



Mechanical and Thermal Properties of Perlite and Rubber Insulation Cement Mortar

Waleed Ahmed Al-Awsh, Ahmed Salem Al-Tamimi*, Mohammed Ali Al-Osta, and Omar S. Baghabra Al-Amoudi

*Department of Civil Engineering, King Fahd University of Petroleum & Minerals
Dhahran 31261, Saudi Arabia*

Abstract. The thermal analysis of the concrete walls showed that the connection mortar between the bricks works as thermal bridges, which transfer the heat to the interior wall surfaces. Therefore, insulation materials were used to produce insulation mortar in this research. Powder perlite and fine rubber were substituted with sand with three dosages 5%, 10%, and 15% by weight. The compressive strength, thermal conductivity, density, and absorption were measured experimentally in the lab. The results showed that the maximum reduction in compressive strength was 44% and 63% for 15% substitutions of perlite and rubber, respectively. On the other hand, the absorption of perlite was higher than rubber mortar by 59%, for the content of 10%. The thermal conductivity results proved the higher efficiency of perlite and rubber, which reached around 50% and 30%, respectively for the contents of 15%. According to ASTM C 270, the perlite and rubber mortars were satisfying the conditions.

Keywords. *compressive strength, insulation mortar, perlite, rubber, thermal conductivity.*

*Correspondence:
g201406100@kfupm.edu.sa
ahmatt2013@gmail.com

Introduction

In Gulf countries, the exterior surfaces of buildings are exposed to excessive solar radiation because it is sunny on most days throughout the year in the United Arab Emirates (UAE), thereby the temperature increases sharply on the exterior surfaces of building (roofs and walls). In summer, the air temperature can reach 50°C inducing the exterior building envelopes to absorb the heat rapidly, resulting in a surface temperature of about 80°C (Zhou et al., 2014). As a consequence, the interior surface temperature and the air-conditioning demand will significantly increase. In Abu Dhabi, around 70% of electricity consumption was attributed to the high usage for air conditioning due to the desert climate in UAE (Powerwise, 2018). In Saudi Arabia, air-conditioning systems constitute 65% of the building's electrical consumption due to the hot environment (Almujahid and Kaneesamkandi, 2013). Therefore, controlling the amount of solar radiation

that can be penetrated to the interior surfaces, could be minimized by using insulation materials in mortar, thereby, the electricity and fuel consumptions could be minimized. In fact, decreasing the temperature of air conditioning (AC) just by one degree could reduce the electricity consumption by 6% (Powerwise, 2018). The main objective of this research was to reduce the heat flow from outdoor to indoor through producing insulation mortars experimentally that could be used to build the masonry brick walls.

Literature Review

Many studies were conducted to enhance the insulation of buildings by reducing the thermal conductivity using different materials and techniques. Many researchers used perlite and rubber to produce thermally efficient mortars.

Bulut (2010) investigated the possibility of using a fine particle size of perlite as a pozzolanic additive material to lime mortar. The addition of perlite increased the compressive strength by about 0.5 MPa, as compared to lime mortar, which can be used in historical buildings. This mortar (without using cement) is useful in preserving the historic style of buildings.

Zulkifeli and Saman (2016) evaluated experimentally the effect of fire on the perlite cement mortar. The sand was replaced by perlite with the contents of 10%, 20%, 30%, and 40% by volume. The mortars were exposed to different high temperatures of 200°C, 400°C, 700°C, and 1000°C. The compressive strength was reduced with increasing the perlite content, particularly for low temperature exposure, while the performance improved in high temperature.

Lanzón and García-Ruiz (2008) studied the influence of perlite on the fresh and hardened state of cement mortar. Water absorption, workability, mechanical strength, and sorptivity were reported. The outcomes indicated that water absorption, sorptivity, and mechanical strength induced a negative effect, while water retentivity and workability have improved generally.

Xu et al. (2016) produced a new type of rubber and perlite mortar modified by SBR latex and polyester. Thermal and Mechanical properties were studied. The experimental results showed that the amount of rubber and perlite have a major influence in a compressive strength and thermal conductivity. With increasing rubber and perlite dosages, the compressive strength and thermal conductivity decreases. The reduction in compressive strength was 25–65%, as compared to the control mortar. The reduction of thermal conductivity was 6–12% and 30–35% for rubber and perlite, respectively.

Meshgin et al. (2012) used recycled tires rubber as insulation material in cement mortar with additive materials. Two different size of rubber particles were used in four mix groups. The study indicated that adjusting the size of rubber particles had a slightly effect on mechanical and thermal properties. Two mix proportions with fine and course rubber were prepared. The resulted strengths were 6.93 and 7.55 MPa for fine and coarse rubber particles, respectively, at 28

days, while the k-values were 0.364 and 0.323 W/Km.

Al-Tamimi et al. (2017) have developed FEM for a hollow brick masonry wall by filling the cavities with insulation materials. Three types of mortar were used to join the bricks (ordinary, light, and insulation mortars). The insulation and light mortars reduced the temperature by 1.30 and 0.60°C, as compared to ordinary mortar. The effect of the mortar reduced when increasing the thermal conductivity of the cavity insulation material.

Experimental Program

This section presents the replacement insulation materials, mix proportions, casting, and curing the samples.

Insulation Materials

Two insulation materials were used in the mix as replacement of sand. The perlite was powder (Figure 1) with a specific gravity of 0.30 and absorption of 100%. The rubber particles were fine with a particle size of 0.6 mm to 2 mm, as shown in Figure 1. The specific gravity was 1.12 and no absorption.

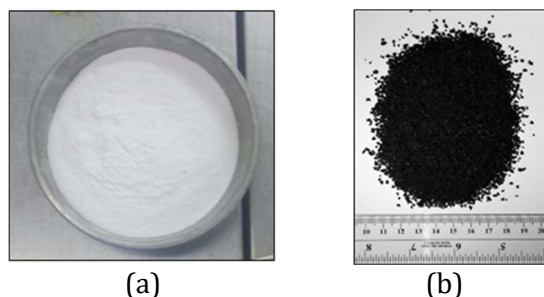


Figure 1: (a) Powder perlite; (b) Fine rubber

Mix Proportions

The control mix followed the conditions of the ASTM C 270 (ASTM, 2004). The sand was replaced with perlite and rubber with percentages of 5%, 10%, and 15% by weight. Seven mixes were prepared, the control, perlite, and rubber mortars, as presented in Table 1.

Table 1Mix proportions for 1 m³ of control, perlite, and rubber mortars

Mix Proportion	Control	PL-5	PL-10	PL-15	Ru-5	Ru-10	Ru-15
Cement	445	445	445	445	445	445	445
Water	267	315	342	359	265	263	261
Sand	1495	1032	767	597	1334	1192	1065
Perlite or Rubber	---	54	85	105	70	132	188

Table 2

Compressive strength of control, perlite, and rubber (MPa)

Time (Days)	Control (MPa)	Perlite 5	10	15	Rubber 5	10	15
7	25.52	13.39	11.49	9.64	20.00	14.08	7.75
14	26.93	22.32	16.96	15.91	22.68	17.27	10.67
28	32.83	27.06	19.82	18.34	25.95	19.21	12.31

Casting and Curing

For each mix, nine cubes (50 mm) and three discs (50 mm dia. and 25 mm thickness) were cast and compacted using a vibration table, to measure strength absorption and thermal conductivity (Figure 2). Each three cubes were cured for 7, 14, and 28 days in sweet water inside the lab.

**Figure 2:** 50-mm cubes and thermal discs

Results and Discussions

As shown in Table 2, the compressive strength of control, perlite, and rubber mortars were summarized with a curing time of 7, 14, and 28 days. All strengths was satisfying the ASTM C 270 for

mortar specifications (5.4 MPa; ASTM, 2014). For control mortar, 80% of the strength was gained in the first 7 days with 25.52 MPa and increased slightly to 26.93 and 32.83 MPa, for 14 and 28 days, respectively.

As shown in Figure 3, the strength of perlite was lower than the control by 48%, 55%, and 62% for 5%, 10%, and 15% perlite mortar, respectively, for 7 days curing. The strength reduced sharply on the seventh day because hydration was not completed due to the presence of perlite. Then, the strength was gained gradually until day 28 with an increment of about 50%. The reduction with perlite content of 10% was about 27% and 7.5%, as compared to 5% and 15%, respectively.

Figure 4 shows the strengths of rubber mortar with rubber contents of 5%, 10%, and 15% at curing days of 7, 14, and 28. The strength was obviously dropped with increasing rubber content with 21%, 41%, and 63% for 5%, 10%, and 15% rubber content, as compared to the control mortar (after 28 days). Furthermore, the reduction was 26% and 36% for 10% and 15% rubber content, as compared to 5%, for day 28, while 5% rubber reduced the strength by 21% relatively to the control mortar.

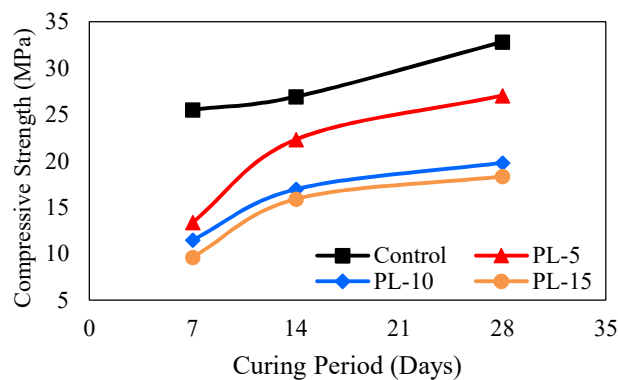


Figure 3: Compressive strength for perlite mortar

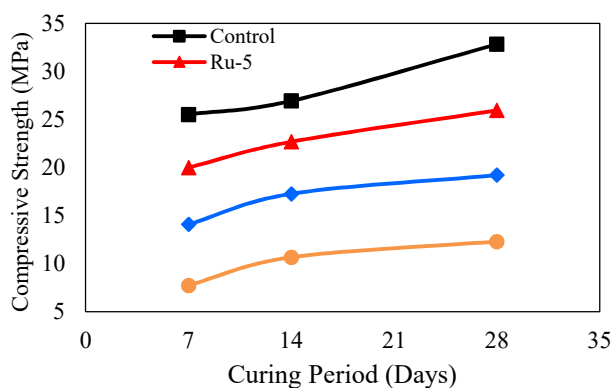


Figure 4: Compressive strength for rubber mortar

Figure 5 shows comparisons between perlite and rubber mortars with the contents of 5%, 10%, and 15%. For 5% and 10%, the difference was very slight on day 14 and 28, while on the seventh day, the strength of rubber was higher with 20–30% compared to perlite due to the delaying of hydration. For 15% of perlite and rubber, the strength for rubber mortar was reduced greatly (30–40%) for curing days of 14 and 28. On day 7, the perlite was higher than rubber by 20% due to the presence of a high quantity of rubber.

The results of thermal conductivity (k-value) for perlite and rubber mortars were summarized in Table 3 for the contents of 5%, 10%, and 15%. The k-values were reduced with increasing the content of rubber and perlite, while perlite achieved higher thermal resistivity, as shown in

Figure 6. The maximum reductions were 50% and 30% for perlite and rubber, respectively, for the content of 15%. The thermal conductivity of perlite reduced when increasing the content by 20% per each extra 5% of perlite.

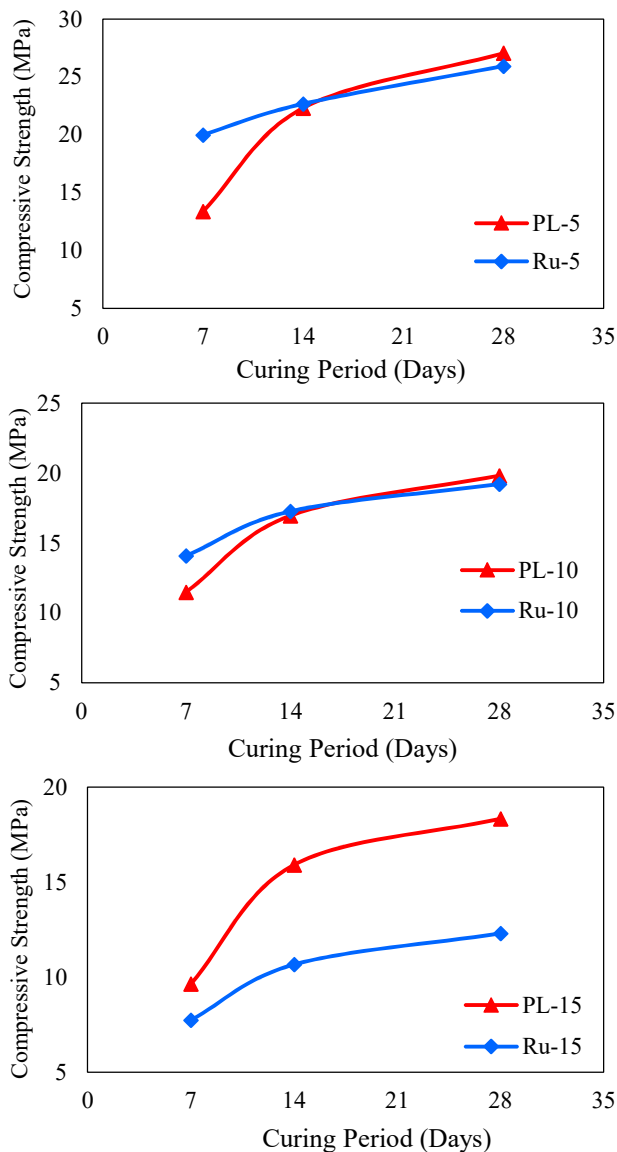


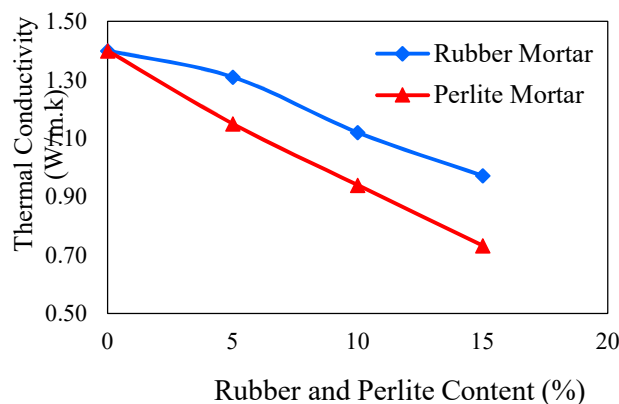
Figure 5: Comparisons between compressive strength for perlite and rubber mortar

On the other hand, the values for rubber mortar depicted a reduction of 15% for adding each 5% of rubber excluding the first 5%, which achieved half the reduction.

Table 3

Thermal conductivity of perlite and rubber mortars

Content	Thermal Conductivity (W/m.k)	
	Perlite	Rubber
0	1.40	1.40
5	1.15	1.31
10	0.94	1.12
15	0.73	0.97

**Figure 6:** Thermal conductivity for perlite and rubber mortars

The wet and dry densities were summarized in Table 4 with the absorption for perlite and rubber mortars. The wet density was in the range of 1.94 to 2.28 gm/cm³, while the dry density was 1.70 to 2.15 gm/cm³. For perlite mortar, the dry densities were reduced with increasing perlite content by about 12% for 5% perlite and 21% for both 10% and 15%, as compared to the control mortar (Figure 7).

The dry density for rubber mortar reduced slightly for 5% and 10% of rubber content relatively to the control mortar, while the content of 15% reduced the density by 15% due to the little segregation with high content of rubber particles (i.e. high content of air gaps), as shown in Figure 7. The dry density of perlite was much lower than rubber mortar with a maximum reduction of 19% for the content of 10% (Figure 7). For 15% perlite, the dry density was almost the same

with 10% perlite, which was ascribed to minimizing the air gaps with increasing the perlite content (i.e. increase the rate of hydration).

The absorption of control mortar was 6.19%, which increased sharply for perlite mortar by 42%, 58%, and 55%, for 5%, 10%, and 15% perlite content, respectively, as illustrated in Figure 7. Since the absorption of sand was higher than rubber (rubber absorption = zero), the absorption of 5% rubber mortar was reduced by 5%, as compared to the control mortar. Although the amount of sand was higher in 5% rubber mortar, the absorption was slightly lower (2%) than 10% rubber mortar, in which air gaps take place. Similarly, 15% rubber mortar has a much higher absorption than 5% rubber mortar by about 28%. The increment tends to the air gaps, which increase when increasing the rubber content, due to gathering rubber particles.

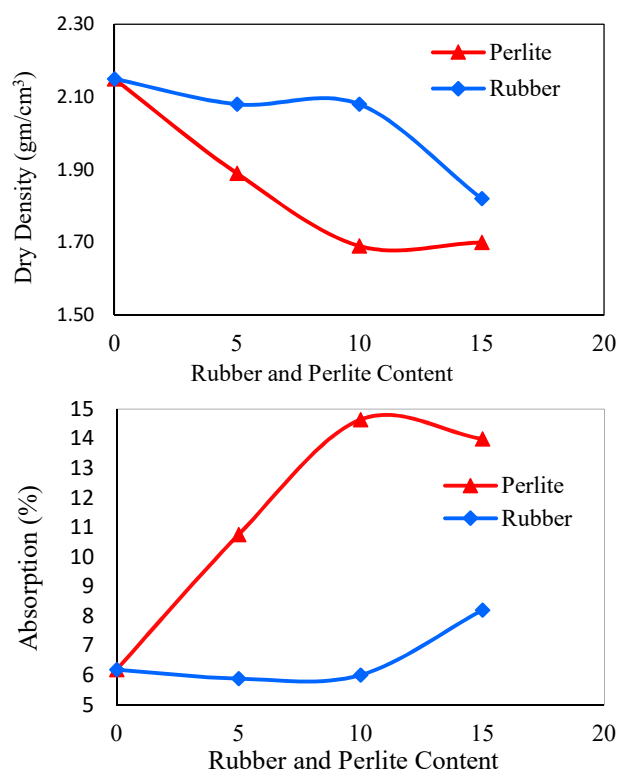
**Figure 7:** Dry density and absorption of perlite and rubber mortars

Table 4

Absorption for wet and dry densities of perlite and rubber mortars

Content Mortar	0 Control	5 Perlite	Rubber	10 Perlite	Rubber	15 Perlite	Rubber
Wet Density (gm/cm ³)	2.28	2.09	2.21	1.94	2.2	1.94	1.97
Dry Density (gm/cm ³)	2.15	1.89	2.08	1.69	2.08	1.7	1.82
Absorption (%)	6.19	10.75	5.89	14.64	6.01	13.99	8.2

Conclusions

Perlite and rubber were used to produce insulation mortar experimentally with three dosages (5%, 10%, and 15% by weight). Compressive strength, thermal conductivity, densities, and absorption were measured in the lab. Based on this experimental investigation, the following conclusions could be drawn:

- (1) The strength of perlite and rubber mortar dropped with maximum values of 44% and 63%, respectively, for the content of 15% after day 28.
- (2) The maximum reductions of thermal conductivity were 50% and 30% for perlite and rubber, respectively, for the content of 15%.
- (3) The dry density for rubber mortar reduced slightly for 5% and 10% of rubber content relatively to the control mortar, while the content of 15% reduced the density by 15% due to the little segregation with high content of rubber particles.

- (4) The dry density of perlite was much lower than rubber mortar with a maximum reduction of 19% for the content of 10%.
- (5) The absorption of control mortar was 6.19%, which increased sharply for perlite mortar by 42%, 58%, and 55%, for 5%, 10%, and 15% perlite content, respectively.
- (6) The absorption of rubber mortar was reduced by 5% (for 5% rubber) because the absorption of rubber was zero and the particles were distributed homogeneously (no particle segregation).
- (7) For 10% and 15% rubber content, the absorption was increased by 2% and 28%, respectively, as compared to 5% rubber mortar. The increment tends to the air gaps, which increase when increasing the rubber content, due to gathering rubber particles.

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