A Review on the Effect of Environmental Conditions on Concrete Evaporation and Bleeding

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Abstract. The formation of plastic shrinkage crack increases on the fresh concrete placed in hot and windy conditions. The cracks affect the durability of the concrete in a negative way. This type of cracking is mostly seen on slabs, pavements, beams and other flat concrete surfaces. Many factors influence evaporation, which is the main source of cracks. Evaporation is the function of climatic variables like relative humidity, temperature and speed of wind. In this study, experimental results of plastic shrinkage obtained from the literature are examined and compared to predict the effect of environmental conditions on evaporation and bleeding of concrete.

Keywords: Concrete · Evaporation · Bleeding · Humidity · Temperature

1 Introduction

Main factors that accelerate the evaporation on the surface of fresh concrete are climatic ones; such as, low relative humidity, high temperature, high wind speed or sunbeams. Evaporation occurs when thermal energy like sunbeams affects liquid or pressure on the surface of liquids is less than the pressure inside the liquid. Evaporation takes place as active water molecules move away from liquid. Evaporation is accelerated if the wind that provides ongoing motion of water molecules is available. On the other hand, if surface water temperature decreases, evaporation slows down. It is necessary to know what the degree of water temperature on the surface is in order to set the difference of pressure between water surface and air. Temperature of concrete is taken as the temperature of bleeded water [1]. The formula that Dalton drew the main features of evaporation in 1802 is shown with the Eq. (1).

$$E = (e_o - e_a)f(u) \tag{1}$$

In this equation, E, $(e_o - e_a)$, and f(u) are respectively defined with evaporation speed, the difference of pressure, and function of wind (Dalton, 1802) [2]. In 1950–1952,

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broad researches were carried out around Hefner Lake. As a result of these researches, the Eq. (2) was introduced by Kohler.

$$E = (e_o - e_a)^{0.88}(0.37 + 0.0041u) \tag{2}$$

E, evaporation speed; u, wind speed; and $(e_o - e_a)$, the difference of pressure is respectively defined as in/day, miles/day, and in/Hg (Kohler, 1955) [3]. Menzel obtained Eq. (3) by using Kohler formula.

$$E = 0.44\,(e_o - e_a)(0.253 + 0.096v) \tag{3}$$

In this equation, E represents weight of water that evaporates from 1 ft^2 surface in 1 h as ($lb/ft^2/h$); e_o indicates vapor pressure on surface that evaporation occurs as psi; e_a represents vapor pressure of the weather as psi; and v represents wind speed that is measured 50 cm above from the evaporation surface as mile/h. Number (3) equation is presented in an article that was published by Menzel in Portland Cement Association (PCA) in 1954 (Menzel, 1954) [4]. This is the evaporation equation that is known as Menzel's equation. It is necessary to know vapor pressures in order to detect evaporation speed from these formulas. In 1960, Bloem points out temperature that is measured in the concrete and relative humidity of the air as variables, so he finds a solution for this problem. This solution takes place in an article for the name of National Ready Mixed Concrete Association (NRMCA) in a monograph form (Bloem, 1960) [5].

Uno creates formula (4) by using variables of concrete and air temperature without counting vapour pressures by putting Menzel's equation into consideration.

$$E = 5\left([T_c + 18]^{2.5} - r.\,[T_a + 18]^{2.5}\right)(v + 4)10^{-6} \tag{4}$$

E, evaporation speed, with $kg/m^2/h$; T_c, concrete temperature, with °C; T_a, weather temperature, with °C; r, rate of relative humidity, with %; and v, wind speed, with km/h are represented in this equation [1, 6]. Evaporation speeds calculated using these formulas give different values from experiment results.

2 Experimental Results

As it is understood in the formulas, environmental factors that play a role in evaporation are air temperature, relative humidity, wind and water surface (concrete) temperature. Evaporation is the phenomenon that liquid becomes vapor or gas. In other words, evaporation is the penetration of thermal energy to the inside of the water, and the situation that pressure on the surface of liquid is less than the pressure that the water has. As a result of this, active water molecules move away from liquid by evaporating. If the wind that changes its place continuously and water molecules is available, evaporation gains momentum. The loss of energy on the surface of evaporated water means decrease in the temperature of water on the surface. In these conditions, evaporation slows down. The measurement of air temperature variable is certain and

easy. The only condition is to be measured away from direct sunbeams and to reduce direct solar radiation. Relative humidity is the proportion of actual humidity that is available in the unit volume of the air (kg/m^3) to the amount of saturated air humidity, and it is assigned by percentage. When relative humidity accesses to 100 out of 100, evaporation ceases if other factors such as wind do not change saturated air with unsaturated air. The temperature of bleeded water (or the temperature of the surface) is necessary to be measured in order to set the difference of vapor pressure between water surface and air.

It is considered that the temperature of the bleed water is same with the temperature of the concrete. Therefore, what is obtained at the end is the temperature of concrete [1–3]. While Berhane [4] reaches to the maximum evaporation speed in a hot and dry environment half an hour later from its casting, it reaches to this speed in a hot and humid environment after 4–7 h later. Although values that are measured at the beginning of experiment are the same with the results of Menzel equation, values that are obtained in the latter phase of the equation are less than values got in the equation. Hasanain et al. [5] conduct some experimental studies on evaporation of concrete specimens that are produced for a building in clear weather, under the shade and on the conditions that concrete surface is closed with polyethylene plate. The graphic method shows almost the equal results in evaporation speed that is measured in the specimens that are kept in the clear weather in the beginning hours with experimental results. However, it does not indicate the right predications in evaporation speed 3–5 h latter after its casting. Özkul and Öztekin [7] compare the evaporation speeds that they have obtained from the experiential results at the end of their study on plastic shrinkage with the values that are drawn according to Menzel's correlation in graphic method. They also stated that graphic method gives lower values.

Saman et al. [8] state that concrete mixtures which have low resistance and contain high level of water show the maximum evaporation speed, but loss of water and evaporation speed is higher in the concretes that have high resistance because of low water content.

Furthermore, that the amount and speed of evaporation increase as the rate of mineral admixture increases in the specimens of concrete that have mineral additives is stated at the end of another experiment. It is also pointed out that evaporation speed in concrete specimens kept under conditions which 95% relative humidity is available is far less than in concrete specimens kept under the conditions which have 25% relative humidity [9].

The aggregates in fresh concrete decompose in cement paste and particles inside the cement paste are dissolved in the water. This distribution is up to a certain extent depends on attractive and repulsion force between these particulars. This dissolved situation occurs while concrete is being mixed. The particulars are under the effect of a downward force. This gravitational force causes the particulars to precipitate by decreasing the distance between the particulars in verticular axis. Because of precipitation, volume of the hardened concrete is less than the volume that the concrete gains right after being put the concrete to its place. Nonetheless, this change in volume cannot be restricted only to gravitational force. There is also the effect of internal forces such as change in temperature and hydrostatics tensile excessive that affects all of the volume. Aggregate and concrete particles exert pressure to the mixture of water.

Throughout this process, concrete particulars hold too much water in the concrete, but they throw out the extra water by flocculating. In the course of observation, bleeded water seems as if it rose on the surface or boil over occurred on the surface of concrete. Yet, any kind of rising in the level does not take place actually [10]. Powers claims that bleeding speed is low not only because it is dependent on the type of concrete, but also because distribution of aggregate is random [11]. Steinour makes some experiments on various concrete with the same water levels and high water level. According to his observations, if the speed of chemical reaction is high at the beginning, the amount and speed of the perspiration is low in various materials that contain same amount of concrete [12]. Öztekin and Özkul [7] record, in their studies, increased concrete dosage lessens the amount of bleeding by increasing water bond of concrete. The effects of superplasticizers on the properties of new concrete are examined in a study conducted by Akman. At the end of the experiments, it is stated that bleeding increases with the participation of the admixtures. This increase occurs by the help of retarder admixtures in a more obvious way [13]. Özkul et al. [14] point out in their studies that bleeding is correlated with the plug timeframe, and the longer the plug timeframe is, the more the amount of the bleeding is. Tamimi [15] stated that the mixture of concrete that is prepared in the respect of two-tier phase method shows much less the amount of bleeding the mixture of concrete prepared in respect the of common method.

3 Evaluation of Experimental Results

In the results of evaporation experiments conducted in four different environmental conditions, it is extracted that low rate of relative humidity and the amount of evaporation in the specimens that are kept under the windy conditions. Maximum amount and speed of evaporation observed in the specimens that are kept under the 50% relative humidity conditions are 28 °C and 15 km/h wind speed. On the other hand, minimum amount and speed of evaporation observed in the specimens that are kept under the 80% relative humidity conditions are 28 °C. The amount of evaporation that is obtained at the end of 5 h triples because the speed of the wind rises to 15 km/h from 0 under the permanent ambient temperature, and doubles as the rate of relative humidity decreases from 80 to 50%. When the amounts of evaporation are examined, the specimens that have the maximum amount of evaporation at the end of the 5 h are the ones that have C 25/30 quality. It is also observed under four different environment conditions that the concrete specimens in C 25/30 quality that are produced by using CEM II/B-M 32.5 and CEM I 42.5 concrete have much more the amount of evaporation than the specimens of concrete in C 35/45 quality. Why less amount of evaporation occurs in the specimens in C 35/45 quality can be related to the idea that bleeding water on their surfaces is less. In the experiments that are conducted with two different types of concrete, it is noticed that the type of concrete does not have a direct effect on the amount and speed of evaporation.

Evaporation speeds of concretes of C 25/30 and C 35/45 under 28 °C and 50% humidity are given in Figs. 1 and 2. Experimental evaporation speeds are bigger than the ones that are obtained in Menzel and Uno's correlations. At the end of the experiment, maximum evaporation speeds that are measured in the C 25/30 and C

35/45 concrete specimens kept on the level of 28 °C and 50% relative humidity; and produced with both types of the concrete according to Menzel and Uno's correlations are obtained after 60 min. While the experimental values for C 25/30 concrete change between change between 0.350 and 0.125, the ones for C 35/45 concrete change between 0.325 and 0.125.

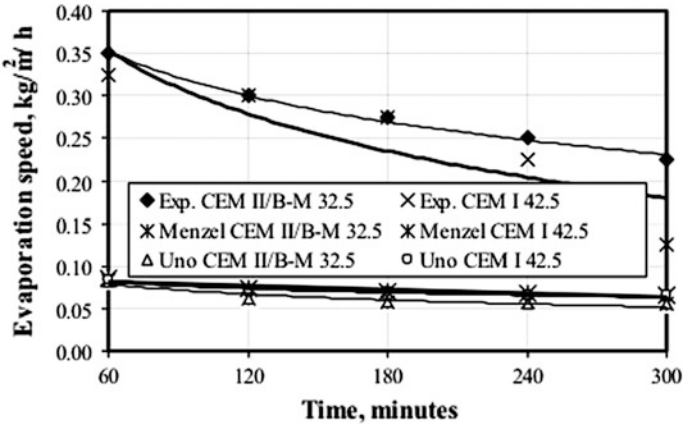


Fig. 1. Evaporation speeds of concretes of C 25/30 under 28 °C and 50% humidity

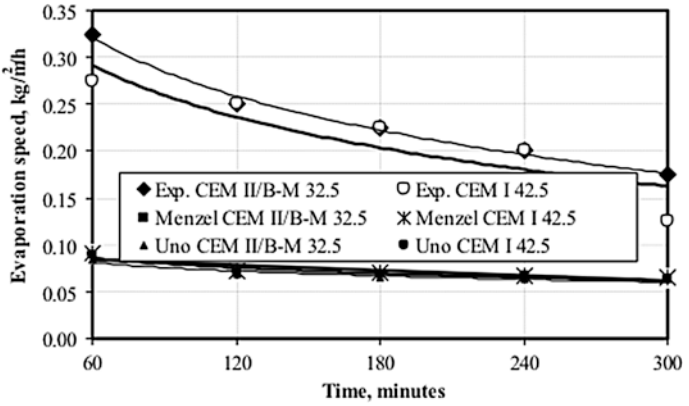


Fig. 2. Evaporation speeds of concretes of C 35/45 under 28 °C and 50% humidity

In Figs. 3 and 4, evaporation speed of C 25/30 and C 35/45 concrete specimens under 28 °C, 15 km/h and 50% humidity are given. Experimental evaporation speeds that are bigger than the evaporation speeds got in Menzel and Uno correlations are obtained. The evaporation speeds for C 25/30 concrete specimens that are kept under 28 °C temperature, 15 km/h speed of wind and 50% the rate of relative humidity change between the values 0.900 and 0.525. In addition to this, the values for C 35/45

concrete specimens change between 0.875 and 0.475. It gives very close results with evaporation speeds obtained in Menzel and Uno's correlations.

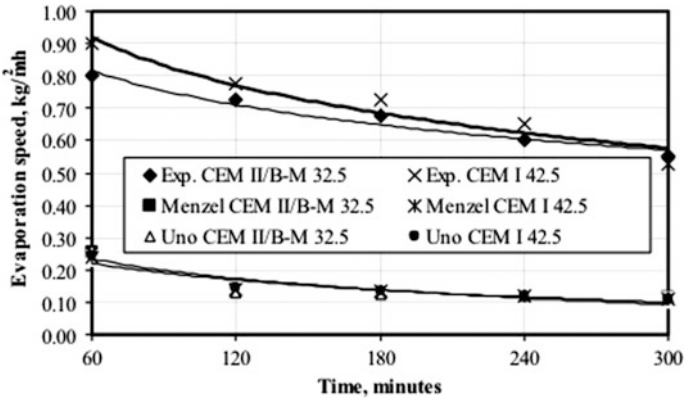


Fig. 3. Evaporation speeds of concretes of C 25/30 under 28 °C, 15 km/h and 50% humidity

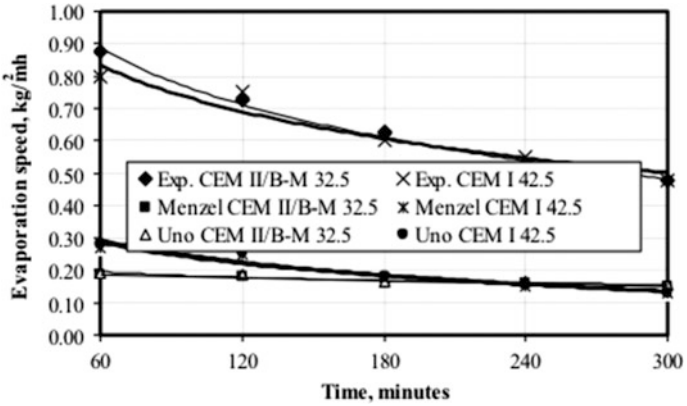


Fig. 4. Evaporation speeds of C 35/45 under 28 °C, 15 km/h and 50% humidity

In Figs. 5 and 6, evaporation speed of C 25/30 and C 35/45 concrete specimens under 28 °C and 80% humidity are given. Experimental evaporation speeds that are bigger than the evaporation speeds got in Menzel and Uno's correlations are obtained. The evaporation speeds for C 25/30 concrete specimens that are kept under 28 °C temperature and 80% the rate of relative humidity changes between the values 0.200 and 0.125. In addition to this, the values for C 35/45 concrete specimens change between 0.175 and 0.075. It gives very close results with evaporation speeds obtained in Menzel and Uno's correlations.

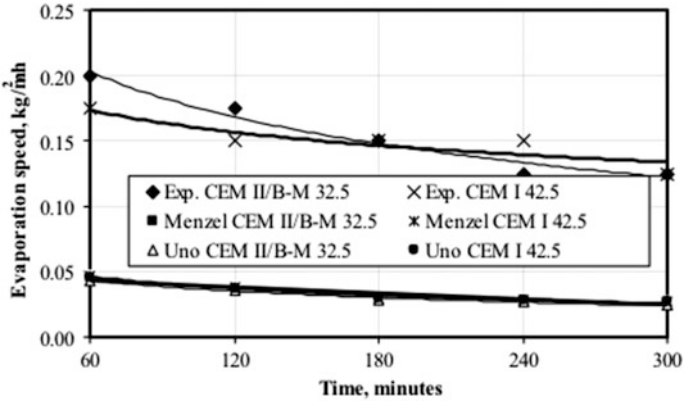


Fig. 5. Evaporation speeds of C 25/30 under 28 °C and 80% humidity

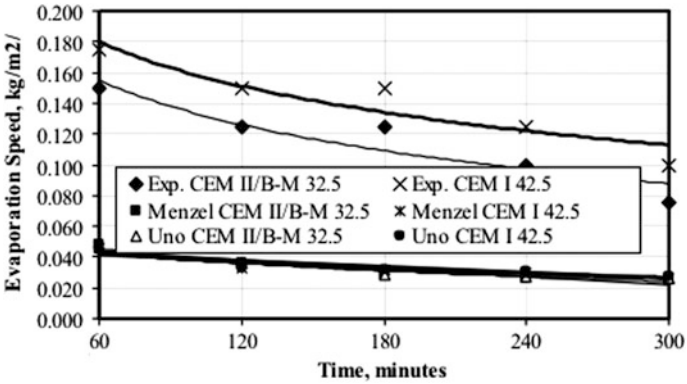


Fig. 6. Evaporation speeds of C 35/45 under 28 °C and 80% humidity

In Figs. 7 and 8, evaporation speed of C 25/30 and C 35/45 concrete specimens under 28 °C, 15 km/h wind, and 80% humidity are given. Experimental evaporation speeds that are bigger than the evaporation speeds got in Menzel and Uno's equations are obtained. The evaporation speeds for C 25/30 concrete specimens that are kept under 28 °C temperature, 15 km/h wind speed, and 80% the rate of relative humidity changes between the values 0.475 and 0.275. In addition to this, the values for C 35/45 concrete specimens change between 0.175 and 0.075. It gives very close results with evaporation speeds obtained in Menzel and Uno's correlations.

Relations that can change according to environmental conditions are observed in different cement concrete specimens that are in the same concrete category. If evaporation experiment results of concrete specimens in C 25/30 quality under the conditions that same rate of temperature and relative humidity exist are analyzed, while C 25/30 concrete made of CEM II/B-M 32.5 cement indicates bigger amount of evaporation under the conditions that there is no wind C 25/30 concrete made of CEM I 42.5 cement shows bigger amount of

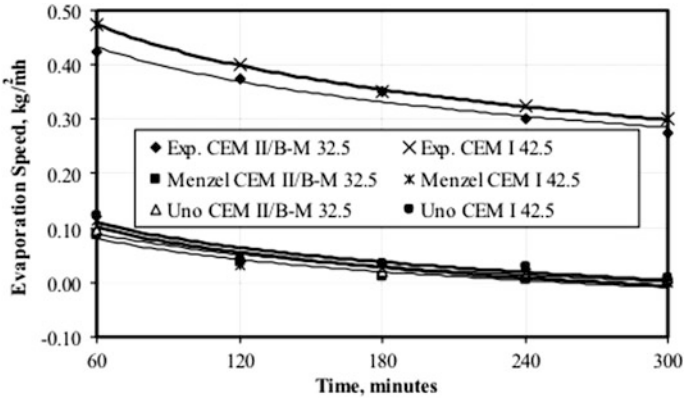


Fig. 7. Evaporation speeds of C 25/30 under 28 °C, 15 km/h wind, and 80% humidity

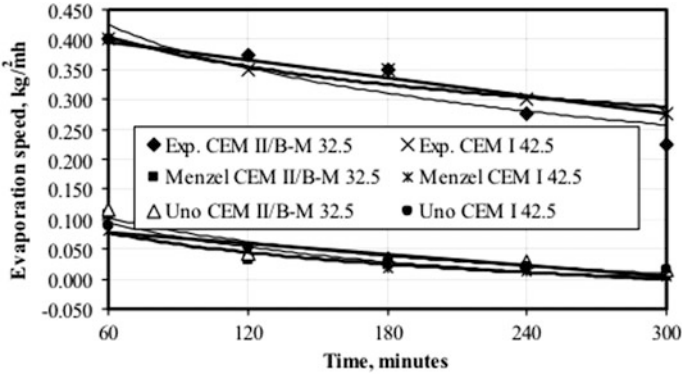


Fig. 8. Evaporation speeds of C 35/45 under 28 °C, 15 km/h wind, and 80% humidity

evaporation when 15 km/h wind speed is available. On the other hand, if evaporation experiment results of concrete specimens in C 35/45 quality are analyzed under the same wind speed and temperature conditions, bigger amount of evaporation is observed in C 35/45 concrete made of CEM II/B-M 32.5 cement under the condition that 50% relative humidity is available; however, under the conditions that high relative exists, much more amount of evaporation speed is observed in C 35/45 concrete made of CEM I 42.5 cement at the end of 5 h. The amount and speed of evaporation that are measured at the end of the evaporation experiments state that evaporation shows much bigger values in the existence of low rate of relative humidity and wind speed. Menzel and Uno's equations give lower values than evaporation speeds calculated by measuring in the experiments in four different environmental conditions including stable ambient temperature, variable wind speed, and the rate of relative humidity. ACI nomograph that is prepared in the respect of Menzel's equation used in the prediction of evaporation speed on the surface of new concrete does not provide the realistic values in these conditions that evaporation experiments are conducted. Furthermore, coefficients of correlation are supplied in the Table 1.

Table 1. Variation of evaporation speeds with and time

Cement type	Environment conditions	Concrete type	Equations (y = a.lnx + b)			
				a	b	R^2
CEM II/B-M 32.5	28 °C temperature 50% humidity	C 25/30	Experimental	−0.075	0.352	0.992
		C 35/45		−0.090	0.321	0.991
		C 25/30	Menzel	−0.017	0.080	0.871
		C 35/45		−0.013	0.082	0.883
		C 25/30	Uno	−0.017	0.079	0.873
		C 35/45		−0.013	0.081	0.884
	28 °C temperature 50% humidity 15 km/sa Wind	C 25/30	Experimental	−0.153	0.816	0.959
		C 35/45		−0.252	0.886	0.993
		C 25/30	Menzel	−0.083	0.229	0.791
		C 35/45		−0.023	0.191	0.900
		C 25/30	Uno	−0.087	0.234	0.792
		C 35/45		−0.025	0.196	0.900
	28 °C temperature 80% humidity	C 25/30	Experimental	−0.051	0.203	0.968
		C 35/45		−0.042	0.155	0.862
		C 25/30	Menzel	−0.013	0.045	0.986
		C 35/45		−0.015	0.047	0.970
		C 25/30	Uno	−0.012	0.044	0.986
		C 35/45		−0.013	0.046	0.970
	28 °C temperature 80% humidity 15 km/sa wind	C 25/30	Experimental	−0.092	0.433	0.961
		C 35/45		−0.104	0.425	0.824
		C 25/30	Menzel	−0.056	0.081	0.968
		C 35/45		−0.060	0.095	0.887
		C 25/30	Uno	−0.055	0.090	0.970
		C 35/45		−0.059	0.103	0.889
CEM I 42.5	28 °C temperature 50% humidity	C 25/30	Experimental	−0.108	0.353	0.747
		C 35/45		−0.081	0.292	0.794
		C 25/30	Menzel	−0.012	0.084	0.948
		C 35/45		−0.015	0.088	0.891
		C 25/30	Uno	−0.011	0.082	0.949
		C 35/45		−0.015	0.086	0.893
	28 °C temperature 50% humidity 15 km/sa wind	C 25/30	Experimental	−0.213	0.919	0.933
		C 35/45		−0.207	0.833	0.927
		C 25/30	Menzel	−0.076	0.221	0.885
		C 35/45		−0.094	0.286	0.931
		C 25/30	Uno	−0.080	0.227	0.887
		C 35/45		−0.098	0.294	0.930
	28 °C temperature 80% humidity	C 25/30	Experimental	−0.025	0.174	0.802
		C 35/45		−0.042	0.180	0.862
		C 25/30	Menzel	−0.013	0.046	0.975

(*continued*)

Table 1. (*continued*)

Cement type	Environment conditions	Concrete type	Equations (y = a.lnx + b)			
				a	b	R^2
		C 35/45		−0.011	0.044	0.924
		C 25/30	Uno	−0.012	0.045	0.975
		C 35/45		−0.010	0.043	0.925
	28 °C temperature 80% humidity 15 km/sa wind	C 25/30	Experimental	−0.109	0.474	0.999
		C 35/45		−0.073	0.405	0.911
		C 25/30	Menzel	−0.067	0.101	0.895
		C 35/45		−0.048	0.077	0.981
		C 25/30	Uno	−0.066	0.110	0.896
		C 35/45		−0.047	0.086	0.982

The results of evaporation experiments that are carried out in four different environmental conditions are analyzed in terms of the relation between evaporation speed and time that are obtained in Menzel and Uno's equations such as y=a.lnx+b. R^2 values that are obtained at the end of the regression analysis are in general terms found reliable.

Bleeding experiments are carried out in three different groups composed of type of concrete, the ratio of water–concrete, and dosage. In the results of the bleeding experiment that is made by choosing four different type of concrete, maximum amount of bleeding emerging at the end of the first hour is seen in the specimen of C 16/20 concrete made of CEM I 42.5 cement. However, minimum amount of bleeding is observed in the specimen of C 35/45 concrete made of CEM II/B-M 32.5 cement. Maximum and minimum amount of bleeding in the concrete specimens that are produced with both types of cement are respectively seen in the specimen of C 16/20 and C 35/45 concretes. The amount of bleeding increases as water and cement ratio increases at the end of the bleeding experiments that are carried out by changing water and cement ratio. Yet, an hour's amount of bleeding stays at the same values at the end of the bleeding experiment whose cement dosage is analyzed. The results of bleeding experiment are shown in Figs. 9, 10 and 11.

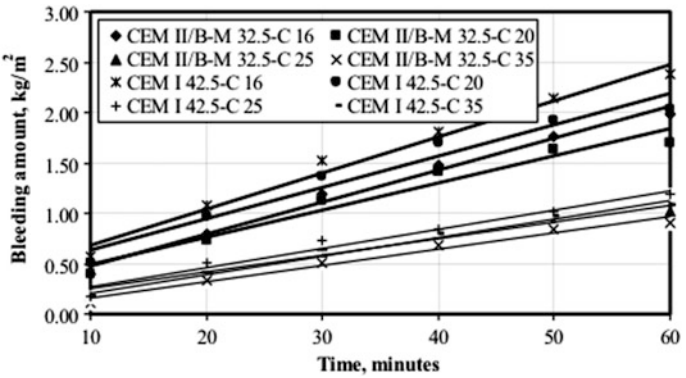


Fig. 9. The variation of amount of bleeding with time in different types of concrete

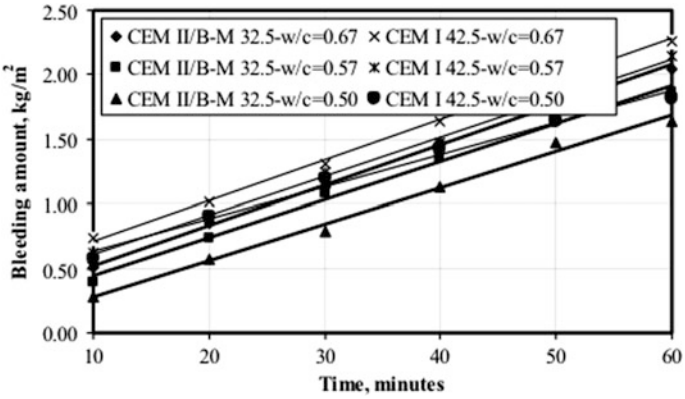


Fig. 10. The variation of amount of bleeding with time in different water/cement ratios

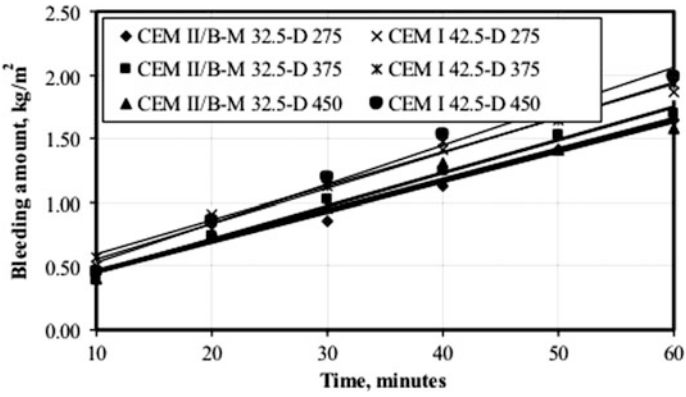


Fig. 11. The variation of amount of bleeding with time in different cement dosages

The direct proportion between the amount of perspiration and time in four different types of concrete composed of C 16/20, C 20/25, C 25/30 and C 35/45 is analyzed, and their correlation coefficients are shown in the Table 2. It is seen that correlation coefficients of all direct relations are high. Direct proportion between three different types of water and cement ratios including 0.67, 0.57 and 0.50 is analyzed, and their correlation coefficients are given in the Table 3. The direct proportion between the amount of bleeding and time in three different types of cement dosages as 275, 375 and 450 kg/m^3 is analyzed, and correlation coefficients are given in the Table 4. CEM I 42.5 cement indicate much more amount of bleeding than CEM II/B-M 32.5 cement in all conditions at the end of the results of bleeding experiment carried out in three groups by applying different concrete types, water/cement ratio, and cement dosage.

Table 2. The equations amount of bleeding with time in different types of concrete

Concrete types	Cement type	Equations (y = a.x + b)		
		a	b	R^2
C 16/20	CEM II/B-M 32.5	0.317	0.154	0.988
	CEM I 42.5	0.359	0.328	0.981
C 20/25	CEM II/B-M 32.5	0.272	0.219	0.957
	CEM I 42.5	0.311	0.328	0.961
C 25/30	CEM II/B-M 32.5	0.163	0.098	0.954
	CEM I 42.5	0.192	0.072	0.969
C 35/45	CEM II/B-M 32.5	0.162	0.0001	0.978
	CEM I 42.5	0.184	0.015	0.991

Table 3. The equations amount of bleeding with time in different water/cement ratios

Water–cement ratio	Cement type	Equations (y = a.x + b)		
		a	b	R^2
0.67	CEM II/B-M 32.5	0.310	0.215	0.997
	CEM I 42.5	0.315	0.397	0.996
0.57	CEM II/B-M 32.5	0.296	0.144	0.995
	CEM I 42.5	0.302	0.309	0.997
0.50	CEM II/B-M 32.5	0.281	−0.004	0.994
	CEM I 42.5	0.247	0.388	0.987

Table 4. The equations amount of bleeding with time in different cement dosages

Cement dosage	Cement type	Equations (y = a.x + b)		
		a	b	R^2
275	CEM II/B-M 32.5	0.236	0.212	0.991
	CEM I 42.5	0.269	0.324	0.986
375	CEM II/B-M 32.5	0.260	0.193	0.991
	CEM I 42.5	0.277	0.287	0.993
450	CEM II/B-M 32.5	0.238	0.234	0.974
	CEM I 42.5	0.306	0.223	0.987

4 Discussion

In hot airs, the crack of plastic shrinkage sticks to the concrete pouring in arid climates. The crack occurs in the concrete that is set in an open place. The amount of water that rises by the help of bleeding initially in the flat elements, beams, foundations and on the surface of the concrete occurs in the other climatic conditions that much more amount of evaporation is available. Plastic shrinkage crack always sets an anxiety in the concrete technology. It is very important to know the possibility that to what extent the

shrinkage crack can occur in terms of the problems that will be encountered in the future. High level of temperature and low relative humidity accelerate the plastic shrinkage of concrete [16]. According to ACI, it is suggested to take precautions when evaporation speed comes closer to the value 1.0 kg/m^2/h (0.2 lb/ft^2/h). While Australian Codes note the value that has the potential plastic shrinkage occurs as 1.0 kg/m^2/h and the value that necessary precautations are taken as 0.5 kg/m^2/h, Canadian Codes points 0.75 kg/m^2/h as the critical value. When the experiment results in the Table 1 are examined, a kind of danger is not visible according to ACI report.

5 Conclusions

At the end of the evaporation and bleeding experiments that are carried out on the concrete specimens prepared by using two different types of cement, high correlation coefficients are obtained. Therefore, it is observed that the amount of bleeding throughout 1 h and the amount of evaporation throughout 5 h on the new concrete provide nearly realistic results. As a result of this, the suggestions and the conclusions below are submitted.

In the bleeding experiments made by the help of different quality of concrete, water/cement ratio, and cement dosages, the concrete specimens prepared with CEM I 42.5 cement show much more amount of evaporation than the concrete specimens prepared with CEM II/B-M 32.5 cement at the end of 1 h. That the concrete specimens that are prepared with CEM I 42.5 cement show much more amount of evaporation than the concrete specimens prepared with CEM II/B-M 32.5 cement can be connected to smaller surface area of CEM I 42.5 cement. One hour's bleeding amount of new concrete decreases since the water/cement ratio decreases as being dependent on cement dosage in concrete combination. Bleeding decreases since growing in the cement dosage increases water bonding of concrete because of cement particles' water bonding features.

In evaporation experiments that are carried out in four different conditions of environment and in two different concrete quality as C 25/30 and C 35/45, more amount of evaporation is measured in the C 25/30 concrete specimens than in the concrete specimens that are prepared with CEM I 42.5 and CEM II/B-M 32.5 cement at the end of 5 h. This situation occurs because more amount of bleeding occurs in the specimens in C 25/30 concrete category compared to the specimens in C 35/45 concrete category. The effects of the environmental conditions to the amount and speed of evaporation are more important than the concrete combination. The amounts and speeds measured at the end of the evaporation experiments point out that evaporation shows bigger values in the existence of low relative humidity and wind speed. Menzel and Uno's equations that are used in the prediction of evaporation speed occurring on the surface of new concrete cannot provide realistic values in evaporation speed. Evaporation speeds found in an experimental way are bigger than the estimated evaporation speeds that are obtained from the equations. It is necessary to work on providing the validity of these equations by increasing the number of the experiment groups. If they are not valid, equations should be reviewed.

References

1. Uno PJ (1998) Plastic shrinkage and evaporation formulas. ACI Mater J 95:365–375
2. Topçu İB (2005) Raising of water and evaporation from freshly placed concrete surface. In: ICCE 12, twelve international conferences on composites or nano engineering, Tenerife
3. Topçu İB, Elgün VB (2004) Influence of concrete properties on bleeding and evaporation. Cem Concr Res 34:275–281
4. Berhane Z (1984) Evaporation of water from fresh mortar and concrete at different environmental conditions. ACI J Proc 81:560–565
5. Hasanain GS, Khalaf TA, Mahmood K (1989) Water evaporation from freshly placed concrete surfaces in hot weather. Cem Concr Res 19:465–475
6. Elgün VB (2003) Influence of concrete properties on bleeding and evaporation. M.Sc. Thesis, Osmangazi University, Science Institute, Eskişehir
7. Öztekin E, Özkul MH (1994) The effect of concrete composition and environmental conditions on plastic shrinkage. In: Proceedings of the national concrete congress, İstanbul, vol 3, pp 163–74
8. Saman TA, Mirza WH, Wafa FF (1996) Plastic shrinkage cracking of normal and high strength concrete: a comparative study. ACI Mater J 93:36–40
9. Almusallam AA, Maslehuddin M, Abdulwaris M, Dakhil FH, Al-Amoudi OSB (1999) Plastic shrinkage cracking of blended cement concretes in hot environments. Mag Concr Res 51:241–246
10. Powers TC (1968) The properties of fresh concrete. Wiley, London, pp 533–603
11. Powers TC (1939) The bleeding of Portland cement paste, mortar and concrete. Portland Cem Assoc Bull 2:465–480
12. Steinour HH (1945) Further studies of the bleeding of Portland cement paste. Portland Cem Assoc Bull 4:1–87
13. Akman MS (1996) The troubles of superplasticizers on fresh concrete workability. In: 4th National concrete congress, İstanbul, pp 55–71
14. Özkul MH, Başkoca A, Artırma S (1997) Influence of prolonged agitation on water movement related properties of water reducer and retarder admixtured concretes. Cem Concr Res 27:721–732
15. Tamimi AK (1994) The effects of a new mixing technique on the properties of the cement paste-aggregate interface. Cem Concr Res 24:1299–1304
16. Almusallam AA (2001) Effect of environmental conditions on the properties of fresh and hardened concrete. Cem Concr Compos 23:353–361