International Journal of Nanoelectronics and Materials
IJNeaM
ISSN 198-5761 | E-ISSN 2232-1535

Performance of Autoclaved Aerated Concrete (AAC) Containing Recycled Ceramic and Gypsum Waste as Partial Replacement for Sand

Efil Yusrianto[a,b], Noraini Marsi[b,c]*, Izzati Abdul Manaf[b], Hafizuddin Hakim Shariff[d]

[a]*Universitas Islam Negeri Imam Bonjol Padang, Jl. Prof. Mahmud Yunus Lubuk Lintah, Padang, 25153 Sumatera Barat, Indonesia*
[b]*Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia, Pagoh Campus, KM 1, Jln Panchor, 86400 Pagoh, Malaysia*
[c]*Advanced Manufacturing and Material Centre (AMMC), Institute of Integrated Engineering, UTHM, Parit Raja, 86400, Malaysia*
[d]*Kim Hoe Thye Industries Sdn. Bhd.,No.99, Lot 143, Jalan Air Manis, Bukit Mor, 84150 Parit Jawa, Johor, Muar, Malaysia*
∗Corresponding author. Tel.: +60178925540; e-mail: mnoraini@uthm.edu.my

Received 18 January 2024, Revised 20 February 2024, Accepted 1 April 2024

ABSTRACT

Today, municipal solid waste (MSW), noise pollution and fire attack are three ongoing issues for inhabitants of urban including in Malaysia. To solve these issues, an eco-friendly autoclaved aerated concrete (AAC) containing recycled ceramic and gypsum waste (CGW) as partial replacement for sand with different ratios (0%, 5%, 10%, 15%, 20% and 25% wt) have been prepared. The work density (ρ_w) and mechanical properties of samples such as compressive strength (f_c) and specific strength (S) have been investigated. The functional properties of samples such as sound absorption coefficient (SAC) and direct fire resistance also have been carried out. All samples showed normal color behavior i.e. grey and free crack with a ρ_w was in the range of 593.71 kg/m^3 to 605.29 kg/m^3. The f_c increased in the range of 6.10% to 29.88%. The maximum value of f_c was 2.13 MPa for 15% wt of CGW. The SAC of samples at low frequency (500 Hz) is higher than reference sample (RS). All AAC-CCW samples are categorized as material class B and C absorbers at frequency 500 Hz. Except for RS, the fire resistance results showed the physical surface of the samples had free crack and not burned during direct fire at 950°C for 300 s. The results showed that CGW have positive effect on the mechanical and functional properties of AAC.

Keywords: *Mechanical-Functional Properties, Autoclaved Aerated Concrete (AAC), Recycled Ceramic-Gypsum Waste*

1. INTRODUCTION

The municipal solid waste (MSW), noise pollution and fire-attack become three of today's biggest concerns in big cities. Similar to MSW, noise pollution and fire attacks are also negative effects of normal population growth and development. For instance, around 10,233 cases of fire-attack in Malaysia during 2018-2020 [1]. The fire-attack is mostly considered as an accidental action that caused a lot of losses including building collapse and fatalities. The fire resistance of material is a critical performance factor in any building today besides sound insulation materials.

Based on literature review, autoclaved aerated concrete (AAC) is a suitable material to solve all of these problems. AAC is not only a member of the lightweight concrete family but also a green building material [2], non-combustible material [3], and a good sound insulation material [4]. The main materials of AAC are fly ash or quartz sand as primary siliceous materials, cement and lime as primary calcareous materials, gypsum as the admixture material and aluminum powder is used as a foaming agent or aerating agent [5].

According to reference [6], the MSW with high silica content is the most efficient way to enhance the mechanical and physical properties of AAC.

Ceramic waste is one type of MSW and has also been recognized as pozzolanic materials due to a high content of silica [7]. The ceramic production in Malaysia was increasing each year at a constant rate of 2.3% and almost 30% of total ceramic production goes as waste in landfills [8]. Although the gypsum materials are not categorized as pozzolanic materials, they have good properties such as lightweight, excellent moldability, fire resistance, and sound absorption [9]. In addition, gypsum as an additive material is often used to improve physical and mechanical of AAC but the composition is not more than 3% [10]. According to Schreiner et al. [11], a proper content of gypsum (2-5% wt) could facilitate the crystallization of the CSH-phases into tobermorite as major phase of AAC which has linear correlation with strength of AAC [12].

Owing to the good properties of ceramic and gypsum waste (CGW) as well as abundance of landfills in Malaysia, it is very interesting to study the mechanical and functional properties of AAC containing recycled CGW as partial replacement for sand. The main objective of this work was to investigate the performance of AAC containing recycled CGW such as work density (ρ_w), compressive strength (f_c), specific strength (S), sound absorption coefficient (SAC) and direct fire resistance.

2. MATERIAL AND METHODS

2.1. Preparation of Raw Materials

In this study, the sand and Portland cement used for preparing AAC samples were purchased from Pekan Pagoh, Johor. The lime and aluminum powder used for preparing AAC samples were purchased from chemical industry, Malaysia. Water from laboratory of Kim Hoe Thye Industries, Johor, Malaysia was used to make AAC slurry (pre-preparation).

The CGW as partial replacement for sand was obtained from Prudent Deals Sdn Bhd 18 Lorong SS 1/11A, Petaling Jaya, 47301, Petaling Jaya, Selangor, Malaysia. The CGW has been grinded by using Ball Mill Machine and sieved manually to get the ceramic waste powder (CWP) and gypsum waste powder (GWP) particle size of approximately 0.5-1mm.

2.2. Preparation of AAC based on CGW

Raw material of each sample has been weighed according to the mixture proportion of Table 1. The GWP is setting at minimum content (2% wt) and CWP ranges from 3% to 23% wt of sand. The error of powder material and water has been controlled within ±0.1g and aluminum (Al) powder was controlled within ±0.01g. For instance E-25R, the amount of sand (45%), ceramic waste (23%), gypsum waste (2%) and 0.58% of water (W/R) have been mixed by using Allefix's 2100W Electric Mixer together for 10 minutes. Then, the amount of cement (18%) and lime (12%) were added and stirred for 5 minutes. Finally, some Al pastes (0.1%) were added whilst stirred for 30 seconds. The mixed slurry has been poured into a 2/3 box mold and shaken slowly until the air bubbles rise to the top. The reaction took around 30 minutes to expand the mixed slurry into the full mold (Figure 1). This step has been repeated for samples with codes RS to D. The slurry has been cut at the cutting line and cured under hydrothermal condition for 12 hours at 200 °C by using saturated steam at a pressure of 12 bars, utilizing an Autoclave Machine for AAC blocks at the laboratory of Kim Hoe Thye Industries.

Table 1 AAC mixes with different ratios of CGW as partial replacement for sand

Sample No.	Siliceous (%)			Calcareous (%)		Al (%)	W/R (%)
	Sand	CWP	GWP	Lime	Cement		
RS-0	70	0	0	18	12	0.1	0.58
A-05R	65	3	2	18	12	0.1	0.58
B-10R	60	8	2	18	12	0.1	0.58
C-15R	55	13	2	18	12	0.1	0.58
D-20R	50	18	2	18	12	0.1	0.58
E-25R	45	23	2	18	12	0.1	0.58

Figure 1 The slurry of raw materials in the box mold

2.3. Work Density and Mechanical Testing

The sample has been cut into size 100 x 100 x 10 mm for mechanical and direct fire testing (Figure 2). The work density of the AAC samples has been weighed by using electrical balance AND GF-6100 at Concrete Lab UTHM Pagoh. The values of work density were calculated [13]. Formula for work density (ρ_w) was defined as equation (1).

$$\rho_w = \frac{M(\text{kg})}{V(\text{m}^3)} \quad (1)$$

where M is the weight of the AAC-CGW sample and V is the AAC-CGW sample volume.

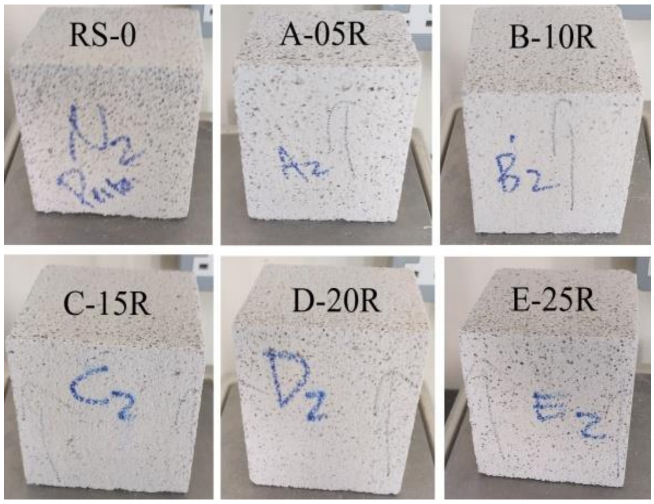

Figure 2 The specimen's dimension for mechanical and direct fire testing

The compressive strength (f_c) of all samples has been carried out by using compressive strength test (ASTM D695) machine with Universal Testing Machine (UTM) brand, Model No: VEW 2308, UTHM, Pagoh. The specific strength of AAC samples has been calculated to obtain compressive comparison among samples at different working densities [14]. Formula for specific strength (S) was defined as equation (2).

$$S = \frac{f_c(\text{MPa})}{\rho_w(kg)} \quad (2)$$

where f_c is compressive strength of AAC sample and ρ_w is work density of AAC sample.

2.4. Sound Absorption Coefficient (SAC) Testing

The SAC has been carried out by using Impedance Tube Model No: AED1000 according to ASTM E1050 at low frequency. The specimen's dimensions of sound absorption were a radius of 100 mm and a thickness of 100 mm. The specimen's dimensions of sound absorption at low frequency in the range of 100 Hz to 500 Hz are shown in Figure 3.

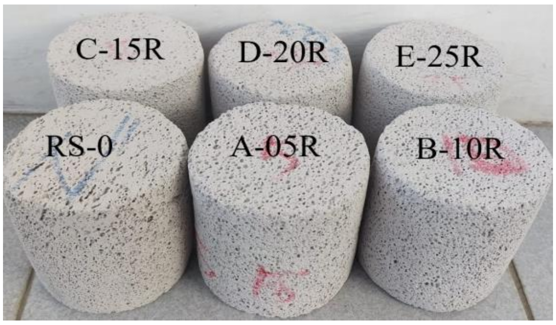

Figure 3 The specimen's dimension of SAC at low frequency

2.5. Direct Fire Resistance Testing

Figure 4 shows the fire tool used in direct fire test. The specimen size of sample was 100 x 100 x 100 mm. All samples were exposed to a direct flame at 950°C for 300 seconds. The samples were visually observed during exposure to the open flame and changes were recorded. The direct fire test of sample was carried out to meet the requirements of United Kingdom fire standards i.e. BS-7974, 2019.

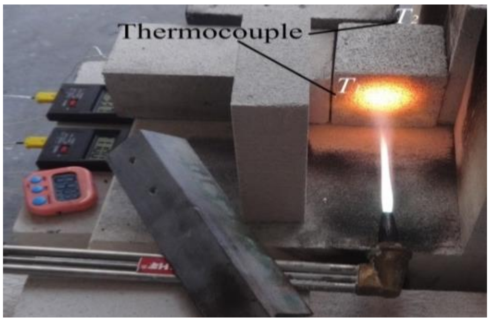

Figure 4 The fire tool used in the direct fire testing

3. RESULTS AND DISCUSSION

3.1. Work Density and Mechanical Performance

All samples showed a normal color behavior i.e. grey. The physical surface of the samples was free of cracks which can be seen by naked eye. Table 2 shows the ρ_w, f_c and S of pure AAC and AAC-CGW. The ρ_w of the sample increased with the increasing of CGW ratios. The ρ_w of the sample hardly increased around 1.06% at 25% wt of CGW. The maximum ρ_w was 1.95% at 15% wt replacement of natural sand when compared to the reference sample (RS). All of work densities of the samples were higher than RS. According to reference [15], the pozzolanic material reduced the porosity and width of the interfacial zone in a way that increased the density. The ρ_w, f_c and S of pure AAC and AAC-CGW are presented in Figure 5.

The results showed that replacing the natural sand with CGW did not significantly change the ρ_w of the samples and the effect was almost negligible. This may be due to the fineness of natural sand and CGW, as well as the ρ_w of these materials was almost similar. Similar results have been reported [16] which studied the ρ_w of AAC based on AAC waste as a partial replacement for sand.

Table 2 The ρ_w, f_c *and* S of pure AAC and AAC-CGW

Samples	ρ_w (kg/m^3)	f_c (MPa)	S (N.m/kg)	Enhance of f_c (%)
RS-0	593.71	1.64	2757.24	-
A-05R	597.35	1.92	3210.85	17.07
B-10R	601.33	2.04	3404.38	24.39
C-15R	605.29	2.13	3514.02	29.88
D-20R	603.49	1.96	3207.59	19.51
E-25R	600.06	1.74	2813.25	6.10

The f_c increased with the increment of CGW ratio for not more than 15% wt. Based on the results, after replacing sand with 5, 10 and 15% wt of CGW, the f_c increased to 17.07, 24.39 and 29.88%, respectively. The results showed that the CGW was more effective in enhancing the f_c of AAC compared to previous studies [17,18] which used gypsum as an addictive material around of 2.352% to 3% wt. Furthermore, ceramic waste together with gypsum waste are more effective in enhancing the compressive strength of AAC compared to strength of aerated concrete based on ceramic waste with fiber addition [19].

The increment of f_c may be due to the pozzolanic effect of ceramic waste which has a higher percentage of silica and alumina. According to reference [20], a higher percentage of silica, alumina and calcium oxide is responsible for pozzolanic reactivity and cementitious property. In addition, the pozzolanic material can improve the long-term strength of Poland cement binder through a pozzolanic reaction with $Ca(OH)_2$ remaining from cement hydration [21]. The positive effect of CGW on the f_c of AAC grade-6 has also been investigated [22].

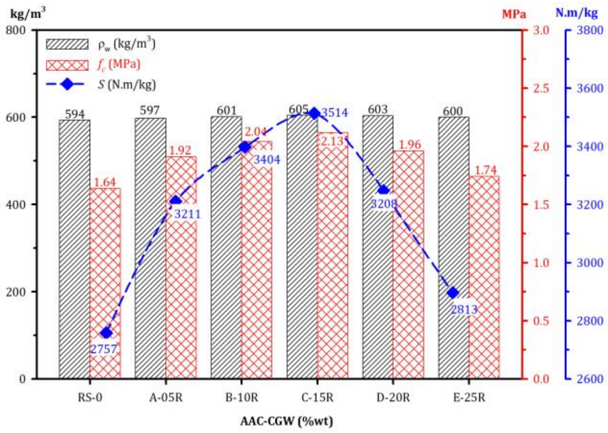

Figure 5 The ρ_w, f_c and S of pure AAC and AAC-CGW

Gypsum waste was suspected to play a role in increasing the f_c of the sample because the gypsum could transform into anhydrite during the autoclaving process to improve physical properties and water resistance. The positive effect of gypsum waste on the f_c of concrete has also been investigated [23]. According to reference [24], the gypsum with main chemical calcium sulfate was suspected to play an important role in cement production and did not only affect on the setting but also on the strength and expansion of concrete.

By increasing the CGW ratio from 20% to 25% of sand weight, the f_c is slowly reduced to 1.96 MPa and 1.74 MPa, but the value is still higher than RS, around 19.51% and 6.10%. The derivation of f_c can be explained by the quantity of calcium hydroxide formed after cement hydration has an insufficient reaction with the high volume of silica from CWP and some silica stayed without reaction [25]. At the same time, the density was also reduced.

The amount of S has also increased from 2757.2 N.m/kg to 3514.0 N.m/kg for CGW from 0% to 15% wt and has generally decreased linearly by increasing the ratio of CGW from 20% to 30% wt. It could be seen the correlation between S with f_c and ρ_w. The value of S of AAC samples increases as the f_c's increment and decreases as the f_c's decrease. The correlation between S with f_c and ρ_w was also studied [26]. The maximum value of S was 3514.0 N.m/kg for 15% wt of CGW. This work showed that CGW has a significant influence on the S performance of AAC.

3.2. SAC Analysis

Figure 6 shows the SAC of AAC-CGW. The SAC has been carried out at low frequency (75-500 Hz). The SAC was around 0.13 to 0.89 at frequency range of 100 Hz to 500 Hz. The SAC was increasing from 0.84 to 0.89 for 5% to 15% wt of CGW. The increment of SAC may be due to the effect of CGW as gypsum and ceramic wastes are porous structural materials [27]. The porous structure of gypsum and ceramics is thought to play an active role in the formation of AAC closed pores which reduces the open pores.

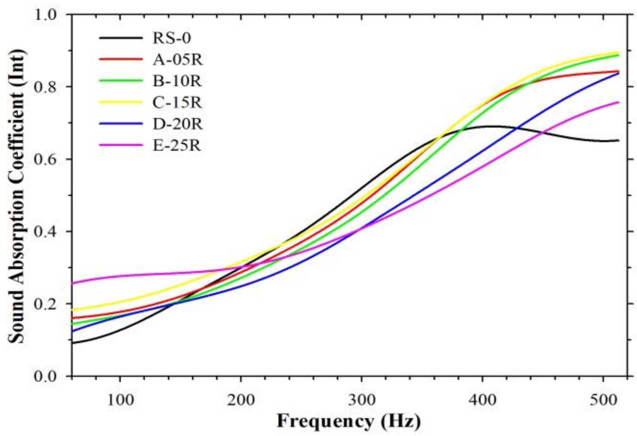

Figure 6 The SAC of AAC-CGW

By increasing the CGW ratio from 20% to 25% of sand weight, the *SAC* is slowly reduced to 0.82 and 0.75, but the value is still higher than RS. This may be some silica stayed without reaction which CGW did not function effectively. Due to the silica remaining unreacted, which is attributed to the high silica content in CGW, the structure of AAC does not become solid. When the structure of AAC was not solid, it means that the connected pore of the sample was more than the closed pore, resulting in a gradual reduction of SAC. The closed pore of the sample has a linear correlation not only with the compressive strength of AAC but also with functional properties of AAC such as SAC and fire resistance. Although, the SAC is slowly reduced, its value is still higher than the RS at a frequency of 500 Hz.

Table 3 The SAC performance of fresh AAC-CGW

Frequency (Hz)	SAC of AAC					
	RS-0	A-05R	B-10R	C-15R	D-20R	E-25R
100	0.13	0.18	0.17	0.21	0.16	0.28
125	0.17	0.20	0.19	0.23	0.19	0.28
160	0.23	0.23	0.22	0.26	0.21	0.29
200	0.30	0.29	0.27	0.32	0.25	0.30
250	0.40	0.37	0.35	0.39	0.32	0.34
315	0.56	0.52	0.49	0.53	0.44	0.43
400	0.69	0.75	0.73	0.75	0.62	0.58
500	0.65	0.84	0.88	0.89	0.82	0.75
Absorber class	**C**	**B**	**B**	**B**	**B**	**C**

Meanwhile, AAC samples with CGW content of 5 to 20% wt were categorized as class B absorbers at frequency 500 Hz. However, AAC with CGW content of 25%, the samples were categorized as a class C absorber at frequency 500 Hz. According to BS EN ISO 11654:1997, a class C absorber refers to a material that absorbs more than 60% of sound while a class B absorber is able to absorb between 80% – 85% of the sound [28]. The results show that SAC did not decrease with increasing of ρ_w and f_c.

3.3. Direct Fire Resistance Analysis

Figure 7 shows the effect of direct fire on the performance of fresh AAC based on CGW as partial replacement for sand. The samples were exposed to a direct fire at temperature more than 950°C for 300s.

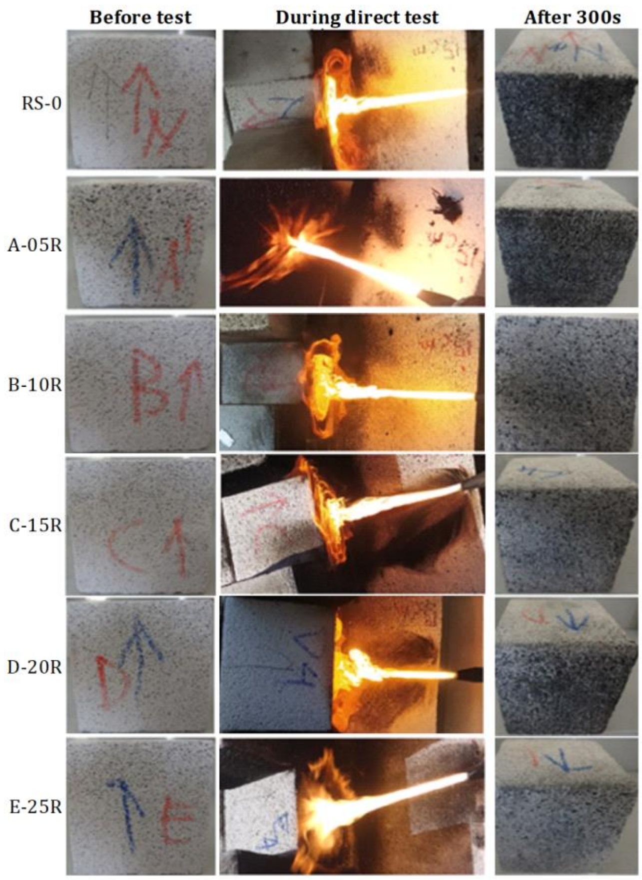

Figure 7 Direct fire resistance performance of AAC-CGW

The samples were visually observed during flame exposure, before and after recording. All samples showed abnormal color behavior such as black. Black color may be due to the fire temperature below 1000 °C. A similar condition has also been reported [29]. Although the samples were exposed to a direct fire at 950 °C for 300 s with the average temperature during process was 952.8 °C, the physical surface of the samples has a free crack and did not burn except for RS. This may be due to the effect of CGW on the performance of AAC. According to reference [30], the ceramic is the most incombustible material with failure temperature is around 700 °C to 1200 °C. The sample was not only crack-free but also cooled down quickly to temperature for T_1. The effect of ρ_w and f_c on direct fire resistance of AAC can not be observed by using surface analysis method. The result only shows that the AAC based on CGW did not melt after exposed to direct fire at temperature for more than 950 °C for 300 s.

Furthermore, Figure 8 shows the temperature surface (T_1) of AAC-CGW during the direct fire process. The results show the graph of temperature before, during and after direct fire testing. The average temperature before and during direct fire was 30.1 °C and 952.8 °C, respectively. The T_1 is almost the same in every minute. After the removal of the flame, the cooling temperature of sample was quickly reduced to 158.4 °C after 900 s.

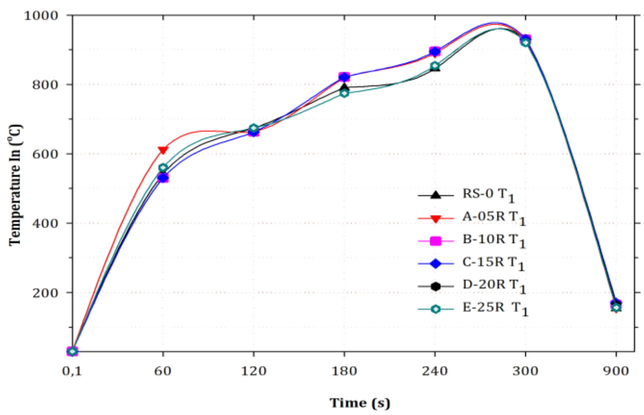

Figure 8 The temperature surface (T1)

Figure 9 shows the opposite temperature (T_2) of AAC-CGW (100 mm far from exposed surface). Although the samples were exposed to a direct flame at high temperature for more than 950 °C (T_1) for 300 s but the average temperature of T_2 were still in 30.5 °C and almost similar to room temperature of workshop. The average thermal diffusion of sample decreased with increasing of CGW ratio. Thermal diffusion of AAC sample was decreasing from 0.6 °C to 0.3 °C which the CGW ratio increased from 5% to 15% wt. Although the effect of CGW is insignificant on the thermal diffusion, the results show that CGW is successful in maintaining T_2 in room temperature during the direct fire process. This may be due to the positive effect of CGW on the performance of AAC which could reduce open pores of sample. According to reference [31], the closed pores are also suspected to play a key role in fire resistance performance of AAC. Meanwhile, the positive effects of ceramic as insulation for improving energy efficiency and flame retardancy of buildings have been reported [32]. For further study, the effect of the ρ_w and f_c on the direct fire resistance performance of AAC is still in progress.

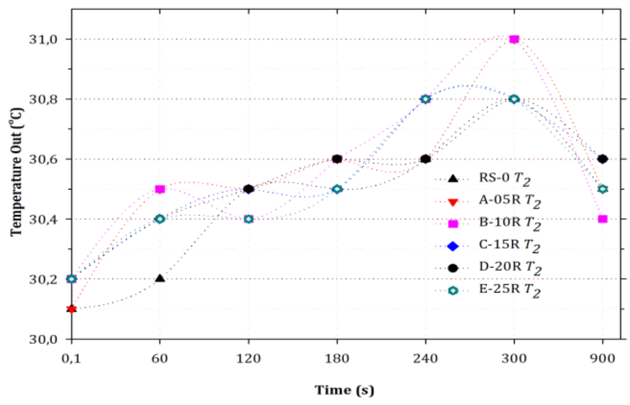

Figure 9 The opposite temperature (T_2)

4. CONCLUSION

Eco-friendly AAC containing recycled ceramic and gypsum waste (CGW) as partial replacement for sand with different ratios (0%, 5%, 10%, 15%, 20% and 25% wt) has been successfully prepared and investigated. All samples showed normal color behavior and free crack. The CGW succeeded in enhancing the f_c of AAC samples in the range of 6.10% to 29.88% and higher than previous studies. All AAC-CCW samples were categorized as class B and C absorbers at frequency 500 Hz. Except for RS, the fire resistance results showed the physical surface of the samples had free crack and not burnt during the direct fire at 950 °C for 300 s. The results showed that CGW has e a positive effect on the mechanical and functional properties of AAC.

ACKNOWLEDGMENTS

This research was supported by Ministry of Higher Education (MOHE) through Fundamental Research Grant Scheme (FRGS/1/2021/STG08/UTHM/03/1). We also want to thank to the Government of Malaysia which provide MyBrain15 program for sponsoring this work under the self-funded grant and L00022 from Ministry of Science, Technology and Innovation (MOSTI). The authors are also acknowledges the FRGS grant vot. K397 and UTHM staff and Kim Hoe Thye Industries Sdn. Bhd for the equipment and technical assistance brought to the project.

REFERENCES

[1] W. N. Wan Jusoh, A. F. Tharima, W. Ghani, M. N. H. Lukman, S. Visvasathan, M. H. Shamsudin, M. N. Z. Zuhudi, and M. N. Nur, "Initial assessment of fire response time between different categories of fire stations in Malaysia," *Fire*, vol. 6, no. 6, 2023.

[2] S. O. Rathi and P. V. Khandve, "AAC Block-A New Eco-friendly Material for Construction," *Int. J. Adv. Eng. Res. Dev.*, vol. 2, pp. 410-414, 2022.

[3] A. Bonakdar, F. Babbitt, and B. Mobasher, "Physical and mechanical characterization of Fiber-Reinforced

Aerated Concrete (FRAC)," *Cement Concrete Compos.*, vol. 38, pp. 8-91, 2013.
[4] A. Laukaitis and B. Fiks, "Acoustical properties of aerated autoclaved concrete," *Appl. Acoust.*, vol. 67, pp. 284-296, 2006.
[5] F. Seddighi, G. Pachideh, and S. B. Salimbahrami, "A study of mechanical and microstructure properties of autoclaved aerated concrete containing nano-graphene," *J. Build. Eng.*, vol. 43, 103106, 2021.
[6] G. Pachideh and M. Gholhaki, "Effect of pozzolanic materials on mechanical properties and water absorption of autoclaved aerated concrete," *J. Build. Eng.*, vol. 26, 100856, 2019.
[7] M. C. S. Nepomuceno, L. F. A. Bernardo, L. A. P. de-Oliveira, and R. O. Timoteo, "Cement-based grouts for masonry consolidation with high content of limestone filler, metakaolin, glass powder, and ceramic waste," *Constr. Build. Mater.*, vol. 206, 124947, 2021.
[8] M. Samadi, G. F. Huseien, M. H. Hosseini, H. S. Lee, N. H. A. S. Lim, M. M. Tahir, and R. Alyousef, "Waste ceramic as low-cost and eco-friendly materials in the production of sustainable mortars," *J. Cleaner Prod.*, vol. 266, 121825, 2020.
[9] F. Iucolano, A. Campanile, D. Caputo, and D. Liguori, "Sustainable management of autoclaved aerated concrete wastes in gypsum composites," *Sustainability*, vol. 13, 3961, 2021.
[10] L. Zhou, B. Ma, H. Zhou, J. Zang, J. Wang, B. Qian, Y. Luo, X. Ren, Y. Xiao, and Y. Hu, "Effect of Ca/Si ratio on the properties of steel slag and deactivated ZSM-5 autoclaved aerated concrete," *J. Indian Chem. Soc.*, vol. 100, 100853, 2023.
[11] J. Schreiner, D. Jansen, D. Ectors, F. Goetz-Neunhoeffer, J. Neubauer, and S. Volkmann, "New analytical possibilities for monitoring the phase development during the production of autoclaved aerated concrete," *Cement Concrete Res.*, vol. 107, pp. 247-252, 2018.
[12] Y. Peng, Y. Liu, B. Zhan, and G. Xu, "Preparation of autoclaved aerated concrete by using graphite tailings as an alternative silica source," *Constr. Build. Mater.*, vol. 267, 121792, 2021.
[13] T. He, R. Xu, Y. Da, R. Yang, C. Chen, and Y. Liu, "Experimental study of high-performance autoclaved aerated concrete produced with recycled wood fiber and rubber powder," *J. Cleaner Prod.*, vol. 234, pp. 559-567, 2019.
[14] L. Cai, T. Tang, M. Liu, and D. Xie, "Comparative study of carbide slag autoclaved aerated concrete (AAC) manufactured under thermal oven and microwave pre-curing process: foaming course, rough body strength, and physic-mechanical properties," *Constr. Build. Mater.*,
[15] T. Ali, A. Saand, D. K. Bangwar, A. S. Buller, and Z. Ahmed, "Mechanical and durability properties of aerated concrete incorporating rice husk ash (RHA) as partial replacement of cement," *Crystals*, vol. 11, 604, 2021.
[16] N. N. Lam, "Recycling of AAC waste in the manufacture of autoclaved aerated concrete in Vietnam," *Int. J. GEOMATE*, vol. 20, issue 78, pp. 128-134, 2021.
[17] A. R. Rafiza, A. Fazlizan, A. Thongtha, N. Asim, and M. S. Noorashikin, "The physical and mechanical properties of autoclaved aerated concrete (AAC) with recycled AAC as a partial replacement for sand," *Buildings*, vol. 12, 60, 2022.
[18] J. Zhang, F. Huang, Y. Wu, T. Fu, B. Huang, W. Liu, and R. Qiu, "Mechanical properties and interface improvement of bamboo cellulose nanofibers reinforced autoclaved aerated concrete," *Cement Concrete Compos.*, vol. 134, 104760, 2022.
[19] A. J. Hamad, R. J. A. Sldozian, and Z. A. Mikhaleva, "Effect of ceramic waste powder as partial fine aggregate replacement on properties of fiber-reinforced aerated concrete," *Eng. Rep.*, vol. 2, e12134, 2020.
[20] L. Li, W. Liu, Q. You, M. Chen, and Q. Zeng, "Waste ceramic powder as a pozzolanic supplementary filler of cement for developing sustainable building materials," *J. Cleaner Prod.*, vol. 259, 120853, 2020.
[21] H. Song, J. Yu, J. E. Oh, and J. I. Suh, "Production of lightweight cementless binders using supplementary cementitious materials to replace autoclaved aerated concrete blocks," *J. Cleaner Prod.*, vol. 384, 135397, 2023.
[22] E. Yusrianto, N. Marsi, I. A. Manaf, H. H. Shariff, and N. Kassim, "Effects of compressive strength and Young modulus of gypsum-ceramic waste on autoclaved aerated concrete (GCW-AAC)," *AIP Conf. Proc.*, vol. 2995, 020001, pp. 1-7, 2023.
[23] I. A. Manaf, N. Marsi, H. H. Shariff, and N. Kassim, "Influence of recycled glass ceramic waste on physical and mechanical properties of foamed concrete," *Int. J. Integrated Eng.*, vol. 14, pp. 55-66, 2022.
[24] G. Gyabaah, S. Miyazawa, and N. Nito, "Effects of gypsum and limestone powder on fresh properties and compressive strength of concrete containing ground granulated blast furnace slag under different curing temperatures," *Construction Mater.*, vol. 2, pp. 114-126, 2022.
[25] H. T. Le and H. M. Ludwig, "Effect of rice husk ash and other mineral admixtures on properties of self-compacting high-performance concrete," *Materials Design*, vol. 89, pp. 166-166, 2016.
[26] G. Chen, F. Li, P. Jing, J. Geng, and Z. Si, "Effect of pore structure on thermal conductivity and mechanical properties of autoclaved aerated concrete," *Materials*, vol. 14, 339, 2021.
[27] S. Hansen and P. Sadeghian, "Recycled gypsum powder from waste drywalls combined with fly ash for partial cement replacement in concrete," *J. Cleaner Prod.*, vol. 274, 122785, 2020.
[28] British Standard (BS) EN ISO 11654, "Acoustics - Sound absorbers for use in buildings - Rating of sound absorption," 2007.
[29] C. Aciu, D. A. I. Varvara, D. L. Manea, Y. Orban, and F. Babota, "Recycling of plastic waste materials in the composition of ecological mortars," *Procedia Manufacturing*, vol. 22, pp. 274-279, 2018.
[30] F. Lugaresi, P. Kotsovinos, P. Lenk, and G. Rein, "Review of the mechanical failure of non-combustible facade systems in fire," *Construction and Building Materials*, vol. 361, 129506, 2022.

[31] N. Narayanan and K. Ramamurthy, “Structure and Properties of Aerated Concrete: a Review,” *Cement & Concrete Composites*, vol. 22, pp. 321-329, 2000.

[32] S. Wi, S. Yang, U. Berardi, and S. Kim, “Assessment of recycled ceramic-based inorganic insulation for improving energy efficiency and flame retardancy of buildings,” *Environment International*, vol. 130, 104900, 2019.