Challenge Journal of Concrete Research Letters

Research Article

The physico-mechanical properties of concrete with red-mud at high temperatures

Ibrahim A. Alameri [a,b,*], Meral Oltulu [b]

[a] *Department of Civil Engineering, Sana'a University, Sana'a 13341, Yemen*

[b] *Department of Civil Engineering, Atatürk University, Erzurum 25240, Turkey*

ABSTRACT

Reuse of treated waste can provide significant environmental, social and economic benefits. It is necessary to use it in the right places while keeping the properties of the waste in mind. Aluminum-rich wastes such as red mud derived from bauxite may be used in places exposed to high temperatures. This article discusses the effects of high temperatures of 25, 200, 300, 400, 600 and 800°C and 3 hours of exposure on concrete samples replaced by red mud at 0, 10, 15 and 20%. To study the concrete's mechanical and permeability properties, loss in weight, compressive strength, splitting tensile strength, capillary water absorption and water permeability tests were performed for all mixes. Results were closer to those of the control specimen, which ultimately supported the use of red mud at a ratio of 10%.

ARTICLE INFO

Article history:
Received 18 June 2020
Revised 20 July 2020
Accepted 11 August 2020

Keywords:
Waste materials
Red-mud
Elevated temperatures
Mechanical properties
Permeability
Capillary water absorption

1. Introduction

The physicochemical, mechanical properties and microstructure of concrete during or after exposure to high temperatures are required to predict its structural behavior and capacity. Concrete may be exposed to high temperatures in areas such as nuclear reactors, near furnaces, areas exposed to fire and areas exposed to jet engine explosions. Additionally, most buildings and infrastructure face a major fire risk. In order to understand the behavior of concrete at high temperatures or under fire, the most appropriate parameters were identified and investigated. These parameters related to the type of concrete that is used include exposure time, temperature increase rate, concrete age, type of aggregate used, type of cement used, type of different additives, and water/cement ratio.

Concrete seems to be exposed to no significant damage when subjected to temperatures up to 200°C, but for higher temperatures than 200°C, it is essential to study the exposure conditions and the employed concrete. The effect of high temperatures on normal concrete is summarized in Table 1.

Waste materials exhibiting other pozzolanic properties that are used in concrete include silica fume, fly ash, blast furnace slag, calcined clay and alkali-activated slag cement (Ardahanlı et al., 2019; Alameri et al., 2019; Alameri and Oltulu, 2019). In addition to these materials, red mud derived from bauxite is also among the recently researched materials. Moreover, alumina is known to have a high resistance to high temperature, and red mud contains a high content of alumina. Today, approximately 120 million tons of red mud is produced annually, and it is not satisfactorily disposed of or recycled. Traditionally, the method of red mud disposal in ponds often has adverse environmental effects during the monsoon period.

The waste causes pollution of groundwater when the red mud gets mixed with water, and underground water resources such as wells or aquifer may get polluted by alkali seepage, impact on plant life, alkaline air born dust is carried with air and has effects on the transpiration process of plants, resulting in reduction of plant life. This may also include soil properties changed by land disposal, which results in reduced fertility when this waste is mixed with fertile land, vast areas of land are consumed

* *Corresponding author.* E-mail address: i.ameri@eng-su.edu.ye (I. A. Alameri)
ISSN: 2548-0928 / DOI: https://doi.org/10.20528/cjcrl.2020.04.001

because of dumping of red mud, and if service reservoirs get polluted, it may create hurdles for the society (Sawant et al., 2012; Rathod et al., 2014; Rana and Sathe, 2015).

In order to reduce these harmful effects, studies were carried out on red mud in road construction, cementitious products, stabilization material and wastewater treatment areas (Hu et al., 2018). Moreover, a limited number of studies have been conducted on the topic of concrete. In these studies, red mud was used instead of cement partially to investigate the cementitious properties of the composites. A lot of studies have been performed on the ratio of the red mud that is used, and these are presented in Table 2.

Table 1. Effects of temperature on concrete (Baradan et al., 2010).

Temperature	Effect
100–150°C	Evaporation of free moisture in the concrete mass takes place.
150–250°C	Shrinkage, crack formation, degradation in tensile strength, pinkish color.
250–300°C	Aluminum and iron oxide compounds, loss of body water, decrease in compressive strength.
400°C	$Ca(OH)_2$ converted into CaO (33% degradation in volume).
400–600°C	Destruction in the structure of CSH, gray-white color, degradation in compressive strength would be 80%.

Table 2. Red mud studies, experiments and optimum red mud ratio.

	Authors	Red mud ratio	Experiments	Optimum ratio of red mud
1	Ribeirol et al. (2010)	10, 20, and 30%	Compressive strength	10%
2	Rathod et al. (2014)	5, 10, 15, 20, 25, 30, and 40%	Compressive, and split tensile strength test	25%
3	Bishetti and Pammar (2014)	0, 5, 10, 15, 20, and 25%	Compressive, and split tensile strength	20%
4	Manfroi et al. (2014)	5, 10, and 15%	Pozzolanic activity, compressive strength, and water absorption by capillarity	5%
5	Rana and Sathe (2015)	10%, 15, 20, and 25% with addition of 4, 8 and 12% lime to the weight of red mud	Compressive strength	10% with 4% lime
6	Rathod et al. (2015)	10, 15, and 20% with 5% lime	Compressive, split tensile, and flexural strength	10%
7	Metilda et al. (2015)	5, 10, 15, 20, and 25%	Compressive, split tensile, and flexural strength	15%
8	Liu and Poon (2016)	Fly ash was replaced by red mud at 0, 25, 50, 75 and 100% by weight	Fresh self compacting concrete tests, compressive, split tensile strength, and drying shrinkage	50%
9	Tang (2014)	0-30%	Fresh self compacting concrete tests, compressive, splitting tensile strength, and microstructural test	20%
10	Oltulu and Alameri (2019)	10% red mud with 0.5, 1 and 1.25% of nano-alumina ratios	Compressive, and splitting tensile strength	%10 with 0.5% nano-alumina

As seen in Table 2, the literature does not offer exact information about the optimum proportion of red mud, and a detailed study on red mud which is very rich in alumina at high temperatures is missing in the literature. Due to this limitation in the literature, this experimental study is needed for a better understanding of the effects of temperature on addition of red mud (RM) into concrete. The goals of this study for these reasons were:

a) To find a solution for the aforementioned environmental problems and look for economically viable recycling of red mud alternatives as a component of building materials, this study was conducted to investigate the optimum ratio of red mud as a partial replacement for cement.
b) The feasibility of utilizing the Bayer red mud and investigation of the optimum red mud ratio in concrete at high temperatures are demonstrated. This study will draw attention to increasing the use of aluminum containing waste materials, which will have a positive effect especially at high temperatures in concrete.
c) There has been limited research on red mud in concrete, and in particular, there were no studies on physico-mechanical properties after high temperature treatment. It is expected that this article will illuminate the literature since which the physico-mechanical properties of waste red mud with high alumina content will be determined after applying high temperature.

For the aforementioned reasons, an experimental study was performed by replacing cement with red mud by 0-20% to investigate the optimum percentage of red mud that can be used in concrete and study the effects of materials that have a high content of alumina such as red mud against high temperatures.

2. Material and methods

2.1. Material

Ordinary Portland cement (CEM II 42.5 R) conforming to TS EN 197-1 (2012) and TS EN 196-1 (2016), which is compatible with the European standard, and red mud with index and chemical properties shown in Table 3 were used to produce C40/50 Concrete. Standard 100-mm-diameter and 200-mm-high test cylinders and 150x150x150 test cubes were cast. RM thermal decomposition is shown in the TGA–DTA diagram. With rising temperatures, three weight loss steps were observed in the profile as explained in Table 4 and shown in Fig. 1 (Nath et al., 2015). Fine and coarse aggregate properties listed in Table 5 were used, and tests of specific gravity and water absorption were conducted according to the Turkish standard TS EN 1097-6, 2013, which is compatible with the European standard. Superplasticizer with a density of 1.045 gr/cm^3 and gray/green color based on modified polycarboxylate were added to water before mixing the concrete by 0.75% of the cementitious material.

Table 3. Index and chemical properties of RM and PC.

	RM	PC
Chemical composition (%)		
SiO_2	18,95	17,6
Al_2O_3	25,65	4,45
Fe_2O_3	36,94	3,08
CaO	3,30	60,02
MgO	-	2,29
SO_3	-	2,67
Loss on ignition	17,75	8,49
Na_2O	7,04	0,22
K_2O	-	0,63
Na2O+0,658K2O	-	0,63
Cl	-	0,0144
Unmeasured	-	0,54
Free CaO	-	0,69
Total additives	-	19,9
TiO_2	5,62	-
Others	2,51	-
index properties		
Specific gravity	3.05	3,01
Specific surface (cm^2/g)	-	4403
Compressive strength (MPa)	-	51,03
pH	12-13	-

Table 4. Effect of temperature in red-mud.

Temperature	Effect
25–260°C	Weight loss about 4.3% of total weight the reason is that the evaporation of water.
260–325°C	Weight loss about 8.9% of the total weight the reason is that the loss of H_2O from the sample as a whole and also the removal of H_2O from $Al(OH)_3$.
325–500°C	Weight loss about 10.9% of the total weight due to the release of CO_2 during the decomposition of $CaCO_3$.

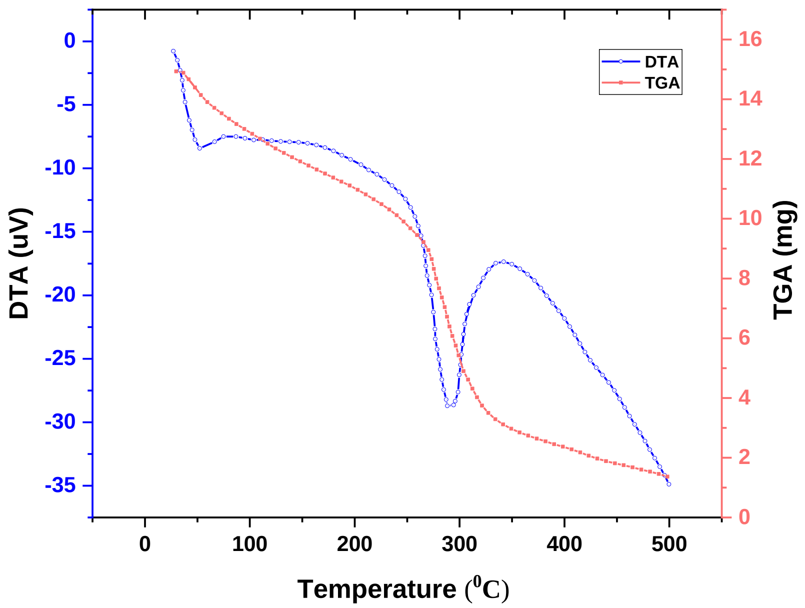

Fig. 1. TGA–DTA diagram of RM in the temperature range of 28°C to 500°C (Nath et al., 2015).

Table 5. Properties of aggregate.

Aggregate size (mm)	Specific Gravity	Water Absorption (%)	Stock Humidity (%)
0-2	2.686	1.77	1.8
2-4	2.671	1.75	1.1
4-8	2.652	1.92	1.0
8-16	2.664	1.56	0.8
16-25	2.678	1.36	0.7

2.2. Concrete mix proportion

Concrete mix design was carried out by using TS EN 206 (2014). C40/50 concrete with a water/binder ratio of 0.48 was produced as a control mix. Four different mix proportions were selected. Red mud replaced 10, 15, and 20% of cement by weight. The mix proportions are listed in Table 6.

Table 6. Concrete mix proportions.

Materials used	C	RM	Aggregate					W	SP's	W/C+RM
			0-2 (mm)	2-4 (mm)	4-8 (mm)	8-16 (mm)	16-25 (mm)			
Units	kg/m³	kg/m³	kg/m³	kg/m³	kg/m³	kg/m³	kg/m³	kg/m³	kg/m³	-
0RM	416.4	-	641.00	206.45	240.27	498.38	137.69	199.64	3.123	0.48
10RM	374.76	41.64	641.00	206.45	240.27	498.38	137.69	199.64	3.123	0.48
15RM	353.94	62.46	641.00	206.45	240.27	498.38	137.69	199.64	3.123	0.48
20RM	333.12	83.28	641.00	206.45	240.27	498.38	137.69	199.64	3.123	0.48

2.3. Experiments

Reduction of the amount of cement by replacing concrete with red mud was explored by comparing the mechanical properties of the samples. Moreover, the physico-mechanical properties of concrete with red mud were evaluated after exposure to high temperature.

2.3.1. High temperature test

The concrete samples were removed from water and dried in air for 1 day at 60% and 25°C mean relative humidity and temperature, respectively (Fig. 2). The samples were then placed in an electrical oven at 100°C for 24 hours before exposing them to high temperatures, while this step was found to be necessary to prevent the concrete samples from exploding in the oven due to the steam formation (Tanyıldızı and Erol, 2018; Ruano et al., 2018; Toric et al., 2014). After that, an electrical oven designed for a maximum temperature of 1200°C was used to heat the concrete samples to 200, 300, 400, 600 and 800°C, with a total duration in the furnace of 3 hours for each temperature (Beglarigale et al., 2016, Sanchayan and Foster, 2016).

2.3.2. Loss in weight

This test was made to measure the moisture mass conservation within the system. During the heating process, moisture is transposed from the specimen to the environment. The specimens were weighed before heating (wi) and after cooling (ws) with an accuracy of 1gm. The changes in specimen weight (W) are expressed as percentages of the initial weights by using the following Eq. (1):

$$W\ (\%) = \frac{w_i - w_s}{w_i} \times 100 \quad (1)$$

2.3.3. Compressive and splitting tensile strength tests

Compressive and Splitting tensile strength tests were conducted based on the TS EN 12390-3, 2019 and TS EN 12390-6, 2010 standards.

2.3.4. Water permeability test

Water permeability test was carried out according to the German Standard DIN 1048 (1991). 200x100 mm cylindrical concrete specimens were exposed to a water pressure of 500 kPa for a period of 72 hours. At once after the end of the tests, the specimens were cut and measured for the depth of water penetration.

2.3.5. Capillary water absorption test

Capillary water absorption test was conducted in accordance with the standard ASTM C1585 (2013). Cube specimens of 150x150x150 mm were used. The sides of the specimens were sealed with tape up to 40 mm in height so that only one face of the specimen was subjected to water. The weight of the specimens was observed over a period of time (0– 24 h) during contact with water.

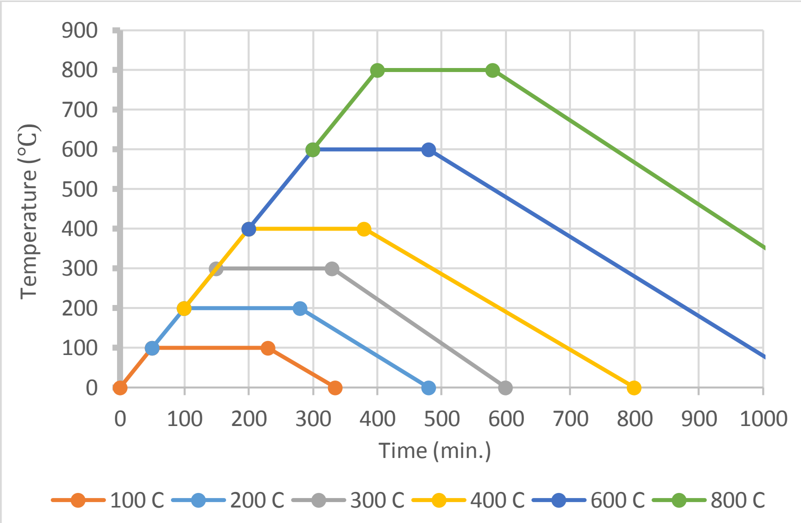

Fig. 2. Heating profile (Alameri, 2017).

3. Results and Discussions

3.1. Loss in weight

The weight of the specimens was measured before and after subjecting them to different temperatures. The weight loss increased with the increase in the maximum exposure temperatures due to accelerated drying. These results agreed with those in the literature (Sancak et al., 2008; Alsheikh 2011). The amount of loss in weight as a percentage is shown in Table 7 and Fig. 3. The Samples with and without RM were subjected to high temperatures, and the highest weight losses for 200°C, 300°C and 400°C were observed in 15RM, whereas those for 600°C and 800°C were observed in 20RM. The increased weight loss was because of the dehydration of the hydration products and the loss of water from the fine pores in the cement paste and aggregate particles. The relationship between the weight loss and the temperature of exposure was non-linear. The 15RM and 20RM concretes showed higher weight losses in comparison to the control concrete, which may be due to the high percentage of red mud. According to the study reported by Nath et al. (2015), three weight loss steps occurred as the temperature increased (Fig. 1).

Table 7. Loss in weight of concrete (%).

Temperature	0RM	10RM	15RM	20RM
25°C	0	0	0	0
200°C	0.76	0.8	0.98	0.67
300°C	1.65	1.40	3.50	3.40
400°C	6.26	6.10	6.90	6.70
600°C	8.29	8.80	8.90	9.10
800°C	11.04	11.20	12.20	12.50

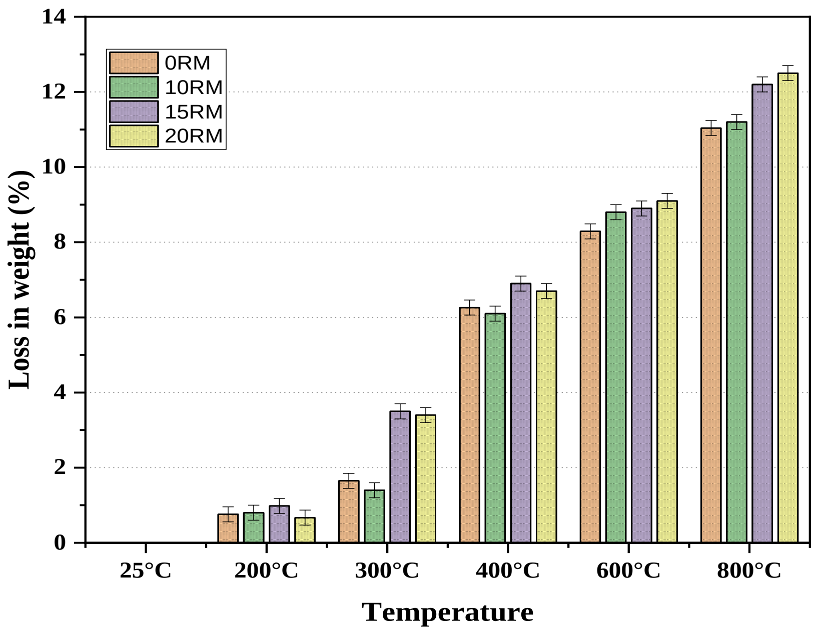

Fig. 3. Loss in weight of concrete at different temperatures.

3.2. Compressive and splitting tensile strengths

3.2.1. Compressive strength

At 25°C, the control mixture 0RM achieved a compressive strength of 41.5 MPa. The mixtures 10RM, 15RM and 20RM achieved compressive strengths of 39.8 MPa, 35.4 MPa and 30.6 MPa, respectively. The compressive strength reached an optimum value at 10RM and then decreased for 15RM and 20RM. A decrease in strength of 4.3%, 14.8% and 26.3% was observed for 10RM, 15RM and 20RM, respectively in comparison to 0RM. The results are shown in Table 8 and Fig. 4.

3.2.2. Splitting tensile strength

Table 9 and Fig. 5 show that, at 25°C, the control mixture 0RM achieved a splitting tensile strength of 4.2 MPa. The mixtures 10RM, 15RM and 20RM achieved splitting tensile strengths of 4.1 MPa, 4.2 MPa and 3.0 MPa, respectively. The splitting tensile strength reached an optimum value at 15RM and 10RM, and the maximum loss in strength was in 20RM. These results showed that the addition of RM reduces the compressive and the splitting tensile strength of concrete. Moreover, these results were compatible with the literature (Rathod et al., 2014; Tang, 2014; Kushwaha et al., 2013; Bishetti and Pammar, 2014).

Table 8. Compressive strength of concrete at different temperatures.

	Compressive strength (MPa) (to their initial 25°C strengths %)				Variation vs. control specimen (%)		
Temperature	0RM	10RM	15RM	20RM	10RM	15RM	20RM
25°C	41.5	39.8	35.4	30.6	-4.3	-14.8	-26.3
200°C	30.4(-26.7%)	34.5(-13.3%)	26.4(-25.4%)	30.3(-1.2%)	13.2	-13.4	-0.6
300°C	35.7(-14.1%)	35.1(-11.6%)	24.7(-30.2%)	23.6(-23.1%)	-1.5	-30.8	-34.0
400°C	38.3(-7.9%)	38.7(-2.6%)	32.2(-8.9%)	29.1(-4.9%)	1.2	-15.8	-23.8
600°C	37.2(-10.5%)	24.2(-39.1%)	25.8(-27.2%)	24.5(-19.9%)	-34.8	-30.7	-34.1
800°C	15.9(-61.7%)	12.5(-68.5%)	8.6(-75.6%)	8.0(-73.8%)	-21.4	-45.7	-49.6

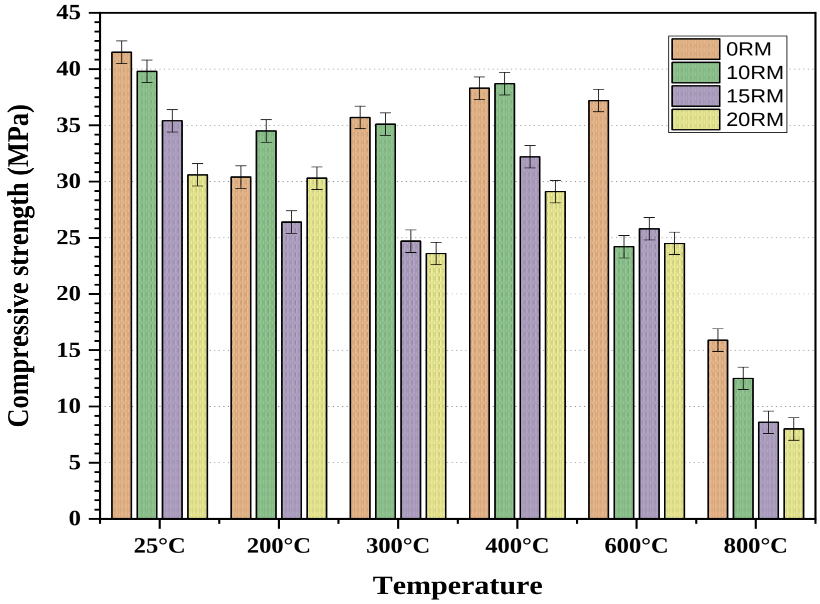

Fig. 4. Compressive strengths of concrete at different temperatures.

Table 9. Splitting tensile strengths of concrete at different temperatures.

	Tensile strength of concrete (MPa) (to their initial 25°C strengths %)				Variation vs. control specimen (%)		
Temperature	0RM	10RM	15RM	20RM	10RM	15RM	20RM
25°C	4.2	4.1	4.2	3.0	-1.9	0.0	-27.9
200°C	3.6(-12.5)	2.7(-33.1)	2.6(-36.7)	2.2(-25.7)	-25.0	-27.6	-38.7
300°C	3.7(-10.0)	2.5(-37.6)	2.1(-48.8)	2.1(-29.5)	-32.0	-43.0	-43.5
400°C	3.3(-19.7)	2.9(-28.9)	2.2(-47.5)	1.6(-46.6)	-13.1	-34.6	-52.0
600°C	1.7(-60.2)	1.5(-62.8)	1.0(-76.3)	0.7(-76.3)	-8.3	-40.5	-57.2
800°C	0.7(-83.8)	0.6(-85.5)	0.5(-88.3)	0.3(-89.5)	-12.3	-27.7	-53.2

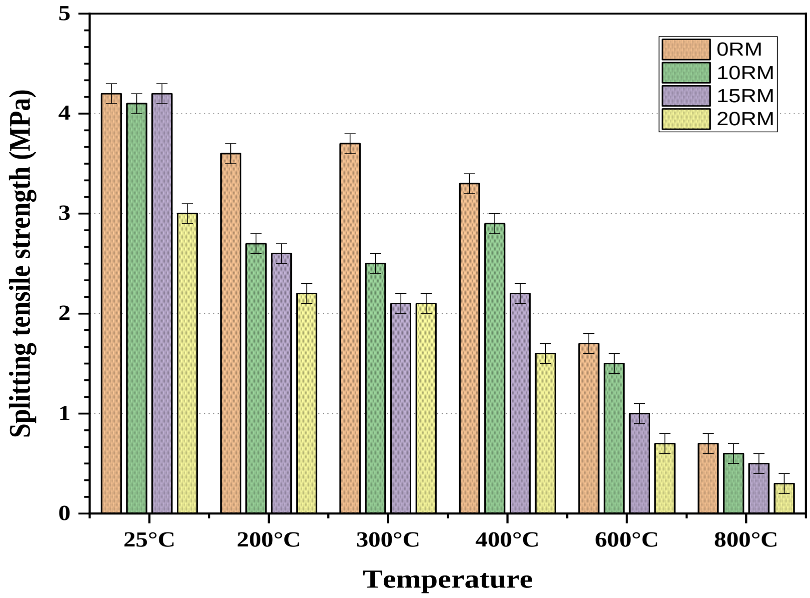

Fig. 5. Splitting tensile strengths of concrete at different temperatures.

3.3. Residual compressive and splitting tensile strengths after heating

In general, compressive strength decreased with the increase in temperature. Fig. 4 and Table 8 show the compressive strength and the decreases in compressive strength compared to 25°C (%), for the concrete samples 0RM, 10RM, 15RM, and 20RM. At 200˚C, the compressive strength of all samples decreased by 13–27% with respect to their strength at 25°C, while when compared to the reference specimen (0RM), the 10RM resulted in an increase in compressive strength by 13.2%, whereas 15RM and 20RM resulted in a decrease in compressive strength by 13.4% and 0.6%, respectively. A considerable decrease in compressive strength was noticed in all mixtures after heating to 300°C. This may have been due to more extensive inner cracking of such a compact structure caused by the build-up of pressure that resulted out of the evaporation of physically and chemically bound water (Behnood and Ghandehari, 2009). In general, a small loss in strength was noticed for all of the concretes when exposed to high temperature, while the 10RM group almost was close to the control group and even better results at 400°C. However, the effect of high temperature was more pronounced for concretes with higher RM ratios. More detailed studies are needed to explain the behavior of RM samples, especially at 400°C, where the effect of RM is positive. Likewise, at 600°C, the maximum reduction in compressive strength compared to 0RM took place at 10RM. This strength loss value was largely attributed to the decomposition of calcium hydroxide (Behnood and Ghandehari, 2009). Note that, compared to 0RM, the maximum reduction in compressive strength took place for the 20% red mud mix when exposed to 800°C.

Similar results were obtained for the tensile strengths of the mixes after exposure to different temperatures for a duration of 3h. The tensile strength for different exposure temperatures at a 28-day interval for the 0%, 10%, 15%, and 20% red mud concrete mixes are presented in Table 9 and Fig. 5. The lowest residual tensile strength was observed in 10RM in comparison to 0RM. The tensile strength losses of red mud concrete were low in comparison to the tensile strength losses of the control (0RM) concrete exposed high temperatures.

3.4. Water permeability test (water penetration depth)

Water permeability test provides a measure of a concrete's resistance against penetration of water. Fig. 6 clearly shows the increase in water penetration depth with red mud. The amount of increase in comparison to 0RM was approximately 21%, 42.1%, and 57.9% for 10RM, 15RM, and 20RM, respectively. 10RM provided the lowest water penetration depth value followed by 15RM and 20RM. The effect of the red mud content on permeability could be clearly recognized. The higher content of red mud was related to an increase in the permeability coefficient. The relationship between compressive strength and depth of penetration was linear and is shown in Fig. 7. In general, a very good correlation was observed between water penetration depth and compressive strength values, i.e., as the strength of concrete increased, the water penetration depth decreased significantly. The change in depth of penetration for a given change of red mud content was lower for lower values of RM ratios as a result of the decrease in concrete porosity as the RM ratio decreased. In conclusion, the water permeability test showed that the 10RM concrete provided the lowest water penetration depth value in comparison to 0RM, which ultimately supports the use of red mud as 10%.

3.5. Capillary water absorption test

Capillary water absorption test determines the rate of water absorption through the concrete surface (Zhu and Bartos, 2003; Medeiros and Helene, 2009). Each point on

Fig. 8 is the averaged value of measurements of three specimens. The capillary permeability of the concrete changed depending on the proportion of red mud addition. It may generally be seen that the control concrete exhibited greater resistance to water absorption by capillary suction than the concrete containing red mud, and 10RM provided the lowest absorption value followed by 20RM, whereas the highest absorption value was obtained in 15RM. Moreover, it may be seen in Fig. 8 that the same absorption value could be obtained with 0RM and 10RM (i.e., about 700 and 800 g/m² capillary absorption in 24 h for 0RM and 10RM, respectively). In addition, it was shown that 15RM and 20RM provided the highest absorption values (i.e., about 6800 and 4200 g/m² capillary absorption in 24h for 15RM and 20RM, respectively).

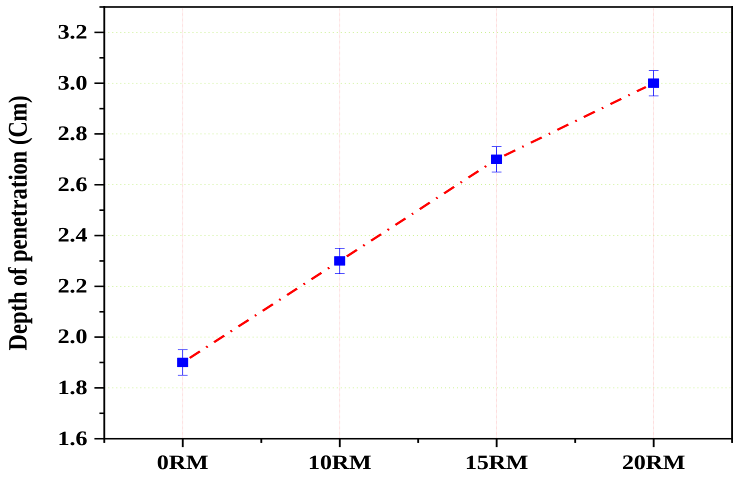

Fig. 6. Permeability test of concrete.

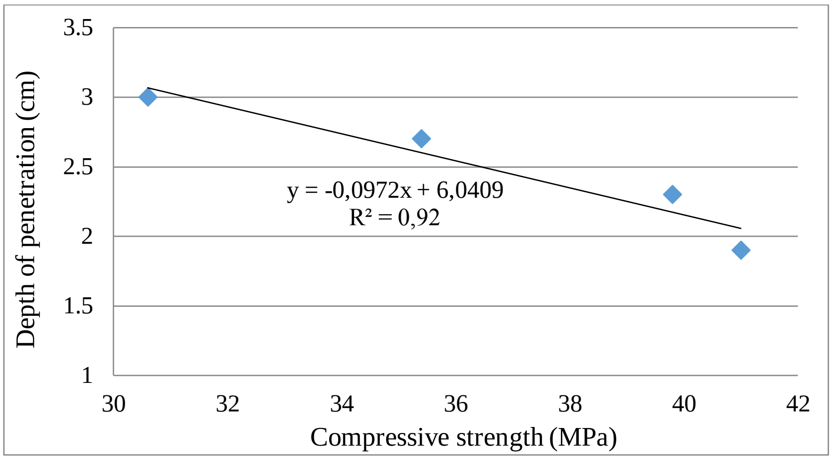

Fig. 7. Compressive strength and depth of penetration relationship.

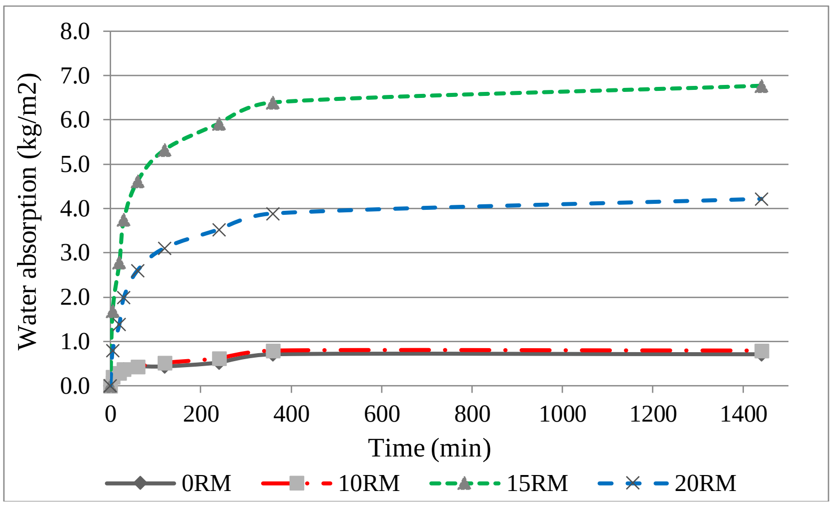

Fig. 8. Capillary water absorption of concrete.

4. Conclusions

The main purpose of this experimental study is to measure the effect of 25, 200, 300, 400, 600, and 800 ° C temperatures for 3 hours. Four mixes with red mud (0%, 10%, 15% and 20%) replacing cement by weight were used to evaluate the residual compressive and tensile strength of concrete as well as weight loss values after high-temperature exposure. Moreover, to study the permeability properties of concrete, capillary water absorption and water permeability tests were performed on all four mixes. The following results were found:

- The weight loss was somewhat higher in the 15RM and 20RM concrete groups in comparison to the control concrete, and this loss was higher especially at a temperature of 300°C.
- From the point of view of compressive strength, the 10RM group almost was close to the control concrete and provided even better results at some temperatures (400°C). However, at higher RM ratios there was a decrease in strength.
- Under high-temperature effect, all mixtures have a marked decrease in their compressive strength when heated to 300°C. At 400°C, however, there was an increase in compressive strength of 10RM and a decrease in higher red mud proportions. More detailed investigations are needed to explain the behavior of RM samples, especially at 400°C, where the effect of RM is positive.
- At higher temperatures (e.g. 600°C), the maximum reduction in compressive strength was observed at 10 RM in comparison to 0 RM. Whereas at 800°C, the maximum reduction in compressive strength was in 20RM.
- In terms of splitting tensile strength, positive results were not obtained in the groups with RM. It is advised to use fibers to increase tensile strength especially when red mud is used.
- The water permeability test showed that the 10RM sample provided the lowest water penetration depth value compared to 0RM, which ultimately supported the use of red mud as 10%.

For further studies,

- Evaluation of the pozzolanic activity of red mud is also required at different ages,
- It is needed to examine the changes in properties with different curing methods and more mineral additive materials,
- The effects of different methods of cooling after high temperature exposure should be examined,
- Detailed microstructure and pore structure studies are recommended on the topic (e.g., MIP, SEM, BET, XRD, TGA) to determine the mechanism of red mud as a partial replacement exposed to high temperature,
- Examination of freeze-thaw and other durability properties is recommended,
- It is advisable to examine the properties of different concrete types with red mud (e.g., high strength concrete and fiber-reinforced concrete) at high temperatures. To increase tensile strength, which is particularly low, different materials (steel fiber, polymer fiber, etc.) could be added to the concrete with red mud.
- Additionally, post-temperature properties should be examined at the sintered state.

References

Alameri I (2017). Atık Kırmızı Çamur ve Nano Al_2O_3 Katkılı Betonların Yüksek Sıcaklık Sonrası Fiziksel ve Mekanik Özelliklerinin İncelenmesi. *MSc thesis*, Atatürk University, Erzurum, Turkey. (in Turkish)

Alameri I, Oltulu M (2019). The effect of high temperatures on the properties of hardened concrete with bauxite residue materials. *Mas International Conference on Mathematics-Engıneering-Natural & Medical Sciences*, Erzurum, Turkey.

Alameri I, Oltulu M, Ardahanlı M (2019). Effect of early-age temperature on the behavior of concrete containing silica fume. *3rd International Conference on Advanced Engineering Technologies*, Bayburt, Turkey.

AlSheikh SA (2011). Mechanical properties for high performance concrete exposed to high temperature. *International Journal of Civil and Structural Engineering*, 2(2), 435–444.

Ardahanlı M, Oltulu M, Alameri I (2019). Evaluation of the mechanical propertıes of self-compacting concrete containing fly ash subjected to early-age temperature. *Hoca Ahmet Yesevi 2. Uluslararası Bilimsel Araştırmalar Kongresi*, Erzurum, Turkey.

ASTM C1585-13 (2013). Standard Test Method for Measurement of Rate of Absorption of Water by Hydraulic-Cement Concretes. ASTM International, West Conshohocken, PA.

Baradan B, Yazıcı H, Ün H (2010). Beton ve betonarme yapılarda durabilite. Türkiye Hazır Beton Birliği, Turkey.

Beglarigale A, Yalçınkaya Ç, Yigiter H, Yazıcı H (2016). Flexural performance of SIFCON composites subjected to high temperature. *Construction and Building Materials*, 104, 99–108.

Behnood A, Ghandehari M (2009). Comparison of compressive and splitting tensile strength of high-strength concrete with and without polypropylene fibers heated to high temperatures. *Fire Safety Journal*, 44, 1015–1022.

Bishetti PN, Pammar L (2014). Experimental study on utilization of industrial waste in concrete. *International Journal of Technical Research and Applications*, 2(4), 49-52.

DIN 1048-5 (1991). Determination of permeability of concrete. Deutsches Institut für Normung eV, Germany.

Hu W, Nie Q, Huang B, Shu X, He Q (2018). Mechanical and microstructural characterization of geopolymers derived from red mud and fly ashes. *Journal of Cleaner Production*, 186, 799-806.

Kushwaha M, Akhtar S, Rajput S (2013). Development of the self compacting concrete by industrial waste (red mud). *International Journal of Engineering Research and Applications*, 3(4), 539-542.

Liu R, Poon C (2016). Effects of red mud on properties of self-compacting mortar. *Journal of Cleaner Production*, 135, 1170-1178.

Manfroi EP, Cheriaf M, Rocha JC (2014). Microstructure, mineralogy and environmental evaluation of cementitious composites produced with red mud waste. Construction and Building Materials, 67, 29-36.

Medeiros MHF, Helene P (2009). Surface treatment of reinforced concrete in marine environment: Influence on chloride diffusion coefficient and capillary water absorption. *Construction and Building Materials*, 23, 1476–1484.

Metilda DL, Selvamony C, Anandakumar R, Seeni A (2015). Investigations on optimum possibility of replacing cement partially by redmud in concrete. *Scientific Research and Essays*, 10(4), 137-143.

Nath H, Sahoo P, Sahoo A (2015). Characterization of red mud treated under high temperature fluidization. *Powder Technology*, 269, 233–239.

Oltulu M, Alameri I (2019). The mechanical properties of concrete with red mud (bauxite residue) and nano-Al_2O_3 at high temperatures. *Fresenius Environmental Bulletin*, 28(6), 4692-4701.

Rana AY and Sathe NA (2015). Analysing the potential substitute of red mud in concrete adding lime and silica. *International Journal of Emerging Technology and Advanced Engineering*, 5(4), 410-414.

Rathod RR, Kulkarni PM, Shingade VS, Deshmukh SS (2015). Suitability of red mud as an admixture in concrete. *International Journal of Modern Trends in Engineering and Research*, 4th International Conference on Recent Trends in Engineering and Technology. SNJB's KBJ College of Engineering, Chandwad, Nashik, Maharashtra, India.

Rathod RR, Suryawanshi NT, Memade PD (2014). Evaluation of the properties of red mud concrete. *Journal of Mechanical and Civil Engineering*, Second International Conference on Emerging Trends in Engineering, Dr.J.J. Magdum College of Engineering, Jaysingpu, India.

Ribeiro DV, Labrincha JA, Morelli MR (2010). Use of red mud as addition for portland cement mortars. *Journal of Materials Science and Engineering*, 4(8), 1-8.

Ruano G, Isla F, Luccioni B, Zerbino R, Giaccio G (2018). Steel fibers pull-out after exposure to high temperatures and its contribution to the residual mechanical behavior of high strength concrete. *Construction and Building Materials*, 163, 571-585.

Sancak E, Dursun Sari Y, Simsek O (2008). Effects of elevated temperature on compressive strength and weight loss of the light-weight concrete with silica fume and superplasticizer. *Cement & Concrete Composites,* 30, 715–721.

Sanchayan S, Foster SJ (2016). High temperature behaviour of hybrid steel–PVA fibre reinforced reactive powder concrete. *Materials and Structures*, 49, 769–782.

Sawant AB, Kumthekar MB, Diwan VV, Hiraskar KG (2012). Experimental study on partial replacement of cement by neutralized red mud in concrete. *International Journal of Engineering and Advanced Technology*, 2(1), 282-286.

Tang L (2014). Study of the possibilities of using Red Mud as an additive in concrete and grout mortar. Svensk Kärnbränslehantering AB Swedish Nuclear Fuel and Waste Management Co., Stockholm, Sweden.

Tanyıldızı H, Asiltürk E (2018). High temperature resistance of polymer-phosphazene concrete for 365 days. *Construction and Building Materials*, 174, 741-748.

Torić N, Boko I, Juradin S, Baloević G (2014). Post-fire reductıon of concrete's mechanical properties and its impact on residual load capacity. *8th International Conference on Structures in Fire*, Shanghai, China.

TS EN 196-1 (2016). Methods of testing cement-Part 1: Determination of strength. Turkish Standards Institute, TSE, Ankara, Turkey.

TS EN 197-1 (2012). Cement Part 1: Compositions and conformity criteria for common cements. Turkish Standards Institute, TSE, Ankara, Turkey.

TS EN 206 (2014). Design of concrete mixes. Turkish Standards Institute, TSE, Ankara, Turkey.

TS EN 1097-6 (2013). Specific gravity and water absorption. Turkish Standards Institute, TSE, Ankara, Turkey.

TS EN 12390-3 (2013). Testing hardened concrete–Part 3: Compressive strength of test specimens. Turkish Standards Institute, TSE, Ankara, Turkey.

TS EN 12390-6 (2010). Testing hardened concrete: tensile strength of test specimens. Turkish Standards Institute, TSE, Ankara, Turkey.

Zhu W, Bartos PJM (2003). Permeation properties of self-compacting concrete. *Cement and Concrete Research*, 33(6), 921-926.