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PROPERTIES OF FRESH AND HARDENED MORTARS WITH AIR-ENTRAINING AGENT

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The influence of the air-entraining agent (AEA) on a density, the volume of entrained air of mortar mix and compressive strength of hardened mortar was studied in this article. Results show that the addition of AEA results in the reduction of water to cement ratio to provide the targeted flow and the density that depends on the volume of entrained air. The addition of AEA causes the decrease of the density of mortar (C:S=1:2) by 8,2 % and the increase of the compressive strength by 13,9 % after 28 days of hardening compared to the mortar (C:S=1:2) without AEA. The further increase of a sand content in a mortar (C:S=1:3) results in slight decrease of a density of fresh mortar and compressive strength. If C:S ratio is 1:4 the increase of the density and the compressive strength decrease is observed in comparison with the mortar with C:S=1:3. The obtained results show that properties of mortar incorporating AEA depend on its mix proportion.

Keywords: density, fresh mortar, mix proportion, hardened mortar, air-entraining agent, compressive strength

Introduction

The building mortar is one of the very popular material which is used in the different construction purposes. Many scientists devoted a lot of researches to study the properties of this material. Mehmetoğulları et al. (2020) studied the influence of a grain-size of fine aggregate on the physical and mechanical properties of hardened mortar. The cement replacement (0–20 % by mass) with waste glass powder was also investigated in building mortars (Dębska et al., 2020). Air-entraining agent is used in the most cases to improve the frost resistance of mortar and concrete. The study of the effect of air-entraining admixtures on mortar mix and hardened mortar is of great interest from the practical and theoretical point of view (Tebbal et al., 2018). It was also studied by many other authors, among them Atahan et al. (2008), Chatterji (2003) and Ouyang et al. (2008). According to Du et al. (2005), Fonseca et al. (2015), Jin et al. (2013), Struble et al. (2004) and Ugur Ozturk et al. (2016) AEA improves the workability, slump retention ability and resistance to freezing and thawing cycles. The use of AEA results in obtaining evenly distributed small air-voids nearly spherical and typically in the range of 10–100 µm in diameter both in mortar and concrete which cause the reduction of such technological properties of fresh mortar as segregation and bleeding and as a result the durability (Cultrone et al., 2005; Aïtcin et al., 2015; Pigeon et al., 1995). It is well known that building mortar has a porous structure and the ability to absorb the water which can freeze in winter causing the expansion by about 9 % and its destruction (Blikharskyy et al., 2021; Sun et al., 2010; Coussy et al., 2008). The presence of AEA protects a mortar against damage due to the water freezing (Saucier et al., 1991; Babiak et al., 2018). In the previous studies it was established that the compressive strength of concrete without AEA exposed to freezing and thawing cycles reduces significantly (Markiv et al., 2016). It is well known that properties of a mortar depend on the its composition. However, the effect of the mix proportion on the properties of fresh and hardened mortars with AEA is not thoroughly studied.

That is why, the aim of this article is to study the influence of AEA and the mortar mix proportion on the density, volume of the entrained air of fresh cement mortar and compressive strength of hardened mortars.

Materials and methods

Physical and mechanical properties of Portland cement CEM I 42.5 which was used in this study are presented in Table 1. The Tovarov device and Vicat apparatus were used to determine the specific surface and the setting time of Portland cement, respectively.

Table 1

Physical and mechanical properties of the cement

Specific surface, m^2/kg	Residue on sieve 008, %	Water demand, %	Setting time, min		Compressive strength, MPa		
			initial	final	2 days	7 days	28 days
325	3.1	29.0	155	205	31.2	41.3	52.1

Portland cement and fine aggregate properties were determined according to Ukrainian standards DSTU B V.2.7-185:2009, DSTU B V.2.7-187:2009, DSTU B V.2.7-188:2009, DSTU B V.2.7-232:2010. As the fine aggregate the sand with fineness modulus of 1.0 was used. Bulk density, voidage and the content of dust and clay particles of fine aggregate were 1360 kg/m^3, 48.3 % and 1.4 %, respectively. Cumulative percent of sand, retained on sieves is presented in Fig. 1. Air-entraining agent with a specific gravity of 1.02, pH=8 and solid content of 0.34 % was used in the research.

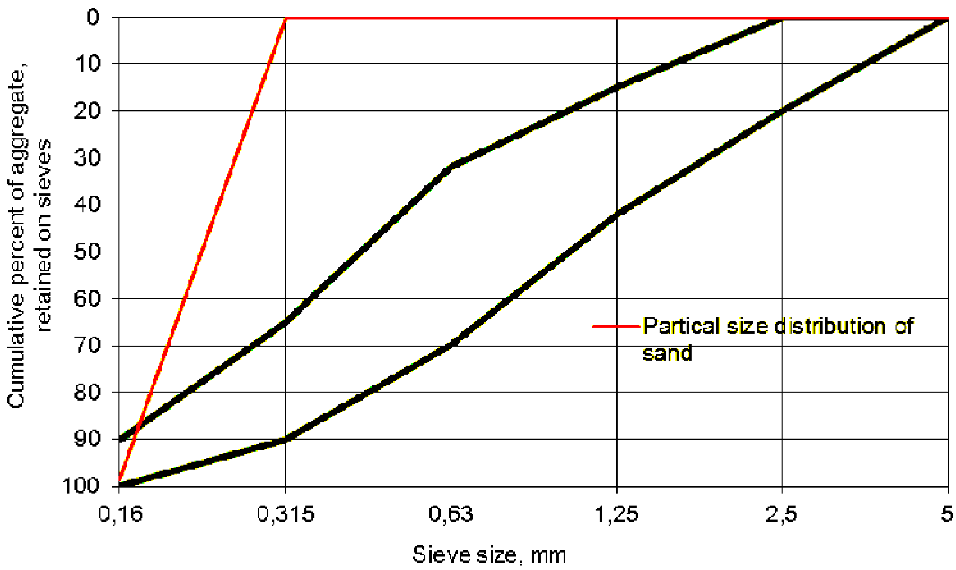

Fig. 1. Cumulative percent of sand, retained on sieves

Four mortars (C:S=1:2, R and C:S=1:2, C:S=1:3, C:S=1:4, with 0,75 % by mass of AEA) with different mix proportions have been prepared. Mortars were prepared and moulded according to DSTU B V.2.7-187:2009 and their compressive strength was determined. The volume of entrained air was determined according to DSTU B V.2.7-114-2002.

Results and discussions

The use of AEA results in entraining required amount of air bubbles which change the density and improve rheological properties of fresh mortar as well as have an influence on the compressive strength of hardened mortars. The addition of AEA results in the improvement of the workability of fresh mortars. It allows to realize the technical effect of the admixture`s use to reduce water to cement ratio. The results of the tests show (Fig. 2) that the significant reduction (by 44 %) of W/C ratio is observed for mortar with the ratio of cement to sand 1:2. If C:S ratio is 1:3 slight reduction of W/C ratio takes place in comparison with the reference mortar. The further reduction of C:S ratio of mortar incorporating AEA causes the increase of W/C ration by 26 %.

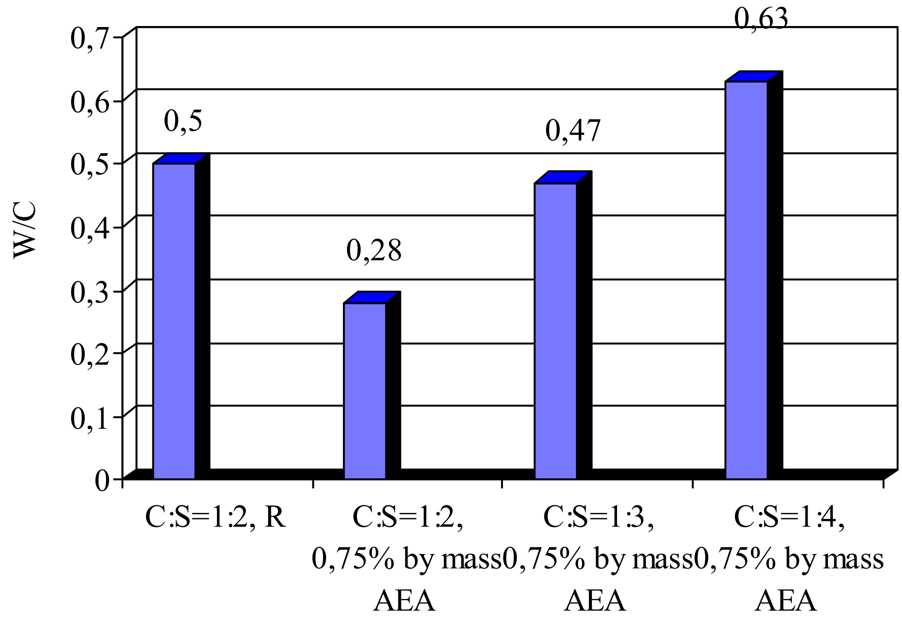

Fig. 2. W/C ratio of mortars with the different proportions of cement to sand (F=125–135 mm)

The density of mortars (F=125–135 mm) containing AEA naturally decreases in comparison with the reference mortar (Fig. 3). The reduction is observed for mortars with C:S ratio 1:2 and 1:3 by 8.2 and 10.6 %, respectively. However, the density increases from 1758 to 1789 kg/m^3 if C:S ratio changes from 1:3 to 1:4.

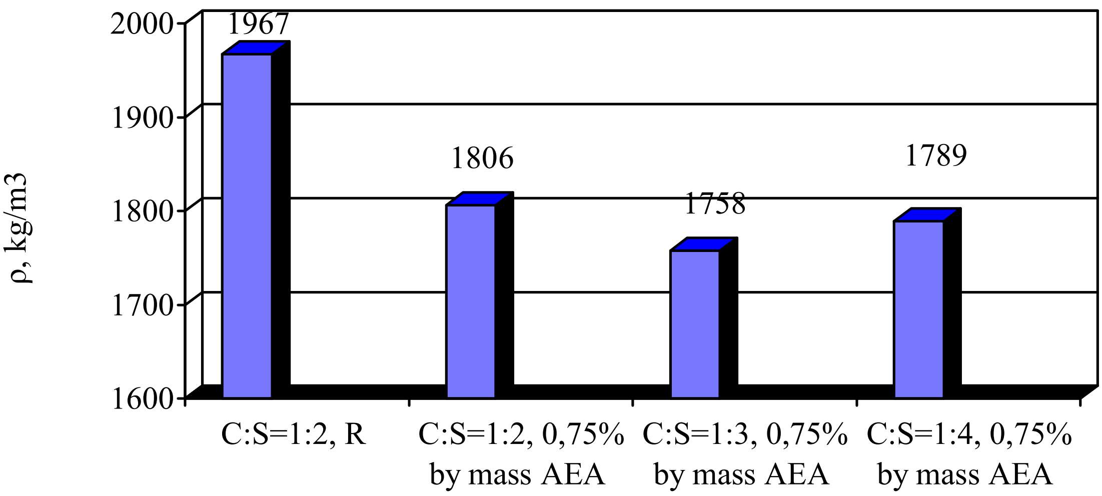

Fig. 3. The density of fresh mortars with the different proportions of cement to sand (F=125–135 mm)

As seen from Fig. 4, the highest volume of entrained air (V=11.4 %) is observed for fresh mortar with the highest content of cement paste (C:S=1:2). If the amount of the sand increases in mortars (C:S=1:3; C:S=1:4), it results in the growth of entrained air from 4.9 for reference mortar to 7.4 and 7.2 %, respectively. The obtained results show that the volume of entrained air depends on the mixture proportion.

The results of the compressive strength tests are shown in Fig. 5. The obtained values show that in spite of the high volume of entrained air in mortar with C:S=1:2 its compressive strength is higher at all stages of structure formation. Thus, the compressive strength increases by 16.7; 56.1 and 13.9 % after 7; 14 and 28 days of hardening. In this case the key role of W/C ratio is indicated. The increase of the sand content in mortars with mix proportion C:S=1:3 and C:S=1:4 and higher amount of entrained air causes the reduction of compressive strength in comparison with reference mortar R. It should be noted that the pattern connected to W/C ration is not retained when the compressive strength increase with the decrease of the W/C ratio. It should be noted from the obtained results that compressive strength reduction depends on the content of cement in mortar and mix proportion.

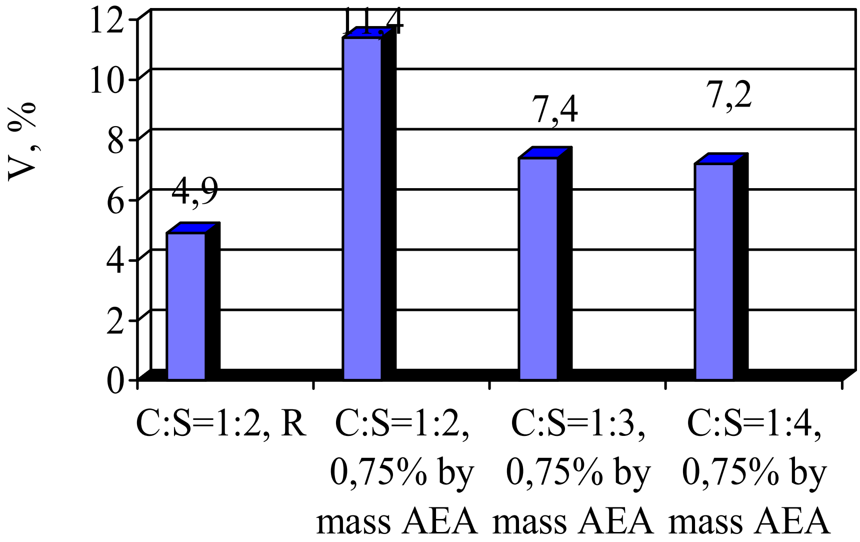

Fig. 4. The volume of the entrained air of fresh mortars with the different proportions of cement to sand (F=125–135 mm)

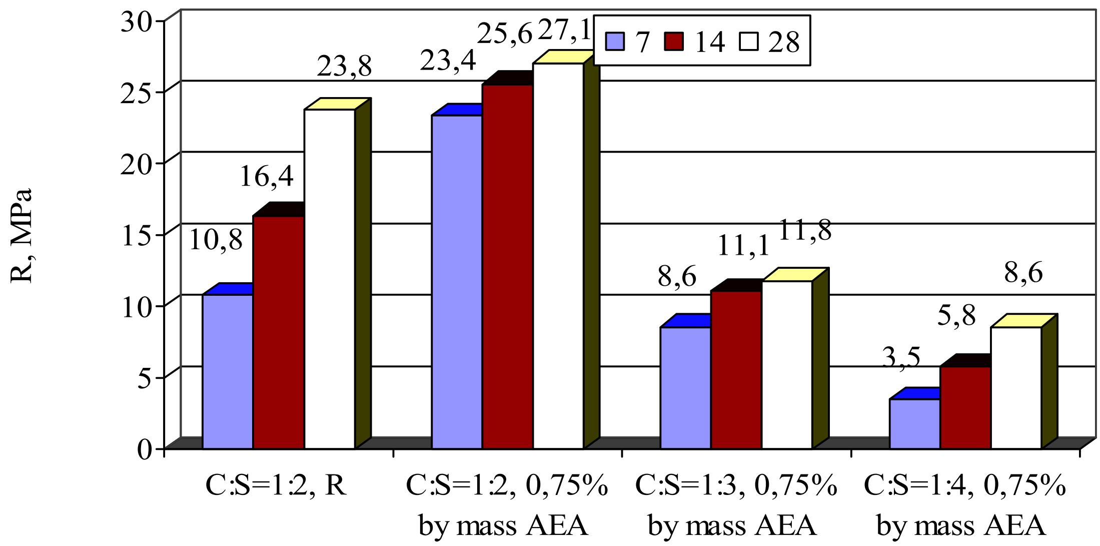

Fig. 5. Compressive strength of mortars with the different proportions of cement to sand (F=125–135 mm)

Conclusions

The effect of air-entraining agent on the properties of mortar mix and compressive strength of hardened mortar was studied in this article. The following conclusions can be drawn:

• The W/C ratio of mortar incorporating 0.75 % by mass of AEA depends on its mix proportion and increases with the reduction of C:S ratio by almost 1.7 and 2.3 times for mortars with the C:S ratio 1:3 and 1:4, respectively, in comparison with the mortar C:S=1:2.

• The correlation between the volume of entrained air and the density of mortar is not strict. The density depends on the mix proportion as well.

• The compressive strength of mortars containing AEA depends on the mixture proportion. The compressive strength increase (by 13.9 %) for mortar C:S=1:2 containing 11.4 % of entrained air is even observed in comparison with the reference mortar after 28 days of hardening.

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ВЛАСТИВОСТІ РОЗЧИНОВИХ СУМІШЕЙ ТА ЗАТВЕРДІЛОГО РОЗЧИНУ З ПОВІТРОВТЯГУВАЛЬНОЮ ДОБАВКОЮ

У статті досліджено вплив повітровтягувальної добавки на властивості будівельних розчинів. Застосування таких добавок призводить до втягування необхідної кількості бульбашок повітря, які покращують реологічні властивості розчинової суміші, впливають на міцність при стиску затверділих будівельних розчинів. Досліджено вплив повітровтягувальної добавки на зміну водоцементного відношення, густину, об'єм втягнутого повітря розчиновою сумішшю та міцність на стиск затверділого розчину. Отримані результати досліджень свідчать, що введення повітровтягувальної добавки призводить до зменшення водоцементного відношення, щоб забезпечити отримання розпливу конуса 125–135 мм і, як наслідок, густини, яка залежить від об'єму втягнутого повітря. Додавання повітровтягувальної добавки спричиняє зниження густини розчину (C:S=1:2) на 8,2 % та підвищення міцності на стиск, за рахунок зменшення водоцементного відношення, на 13.9 % через 28 діб тверднення порівняно з розчином (C:S=1:2) без повітровтягувальної добавки. Збільшення вмісту піску в розчині з повітровтягувальною добавкою (C:S=1:3) призводить до незначного зниження густини розчинової суміші, об'єму втягнутого повітря та міцності на стиск затверділого розчину. При співвідношенні цементу і піску 1:4 навіть спостерігається деяке збільшення густини і зниження міцності на стиск порівняно з будівельним розчином з співвідношенням Ц:П=1:3. Результати проведених досліджень свідчать, що властивості розчинів, які містять повітровтягувальну добавку, залежать найбільше від складу розчинової суміші. Таким чином, використання повітровтягувальних добавок дозволяє покращити технологічні властивості розчинових сумішей та експлуатаційні властивості затверділих розчинів і, як наслідок, їх довговічність, що відповідає стратегії сталого розвитку в будівництві.

Ключові слова: густина, розчинова суміш, склад розчину, затверділий розчин, повітровтягувальна добавка, міцність на стиск.