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Mid-Temperature Thermal Effects on Properties of Mortar Produced with Waste Rubber as Fine Aggregate

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Abstract

This laboratory study aims to investigate curing and thermal effect on mechanical properties of mortar produced with waste rubber as fine aggregate. For this purpose, three type of rubber content was used in mix design like 0%, 10% and 20%. Mortar specimens were produced with 520 kg cement. The type of used cement is CEM I 42.5 R ordinary Portland cement and w/c ratio were kept at 0.485 level at all mix design. Rilem sand was used in the mortar. Rolled crumb waste rubber was used in the composition and the grain size of used waste rubber was between 1-4 mm. The effect of curing age was evaluated on compressive strength and abrasion resistance on the base of three distinct rubber content. Moreover, the compressive strength results were evaluated with two different temperature levels, i.e. 150^{0}C and 200^{0}C and three different curing age condition, i.e. 3 days, 7 days and 28 days. As a result, it was observed that there is a constant decrease at early curing age of mortar in terms of compressive strength, but there is a sharp decrease at 28-days curing condition. As for abrasion resistance, it was determined that abrasion loss was increased in the early curing age of specimens. However, abrasion loss was decreased with increasing rubber content.

Keywords: Curing effect, fine aggregate, mortar, recycled rubber, temperature effect

Orta Derece Isı ve Kür Etkisinin Atık Lastik İnce Agrega ile Üretilmiş Harç Özellikleri Üzerine Etkisi

Öz

Bu laboratuvar çalışması ile atık lastik ince agrega ile üretilen harçların mekanik özellikleri üzerinde kür ve orta dereceli ısı etkisinin nasıl bir etki yaptığını belirtmek amaçlamaktadır. Bu sebeple, karışım hesabında %0, %10 ve %20 gibi üç çeşit atık lastik oranı kullanıldı. Harç numunelerinin karışım hesabında 520 kg çimento kullanıldı. Kullanılan çimento türü, CEM I 42.5 R Portland çimentosu ve su/çimento oranı, tüm karışım tasarımında 0.485 seviyesinde tutulmuştur. Harcın içinde rilem kumu kullanılmıştır. Karışımda yuvarlak atık kauçuk kullanılmış ve kullanılan atık kauçukların dane boyutu 1-4 mm arasındadır. Kür süresinin etkisi, üç farklı atık lastik içeriğinin temelinde basınç dayanımı ve aşınma direnci açısından değerlendirildi. Dahası, basınç dayanımları iki farklı sıcaklık seviyesinde, yani 150ºC ve 200ºC'de ve üç farklı kür süresi koşuluyla, yani 3 gün, 7 gün ve 28 gün ile değerlendirildi. Sonuç olarak, basınç dayanımı açısından, harcın erken yaşlardaki değerlerinde sabit bir düşüş gözlenirken, 28 günlük kür koşullarında keskin bir düşüş görülmüştür. Aşınma direnci ile ilgili olarak, numunelerin erken yaşlarında aşınma kaybının arttığı belirlenmiştir. Bununla birlikte; aşınma kaybı, artan atık lastik içeriğiyle azalmıştır.

Anahtar kelimeler: Kür etkisi, ince agrega, harç, atık lastik, sıcaklık etkisi

INTRODUCTION

All engineering facilities are located on the idea minimum cost, maximum serviceability and durability. Environmental friendly solutions draw attention to fulfill minimum cost, to protect natural resources and to reuse waste material in civil engineering facilities. For this purpose, many alternative of waste material is evaluated by Cemalgil and Onat (2016). Silica fume, fly ash and rubber can be listed for alternative external material can be used for mortar (Benli et al., 2017; Karataş et al., 2017). Rubber is one of the most abundant materials obtained from discarded tire. The purpose of using rubber in construction industry is to obtain high toughness. Rubber contributes resistance against dynamic loading (Onat and Celik, 2017). Mortar behavior with rubber content was investigated with many researchers in terms of different aspects. Topçu and Demir (2007) evaluated durability of mortar and concrete produced with rubber. All selected properties were decreased with increasing rubber content. However, it was reported that the rubber addition increased the freeze and thaw resistance.

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Turatsinze et al. (2007) investigated shrinkage and possible solutions to limit shrinkage of cement-based mortar produced with rubber. Ring test was used to determine free shrinkage and revealed a benefit with increased free shrinkage. Turki et al. (2008) studied mechanical behavior of the mortar, rubber-aggregate composites. For this purpose, rubber particles were added into mortar with different ratio like 0%, 10%, 30% and 50%. The indicated research presented that plastic strain and axial deformation was increased with increasing rubber content. Moreover, Turki et al. proposed linear and nonlinear material properties for Finite Element modelling of mortar specimens with rubber. In another study, Turki et al. (2009) investigated influence of microstructures and of interfacial transition zone on mechanical properties of rubber-aggregate in mortar matrix. Compressive strength, dry bulk density, sound velocity and poison ratio values are presented with continuity index. Uygunoğlu and Topçu (2010) investigated the effect of rubber on shrinkage of mortar and mechanical properties of self-consolidating mortar. This study revealed that differential replacement of rubber particle with sand decrease fresh and hardened properties of mortar. However, rubber provided beneficial contribution to self-consolidating mortar in terms of drying shrinkage. Muhammad et al. (2011) investigated effect of mid-temperature temperature on thermal resistance properties of five sets of mortar mix with different rubber matrix. It was reported that 20% rubber replacement is the optimum ratio to obtain ideal thermal properties. It was emphasized that maximum 5% weight loss reported at the temperature between 340^0 C–460^0 C. More than 340^0 C temperature decay engineering properties of rubberized mortar. Moreover, in the same study, it was emphasized that the addition of rubber increases durability of mortar. Pedro et al. (2013) studied on mortar composed of fine granulated shredded tires. Shredded tires were replaced with natural aggregate. Replacement ratio was 5%, 10% and 15% of total amount of aggregate. It was emphasized that addition of rubber in mortar increased impact resistance. It was concluded in the same research that rubberized mortar can be useful for wall coatings and water vapor permeability. Angelin et al. (2015) carried an experimental investigation on the effect of spheroid and fiber size tire rubber on mortar matrix in terms of flexural and compressive strength with porosity and water absorption. It was reported that water absorption and porosity increased with addition of rubber particles as sand. It was emphasized that 5% rubber replacement in mortar is suitable for water purification systems and building façade. Lanzon et al. (2015) studied on elimination of microstructural limitations to investigate possible use of rendered tire rubber. However, this limitation was overcoming by using sodium-oleat to obtain better capillary, water absorption and mechanical properties. Compressive strength, bending strength, mass loss and water absorption properties of modified mortar with rubber aggregate were investigated under artificial acid environment condition and mid-temperature. It was reported that adding rubber has no significant effect on mass loss, while rubber addition decreased strength and water absorption. With propagation of microcracks between 300^0C and 400^0C, it was observed that there is a drop-in frequency (Tupy et al., 2015). Guelmine et al. (2016) investigated sensitivity of rubberized mortar with dune sand to mid-temperature. Used recycled rubber aggregate in concrete was replaced with dune sand in amount of 3%, 6% and 9%. It was reported that mortar specimens which were produced with maximum 3% recycled rubber can be used safely under mid-temperature while compared with control concrete. Crumbed, shredded and any other type of concrete was studied by many researchers with different aspects (Reda Taha et al., 2008; Muhammad et al., 2011; Bing and Ning 2013; Youssf et al., 2016; Mendis et al., 2017). However, there is a gap in the literature in terms of effect of curing and thermal performance mortar with rolled rubber at different age.

MATERIAL AND METHOD

Method

This paper aims to investigate, curing and thermal effects of mortar produced with waste rubber as fine aggregate. For this purpose, a series of experiments were implemented on conventional and modified mortar. Compressive strength and abrasion resistance tests were performed on the specimens with different curing

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conditions, these are 3 days, 7 days and 28 days and mid-temperature these are 150^{0}C and 200^{0}C. Mechanical test results were evaluated under three curing conditions at the age of 3, 7 and 28 days. Moreover, mid-temperature test results were evaluated and tabulated under two different temperature conditions at 150^{0}C and 200^{0}C. Three type of mortar amount was used with 0% rubber, 10% rubber and 20% rubber.

Materials

In the mix design, an ordinary Portland cement (CEM I 42.5 R) was used to produce control and mixed mortar. Chemical composition of cement used in mix design can be seen in Table 1.

Table 1. Chemical compositions and physical properties of Portland cement

Chemical analysis (%)	Portland cement
CaO	63.57
SiO_2	19.54
Al_2O_3	3.85
Fe_2O_3	4.15
MgO	3.20
SO_3	2.86
K_2O	0.82
Na_2O	0.39
Loss on ignition	1.62
Specific gravity (g cm^{-3})	3.16
Fineness (m^2 kg^{-1})	360*

* Blaine specific surface area

Rolled waste rubber was used in mortar replaced with fine aggregate. This rolled waste rubber was obtained from synthetic soccer turf, after renovation process of the facility complex. Diameter of rolled waste rubber is between 1-4 mm, waste rubber can be seen in Figure 1. Used rubber in mix has a typical service temperature range between –50° F (-45.5° C) and +225° F (107.2° C).

Figure 1. Waste rubber

Rilem sand was used to produce mortar. Physical properties of materials are tabulated in Table 2 and Table 3.

Table 2. Specific gravity cement, rilem sand and rubber

Material Type	Specific gravity (g cm^{-3})
Cement	3.15
Rilem Sand	2.623
Rubber as fine aggregate	1.013

Table 3. Water absorption and water content of rilem sand

Property Type	Measured content (%)
Water absorption	0.61
Water content	0.29

Water absorption and Specific Gravity tests were performed on the base of ASTM C 128-1 (2003) regulation.

Sieve Analysis and Mix Design

Sieve analysis test was performed on the base of TS EN 933-1 (2015) Mix proportions were designed on the base of 50 MPa target compressive strength value of control concrete. Mix design was tabulated in Table 4.

As seen from Table 4, there are three sets of mortar. RSM0R denotes Rilem Sand Mortar with zero percent waste rubber that is control concrete. RSM10R denotes Rilem Sand Mortar with 10% waste rubber and last one is the RSM20R. This last composition demonstrates Rilem Sand Mortar with 20% waste rubber. Water to binder ratio was kept constant at 0.485 level. Sieve analysis test result can be seen in the Figure 2.

Cumulative finer fraction can be seen in

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Figure 2. Maximum diameter of particle of rolled waste rubber is changes between 2 mm and 4 mm.

Mid-temperature procedure applied as follows. Each set (i.e. each hardened state tests for 150^0 C and 200^0 C) composed of three specimens for testing end of 2 hours, 4 hours and 6 hours. First, half of the tested specimens were saved at 150^0 C and half of them were saved 200^0 C. Two different ovens were used for testing mortar specimens. For instance, 9 mortar specimens were saved in the oven. Then, end of 2 hours three specimens were taken from oven and tested. Rest of the specimens were saved end of 4 hours. End of 4 hours, three specimens were also taken to perform test.

RESULTS

Effect of Rubber Ratio on Mechanical Tests

Hardened state of mortar with and without rubber as fine aggregate was evaluated by performing compressive strength and abrasion resistance. For this purpose, compressive strength test was performed on mortar specimen with control set, 10% rubber set and 20% rubber set under curing age of 3 days, 7 days and 28 days. Compressive strength test results were performed on the base of ASTM C349-02 (2002) code. This test was performed on 100mmx100mmx100mm cubic mortar specimens. Figure 3 presents compressive strength test.

Table 4. Mix design composition of control and modified mortar

Rubber replacement volume (%)	Mix ID	w/c	Water (kg)	W of Cement (kg)	W of Aggregate (kg)	W of Rubber (kg)
0	RSM0R	0.485	252.2	520	1430.1	0
10	RSM10R	0.485	252.2	520	1287.1	55.23
20	RSM20R	0.485	252.2	520	1144.0	110.46

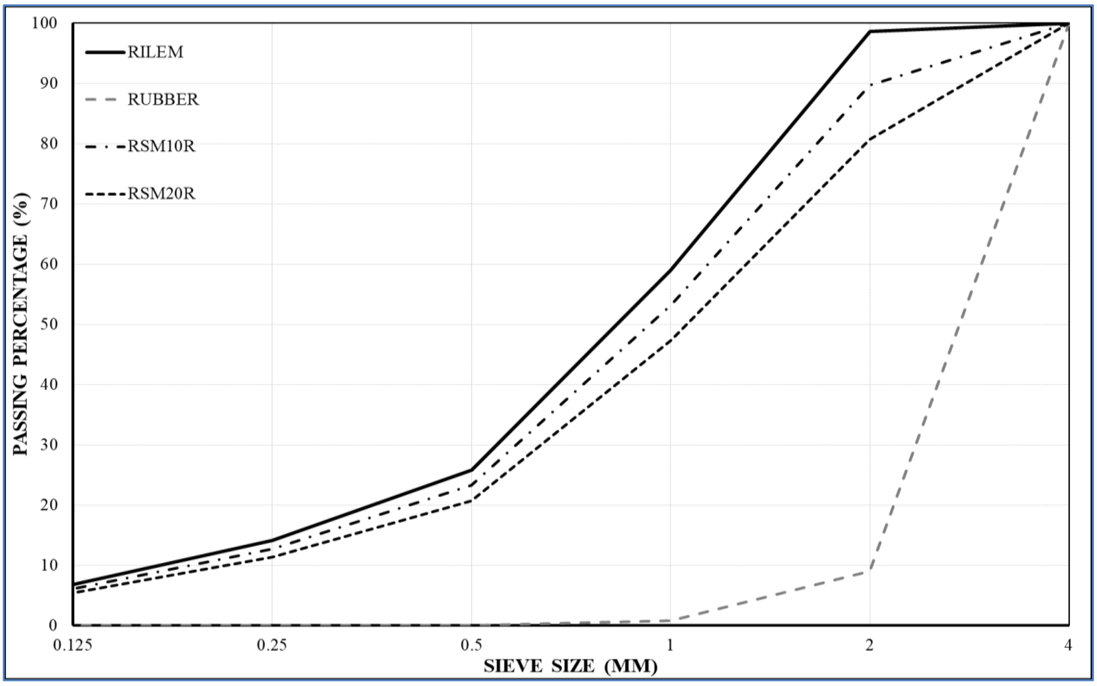

Figure 2. Sieve analysis of compositions

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Figure 3. Compressive strength test of mortar

After applying flexural strength, compressive strength test was performed on the specimen without disturbing the position of the specimen. Vertical load was applied on the specimen in accordance with the Procedure of ASTM C-349-02 (2002). According to mentioned standard,the load rate should be between the range of 200 to 400 lbs/s [0.9 to 1.8 kN/s]. For this study load rate was 1.4kN/s.

Compressive strength test results were plotted in Figure 4.

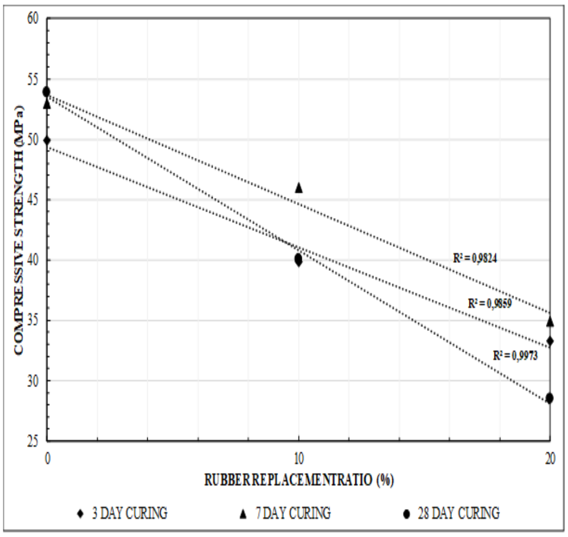

Figure 4. Effect of rubber ratio on compressive strength test results with different curing age

3 days and 28 days curing have the same effect on mortar with 10% rubber. When waste rubber replaced with sand in 20%, 28 days curing effect on compressive strength shows nearly 17% decrease from 34 MPa to 29 MPa. Particle distribution of rubber in mortar can be seen in Figure 5.

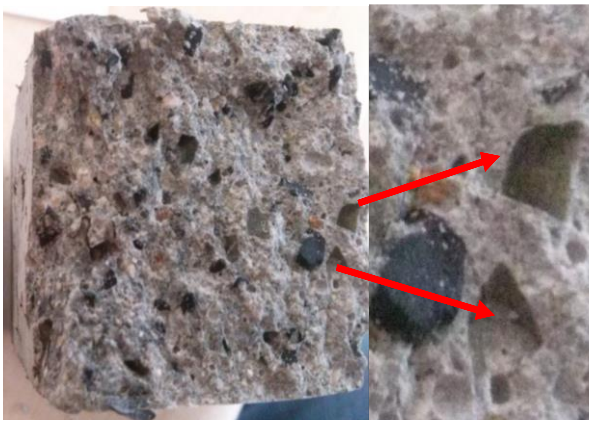

Figure 5. Particle distribution of rubber after compressive strength test

Abrasion test was performed on the base of ASTM C 944 (ASTM 2012) standard and modified mortar after compressive strength test. Curing effect was evaluated on abrasion resistance with changing waste rubber content. Abrasion loss and rubber replacement graph was plotted with different curing age in Figure 6.

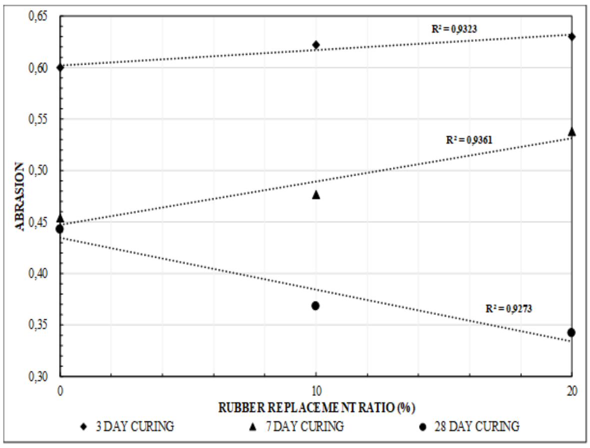

Figure 6. Effect of rubber ratio on abrasion resistance test results with different curing age

Vertical axis shows abrasion loss amount over total specimen weight in percent in Figure 6. As seen from Figure 6, curing age has positive effect on abrasion with 20% substitution amount of rubber. The highest amount of abrasion is

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occurred at 3 days curing without rubber. Minimum abrasion loss was obtained at 28 days age 20% rubber substituted specimen. However, abrasion loss increased with increasing replacement ratio of rubber at early age of curing. Whereas, increasing rubber content resulted weight loss decrease at latter age of the mortar specimens.

Effect of curing and mid-temperature on compressive strength of mortar with different rubber ratio

Temperature effect in mortar is important due to nonstable volume change. For this reason, temperature effect was investigated with different rubber amount. Compressive strength test results were evaluated at two different temperature level that is 150^{0}C and 200^{0}C with three different waste rubber replacement level (0%, 10%, 20%). Figure 7 demonstrates compressive strength test results of mortar with three different replacement level at 150^{0}C.

Compressive strength test was performed on each specimen at 150^{0}C after indicated duration in hour. Combined effect of different rubber content and 3 days curing was evaluated in Figure 7 together. Generally, 20% waste rubber substituted modified mortar compressive strength test results were the lowest while compared with 0% and 10% waste rubber replacement level. The lowest test result was obtained at two hours' application of 150^{0}C temperature at 3 days curing. 50Mpa compressive strength test results were achieved at 3 days curing without rubber. However, achieved strength decreased to 40 MPa at two hours' application of 150^{0}C, then increased to 44 MPa at 4 hours' application and finally increased to 46 MPa under 3 days curing. Modified mortar with 10% replacement ratio of waste rubber, 40 MPa compressive strength was achieved. Then specimens were exposed to 150^{0}C along two hours, after two hours' application, compressive strength test performed on these specimens. Obtained result is 30 MPa under 3 days curing. 4 hours 150^{0}C compressive strength test result showed that strength ratio was increased to 32 MPa and after 6 hours' application, strength ratio increased to 38 MPa. Compressive strength test results of modified mortar specimens with 20% waste rubber content was 33MPa. However, after exposing 150^{0}C temperature 2 hours' strength of specimen decreased to 26 MPa. Then, these specimens's exposed to 150^{0}C along 4 hours' and compressive strength result was 24 MPa. Finally, specimens were exposed to 150^{0}C along 6 hours' and compressive strength test result increased to 37 MPa.

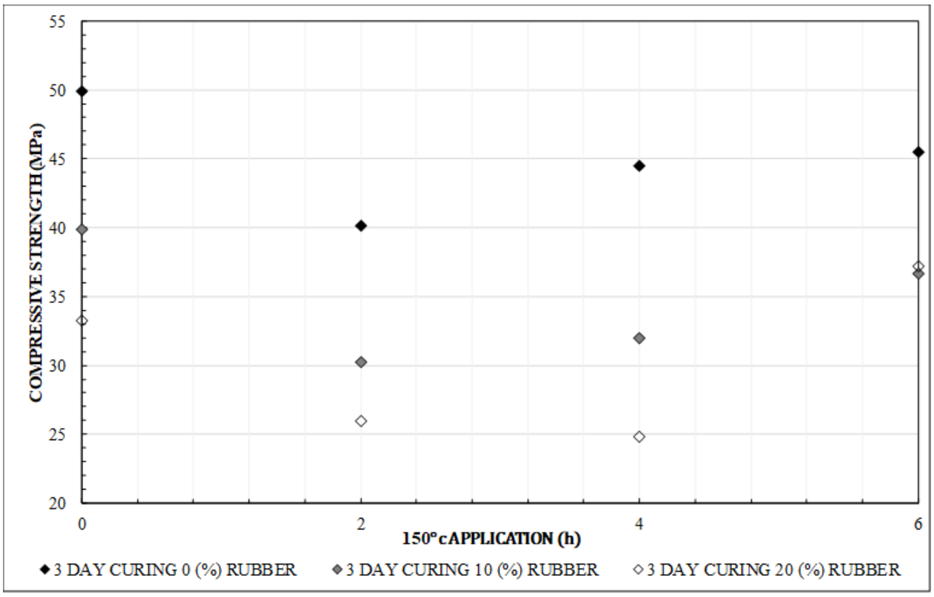

Figure 7. Effect of 150^{0}C temperature level on compressive strength test results with different rubber content under 3 days curing

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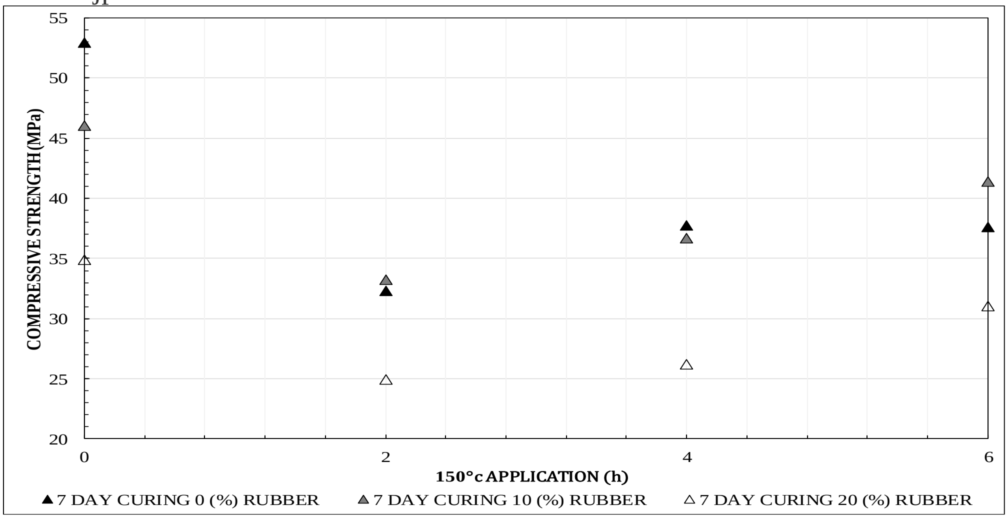

Figure 8. Effect of 150^{0}C temperature level on compressive strength test results with different rubber content under 7 days curing

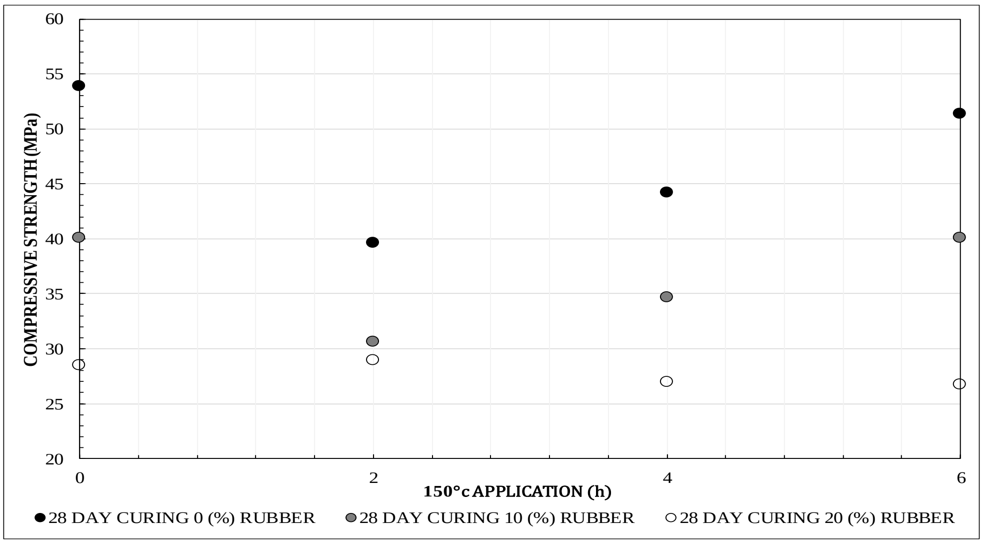

Figure 9. Effect of 150^{0}C temperature level on compressive strength test results with different rubber content under 28 days curing

Control and modified mortar specimens were exposed to 150^{0}C to assess compressive strength under 7 days curing in Figure 8.

Maximum compressive strength test result was measured 53 MPa for control mortar without rubber under 7 days curing condition. Then compressive strength was decreased to 32 MPa after 2 hours' application of 150^{0}C temperature. But, there is a slight increase at compressive strength from 32 Mpa to 38 MPa when the specimens were saved in the oven along 4 hours' under 150^{0}C temperature level. Consequently, after 6 hours' 150^{0}C temperature application to specimens, compressive strength measured 37 MPa. Compressive strength test results of modified mortar with 10% waste rubber was measured 46 MPa after 7 days curing. Then compressive strength test results were measured 33 Mpa, 37 MPa and 42 Mpa. These test results belong to 2 hours', 4 hours' and 6 hours' 150^{0}C temperature application respectively. The lowest results belong to 20% rubber content. These results can be presented as follows. 35 MPa, 25

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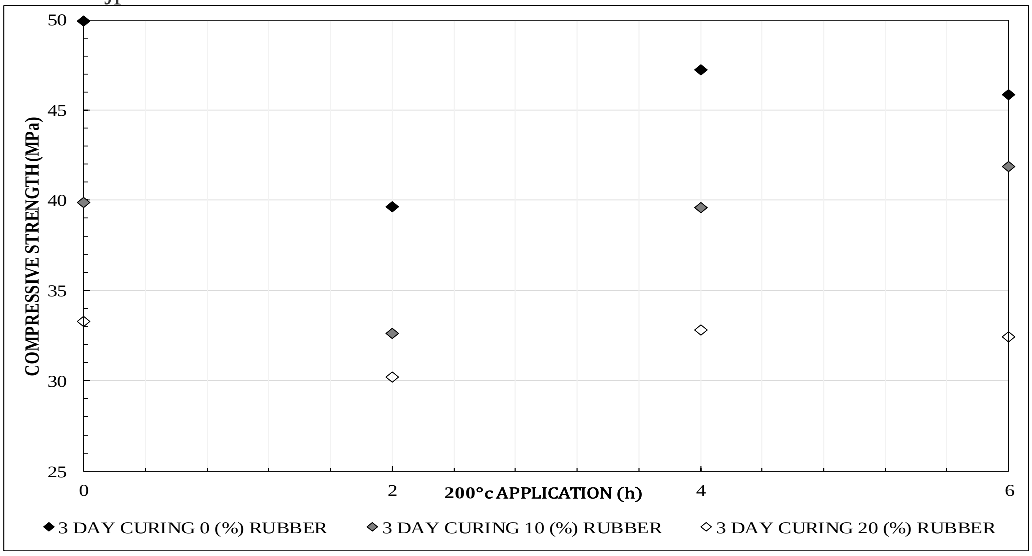

Figure 10. Effect of 200^{0}C temperature level on compressive strength test results with different rubber content under 3 days curing

MPa, 27 MPa and 32 MPa respectively. These results listed per duration of exposing 150^{0}C temperature. 35 MPa test result was obtained after 7 days curing. 25 MPa was obtained from compressive strength test result after exposing specimens 2 hours 150^{0}C temperature. Then a slight increase was observed from 25 MPa to 27 MPa when the specimens were saved in oven along 2 hours at 150^{0}C temperature. However, an increase was observed from 27 MPa to 32 MPa in terms of compressive strength when the specimens were saved in the oven at 150^{0}C temperature along 6 hours.

Control and modified mortar were tested to determine compressive strength with 28 days curing. This test results can be seen in Figure 9.

Compressive strength test result of control mortar was reached to 54 MPa under 28 days curing. Then mortar specimens exposed to 150^{0}C temperature along 2 hours, compressive strength test result was measured 40 MPa. After 150^{0}C temperature applications to specimens along 4 hours, compressive strength was increased to 44 MPa. Finally, after 6 hours' 150^{0}C temperature application to specimens, compressive strength measured 52 MPa. Effect of 10% rubber content was investigated under 28 days curing condition. Compressive strength of modified mortar with 10 % waste rubber was measured 40 MPa. 31 MPa, 35 MPa and 40 MPa test results were measured after exposing the specimens to 150^{0}C temperature through 2 hours, 4 hours and 6 hours respectively under curing of 28 days. Moreover, 29 MPa strength results was achieved with 20% waste rubber content. Then, it was observed that there is no change at compressive strength of modified mortar after exposing the specimens to 150^{0}C temperature with 28 days curing. Furthermore, 27 MPa compressive strength test results were measured with 4 hours and 6 hours 150^{0}C temperature application.

200^{0}C is the other temperature test stage to assess mechanical behavior of control and rubberized mortar under curing age of 3 days, 7 days and 28 days. Figure 10 presents compressive strength test results of control and modified mortar under the 3 days curing.

50 MPa compressive strength was measured with control mortar after 3 days curing. Then, 39 MPa compressive strength test result was obtained from the specimens which were saved in the oven at 200^{0}C along 2 hours after curing the specimen 3 days. There is a great increase that is 47 MPa, observed after exposing the specimens to 200^{0}C along 4 hours. Finally, compressive strength of modified mortar specimens stayed

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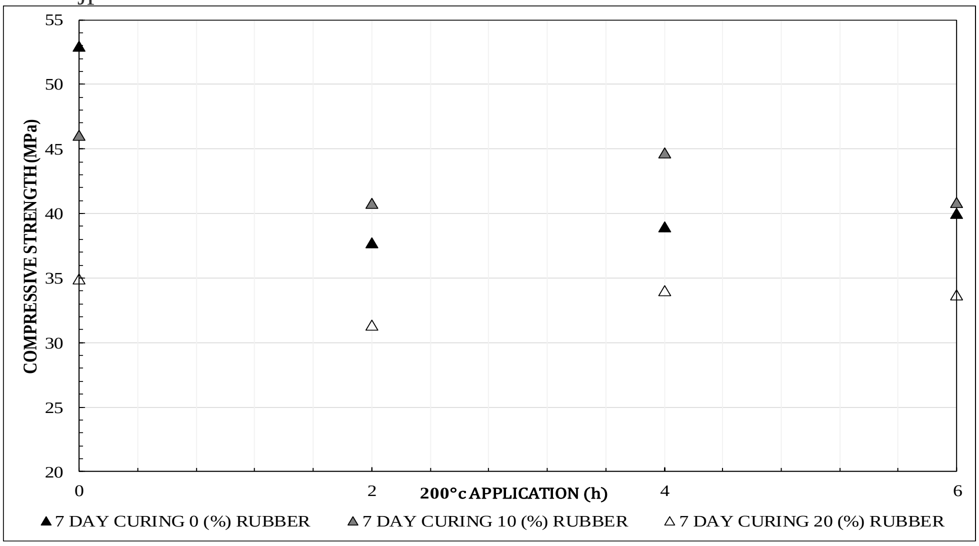

Figure 11. Effect of 200^{0}C temperature level on compressive strength test results with different rubber content under 7 days curing

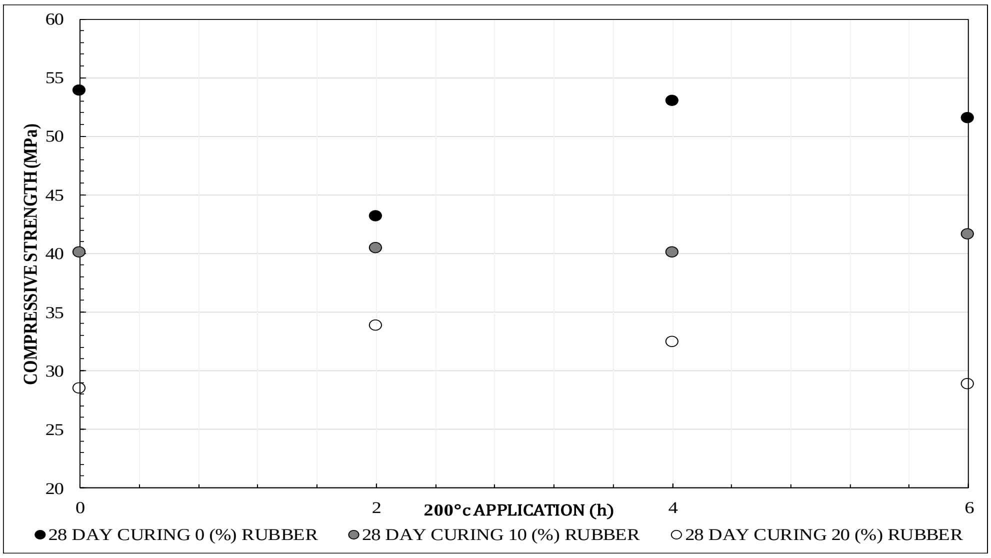

Figure 12. Effect of 200^{0}C temperature level on compressive strength test results with different rubber content under 28 days curing

nearly stable after exposing specimens to 200^{0}C along 6 hours.

7 days curing effect was studied with different rubber content in mortar and control mortar at 200^{0}C temperature level. The results of this test can be seen in Figure 11.

53 MPa compressive strength was measured with control mortar. These specimens were tested under normal laboratory temperature level after 7 days curing. However, there is a certain decrease at control mortar when exposed to 200^{0}C along 2 hours after 7 days curing. Later temperature durations showed that there is no significant change at compressive strength. After 4 hours and 6 hours 200^{0}C temperature applications, compressive strength test results measured like 39 MPa and 40 MPa respectively. But, 10% sand replacement with rubber decreased compressive strength to 46 MPa under laboratory temperature level. But, compressive strength test results were nearly the same at other temperature duration that is 2 hours, 4 hours and 6 hours. 20% rubber

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substitution to produce modified mortar resulted 35 MPa compressive strength after 7 days curing. Saving specimens in oven 2 hours at 200^{0}C after 7 days curing resulted 31 MPa compressive strength. Moreover, there is an increase in compressive strength to 34 MPa when the specimen exposed to 200^{0}C along 4 hours. Furthermore, 1 MPa decrease was measured while compared with 4 hours' application at 200^{0}C when the specimens were exposed to 200^{0}C along 6 hours.

28 days curing effect on control and modified mortar with different rubber content was demonstrated in Figure 12.

Achieved compressive strength of control mortar is 54 MPa experimented at laboratory temperature condition after 28 days curing. Then, 44 MPa was measured from the specimen which of them exposed to 200^{0}C temperature along 2 hours under 28 days curing. Whereas, compressive strength of the specimens, which exposed to 200^{0}C along 4 hours, suddenly increased to 53 MPa after 28 days of curing. Compressive strength of the specimens, saved 6 hours at 200^{0}C, was 51 MPa after 28 days of curing. Compressive strength of modified mortar specimens, which was replaced with Rilem sand with 10% rubber resulted 40 MPa compressive strength tested at laboratory. However, compressive strength of 10% rubber replaced modified mortar which was exposed to 200^{0}C temperature along 2 hours interestingly increased to 41 MPa. 40 Mpa and 42 MPa test results were measured from the mortar specimens saved in the oven along 4 hours' and 6 hours' respectively. 20% replacement of Rilem sand with waste rubber decreased compressive strength very low level like 28 MPa which of the specimen tested at laboratory temperature level. Unexpectedly, compressive strength test results of the modified mortar specimens with 20% waste rubber resulted with 34 MPa after exposing 200^{0}C temperature along 2 hours end of the 28 days curing period. Then, 32 MPa compressive strength measured end of the 4 hours at 200^{0}C temperature saved modified mortar specimens. Eventually, 29 MPa compressive strength test results showed that there is no significant change between the mortar specimens tested and the mortar specimen saved in the oven at 200^{0}C temperature along 6 hours along.

Rubber particles have not melted at 150^{0}C, but these particles reach end of its elastic limit at 150^{0}C. Due to unfinished melting process at 150^{0}C, specimen continue to resist load after 2 hours exposure to mid-temperature. Although, rubber particles which are located close to surface of the specimen were melted under 200^{0}C application, load resistivity was continued after 2 hours temperature application until 4 hours temperature application.

Effect of curing and mid-temperature on abrasion resistance of mortar with different rubber ratio

Abrasion resistance test was performed on the specimen whom dimensions 100 mm×100 mm×100 mm on the base of ASTM C 944 (2012) standard. This standard clearly presents how to perform abrasion resistance of concrete and mortar by using rotating-cutter. Each surface of the specimens exposed to abrasion test along 2 minutes at 200 rev/min. Vertical force on each specimen kept constant at 197 kN. Test machine can be seen in Figure 13.

Figure 13. Rotating cutter test machine to perform abrasion resistance test

Abrasion resistance test was performed and results were plotted in Figure 14.

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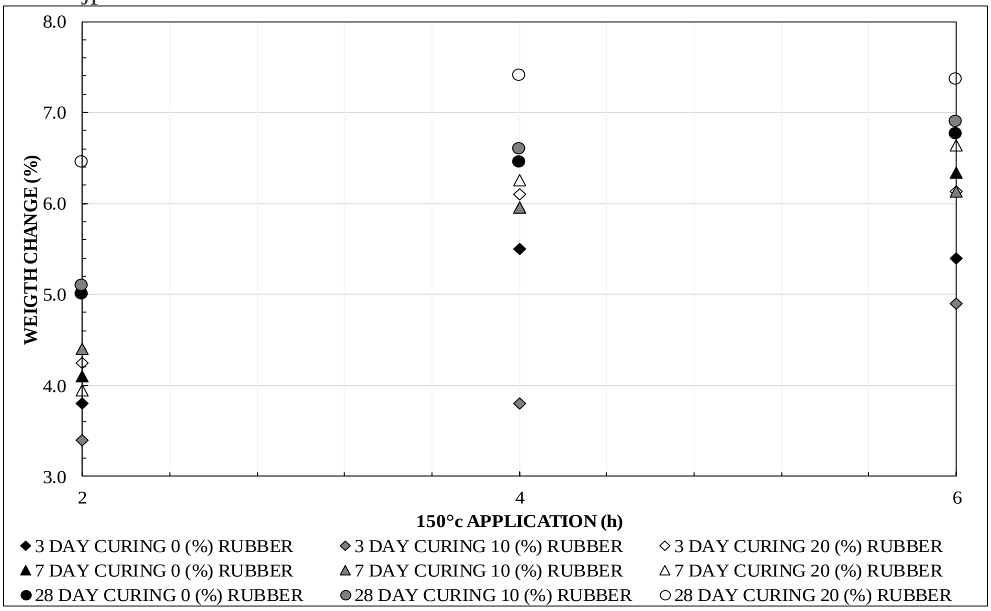

Figure 14. Abrasion resistance test results of control and modified mortars under different curing conditions at 150^0C

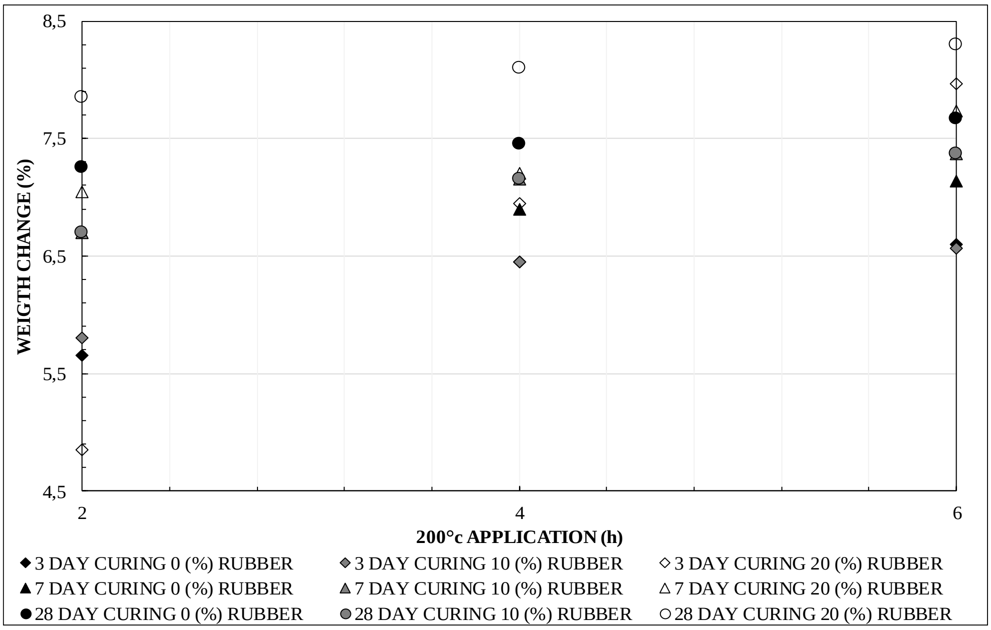

Figure 15. Abrasion resistance test results of control and modified mortars under different curing conditions at 200^0C

Abrasion resistance test results show that maximum weight loss was measured at 28 days age specimen produced with 20% rubber as fine aggregate at 150^0C temperature application. Minimum loss was measured from specimens exposed to 3 days water curing which were produced without waste rubber at 150^0C. Addition of waste rubber increased weight loss of mortar specimen. However, there is an important point that weight loss differences were decreased with increasing temperature applications as seen in Figure 14.

Figure 15 presents abrasion test results at

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150^{0}C application.

Abrasion resistance test results show that maximum and minimum weight loss was measured as 0.54 and 0.75 range for the 1500C with 4 and 6-hour period, respectively. However, for the same period of application for 2000C, 20% rubber and 28 day cured samples exceed this range. Consequently, 20% rubber and 28 day cured samples has the max weight loss for all the temperature exposing period and temperature while 10% rubber content and 3-day cure reduced the weight loss for 1500C and all the temperature exposing period.

CONCLUSION

This paper is devoted to investigate the effects of water curing and rubber as fine aggregate content on mechanical properties of cement mortars. Based on the experimental study presented above the following conclusions can be drawn below:

- Addition of 10% rubber decreased axial compressive strength 26% at 150^{0}C and 200^{0}C.
- All of the strength loss are shown almost an increasing trend with the increasing water curing time according to control mix values at same age.
- Maximum compressive strength was obtained with 0% rubber content at 28 days water curing condition both for 150^{0}C after 6 hours and 200^{0}C after 4 hours.
- In all mixes, maximum compressive strength was obtained with 10% rubber content at 7 days water curing condition both for 150^{0}C after 6 hours and 200^{0}C after 4 hours.
- The lowest compressive strength is obtained with 20% rubber content at 28 days water curing condition.
- Maximum weight loss was obtained with 20% rubber content at 3 days curing for both 150^{0}C and 200^{0}C temperature level at abrasion resistance test.
- Minimum weight loss was obtained with 20% rubber content at 28 days curing for both 150^{0}C and 200^{0}C temperature level at abrasion resistance test.
- 20% rubber substitution decreased compressive strength nearly half of the target strength. This decrease is very low during the increasing temperature.
- Compressive strength of mortar showed a 20% decrease at 2 hours' temperature application, then compressive strength increased to certain level but could not reach control mortar strength at all temperature levels (150^{0}C and 200^{0}C)
- As for abrasion resistance, it was determined that abrasion loss was increased in the early curing age of specimens. However, abrasion loss was decreased with increasing rubber content.
- Abrasion loss of control mortar is the maximum at 200 temperature application through 6 hours around 6.8% for 28 days age of mortar.
- Abrasion loss of mortar with 10% rubber content lost its weight nearly 6.8%.

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