and recycled waste materials in concrete composites in the scope of sustainable construction development in Serbia: investigation and environmental assessment of possible applications", supported by the Ministry of Education, Science and Technology, Republic of Serbia. This support is gratefully acknowledged.

REFERENCES

[1] Pigeon M, Marchand J, Pleau R. Frost resistant concrete. Constr Build Mater **1996**;10(5):339–48.
[2] ACI 201.2R-01. Guide to durable concrete. ACI manual of concrete practice. Farmington Hills (MI): American Concrete Institute; **2001**.
[3] Crawford GL, Wathne LG, Mullarky JI. A ‘‘fresh’’ perspective on measuring air in concrete. **2003** Concrete Bridge Conference.

UTICAJ AERANATA NA SVOJSTVA BETONA

Rezime: Betoni koji su izloženi dejstvu mraza i soli za odmrzavanje moraju se štititi aeriranjem. Zaštita se postiže dodavanjem hemijskih dodataka koji uvlače vazduh u svež beton. Ovakvi betoni imaju za posledicu pad čvrstoće pri pritisku betona od 5% za svaki procenat uvučenog vazduha u odnosu na konvencionalne betone. Spravljene su tri mešavine betona sa različitom vrstom aeranata. Izvršeno je ispitivanje svojstava svežeg betona i uticaj dodavanja različitih vrsta aeranata na svež beton. Prikazani su rezultati dobijeni na svežem betonu kao i čvrstoća pri pritisku u starosti od 3, 7 i 28 dana.

Ključne reči: *aeranti, svež beton, čvrstoća pri pritisku*