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Alternative Bricks Filled with Crumb Rubber for Thermal and Acoustic Performance

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Abstract

Brick is commonly material used in low and medium cost development and other commercial construction due to its strength, inexpensive cost, insulating ability, and mechanical longevity. This Study use of rubber's benefits, which include its low heat conductivity, and ability to absorb sound. Objective in this studt was to analyze the mechanical, acoustic, and thermal properties of the alternate brick, select the optimum proportion and compare the altenative brick with previos study. The sample crumb rubber sand brick were create using dry mix and applying vibro-compacted. Several test was conduct which density test was taked at 7 and 28 days, water absorption using 24 hours submurged, compressive strength using universal test machine, acoustic using impendence tube and thermal conductivity using thermal conductivity of building Materials Apparatus. Altenative brick densitiy test results show a very significant decerease which 30% replacement the density at 7 day is 935.29 kg/m^3 and at 28 day is 876.68 kg/m^3 follow by compressive strenght at 7 day 0.45 MPa and at 28 day 0.74 MPa . However, the results of the water absorption test indicate that the brick with rubber 30% replacement have increasing water absorption capacity which 18.86% compare to control. Meanwhile, sound absorption show at low frequency 30% repacement sound absorption cooficient is 0.68 and thermal conductivity test show 30% replacement K value is 0.06 W/m˚c. Sugested to maintain the physical properties which requiered strength for non-load bearing, the crumb rubber used to place sand shall not axceed 10%. From the results show that, filled crumb rubber in making sand brick have better performance in thermal conductivity.

1. Introduction

Sand cement bricks are widely used in a variety of commercial buildings and low- and medium-cost residential constructions. It is easy and affordable to make cement and sand brick. The cost of making sand cement bricks from natural resources was a worry, especially in developing nations where producers find it difficult to obtain sufficient amounts of natural aggregate [1]. Sand is used as an aggregate, cement is used as a binder, and water is used to create brick, a common building material that solidifies into a mass substance that resembles stone, but it has environmental issues which is causing high energy consumption and carbon dioxide emission [2].

In other hand, production to make bricks the excessive use of soil material has caused a large consumption of raw resources and high energy consumption. In addition, natural rubber is produced for use in the production of making tires in large numbers. This industry is increasing every year and impact to used many tires and discard [3]. Discard tires which create a problem to environment management. In this context, found that tires tend to be recycle instead of on fire or through in a landfill because they are serious threat to the global ecosystem. In a two decade recently, government around the world encourage the recovery and recycle of tires [4]. Modern housing buildings became more dependent on artificial means to provide comfortable thermal environment with high energy consumption. Cement sand brick show poor thermal comfort performance and artificial cooling systems are therefore used to achieve required thermal comfort. Air conditioners were used by locals to regulate the indoor temperature and humidity [4].

Prefabricated building materials like masonry bricks and hollow blocks frequently contain crumb rubber. However, a number of investigations have demonstrated a decrease in the compressive strength of bricks containing crumb rubber [1–4]. decreasing strength due to improper cement, sand, and crumb rubber bonding since crumb rubber does not stick to cement due to its smooth surface [6]. There exists a market for non-load bearing brick products with medium to low strength requirements, despite the poor mechanical qualities of crumb rubber brick. When compared to traditional units, these goods also exhibit better qualities in terms of acoustic and thermal insulation [5-8]. In order to reduce ambient noise and utilize renewable waste, sound absorbers and barriers are frequently utilized. A sturdy composite material that has the ability to both absorb and reflect sound is crumb rubber brick. Furthermore, since it lowers the yearly energy consumption for building maintenance, the use of ribbed masonry components in vertical walls is a great energy-saving technique [9].

The use of brick construction materials has been continuously developed based on research conducted from the past to the present. It is important to note, however, that not much research has been done on the brick that is utilized in Malaysia. Based on the previously mentioned, this study's primary goal was to analyze the mechanical, acoustic, and thermal properties of the alternate brick. In order to partially replace the sand in the mixture, crumb rubber was added. This score highlights the building's innovative mechanical and physical qualities, as well as its superior sound absorption and heat resistance. The findings of this study may allow for the use of lightweight, standard-grade medium-strength wall materials with good flexibility, low heat conductivity, and sound absorption in construction. Brick properties will be developed for future construction thanks to these benefits.

2. Methodology

2.1 Materials

Ordinary Portland Cement (OPC) from local manufacturer is used as a binder in the mixture of brick. The cement grade is 52.5N and OPC specification of MS EN 197-1:2014. River sand was used as the fine aggregate to produce cement sand brick and sieve analysis in accordance with BS812: 103 was carried out to identify the grading of the fine aggregate. Only aggregate that retained range between sieve 1 to 4.75mm was used shown in Fig 1(a). Tire waste was manufactured obtained from local factory and used as replacement of sand in the brick and the crumb rubber particle size range 1mm-3mm as shown in Fig 1(b). This study, water-cement ratio used is 0.50.

(a) (b)

Fig. 1: (a) River Sand, (b) Crumb Rubber

2.2 Mix proportion and method

The mix design involves developing sand bricks incorporating crumb rubber as a partial replacement for sand. The primary materials used include Ordinary Portland Cement (OPC) with a grade of 52.5N, river sand with a particle size range of 0.5-2mm, crumb rubber with a particle size of 1-3mm, and tap water with a fixed water-cement ratio of 0.5. The cement-to-sand ratio follows 1:3 as per IS 4031-Part 6. Crumb rubber replaces sand in varying proportions of 0%, 10%, 15%, 20%, 25%, and 30%, ensuring a comprehensive analysis of its impact on brick properties.

The mixing method follows a dry mixing approach, beginning with the preparation and weighing of materials. Table 1 shows the mix proportion consisting of six trial mixes at five of crumb rubber replacement (10%, 15%, 20%, 25%, and 30%) The sand and crumb rubber are first spread evenly and mixed before adding cement shown in Fig 2(a). Initially, one-fourth of the water is added and mixed, followed by the gradual addition of the remaining water to achieve a uniform consistency shown in Fig 2(b). Once mixed as in Fig 2(c), the material is placed into molds of 210mm x 100mm x 65mm and 300mm x 300mm sizes, with a thin layer of oil applied beforehand to ease demolding. The bricks are then compacted using vibro-compaction to enhance density and strength. After molding, the bricks are left to dry for 24 hours before being removed from the mold. They undergo a curing process for 7 and 28 days before being subjected to various tests. This methodology ensures consistency in the production process, facilitating a reliable evaluation of the thermal, acoustic, physical, and mechanical properties of crumb rubber sand bricks. Fig 3 demonstrates the alternative sand brick with various percentage containing crumb rubber (CR).

***Table 1*: Mix proportion**

Specimens (%)	Cement (kg)	Sand (kg)	Crumb rubber (kg)	Water (kg)
0	2	6	0	1
10	2	5.4	0.6	1
15	2	7.65	0.9	1
20	2	4.8	1.2	1
25	2	4.5	1.5	1
30	2	4.2	1.8	1

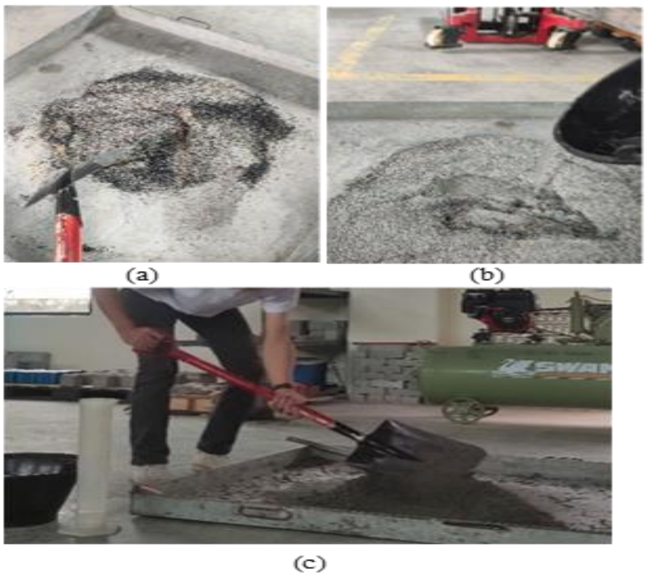


Fig. 2: (a) Initial Dry mix, (b) Water added, (c) Manually mixed

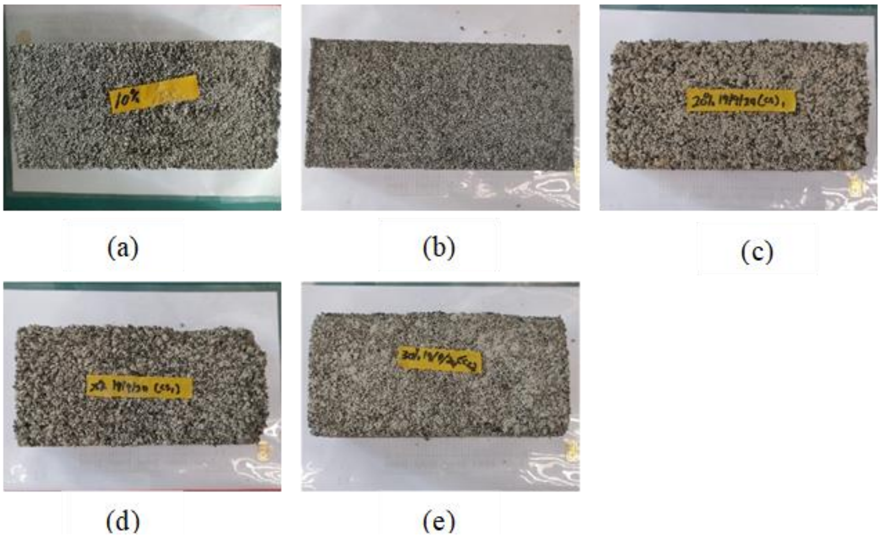


Fig. 3: (a) 10% CR, (b) 15% CR, (c) 20% CR, (d) 25% CR, (e) 30% CR

2.3 Testing Procedure

The compressive strength and density were tested using Universal Testing Machine (Model: VEW 2302) with brick size 210mm x 100mm x 65mm made from laboratory Universiti Tun Hussein On in according with requirements of British Standard (BS 1881: Part 116). The compressive strength test was performed using compression test machine as shown in Fig 4(a). The density of the specimens is calculated at 7 and 28 days by dividing the weight with the volume of the specimens using the equation (1). The water absorption capacity of cement sand brick has measured using a 24-hour submersion test as in Fig 4(b). The sample were tested with size 100mm after curing 28 days. The water absorption % may be calculated using the equation 2.

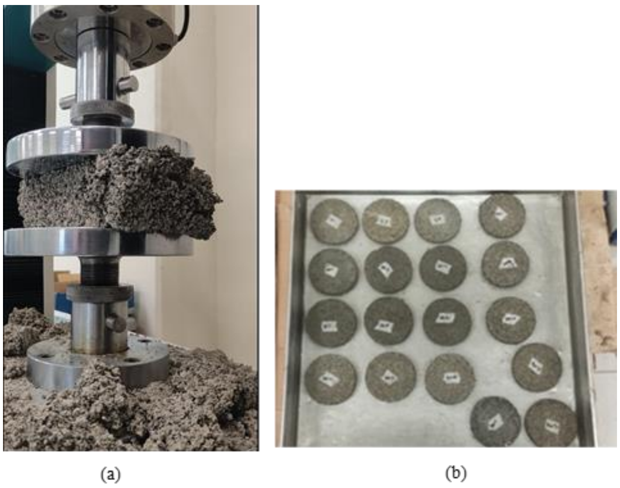
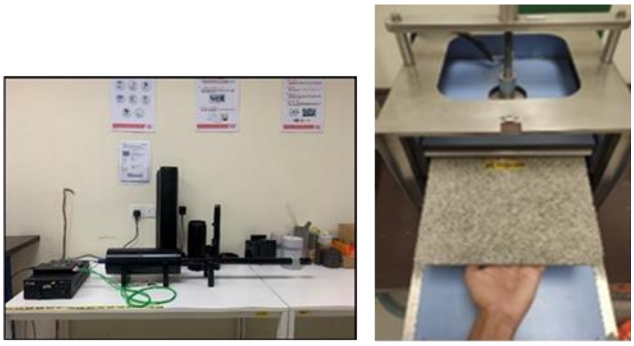


Fig. 4: (a) Compressive Strength Test, (b) Water Absorption Test

$$Density = \frac{\boldsymbol{weight\ (kg)}}{\boldsymbol{volume\ (m^3)}} \ / \ P = \frac{\boldsymbol{m}}{\boldsymbol{v}}, \boldsymbol{kg/m}^3 \quad (1)$$

$$\text{Water absorption (\%)} = \frac{\boldsymbol{W2-W1}}{\boldsymbol{W1}} \boldsymbol{x\ 100} \quad (2)$$

Acoustic properties of sand cement brick sample were characterized by Sound absorption coefficient. Sound absorption was tested following ISO10534-2 by using the impedance tube method, show in Fig 5(a). the sample were test at low frequency with size 100mm and high frequency with size 30mm. Thermal conductivity used a sample size of 300x300x10 mm for the test was conducted using Thermal Conductivity of Building Materials Apparatus (Model: HE110) in accordance with ISO 8302:1991 as in Fig 5(b).



(a) (b)

Fig. 5: (a) Acoustic Test, (b) Thermal Conductivity Test

3. Result and Discussion

3.1 Compressive Strength

Compressive strength is a mechanical property of crumb rubber sand brick at day 7 the highest is 1.92 MPa and the lowest is 0.45 MPa in the mixture of 10% and 30%. For day 28 the highest is 3.17 and the lowest is 0.74 MPa in the mixture of 10% and 30%. it was found that the compressive strength was reduced when the rubber content increased, as shown in Fig 6, which is consistent with the previous studies [1-4].

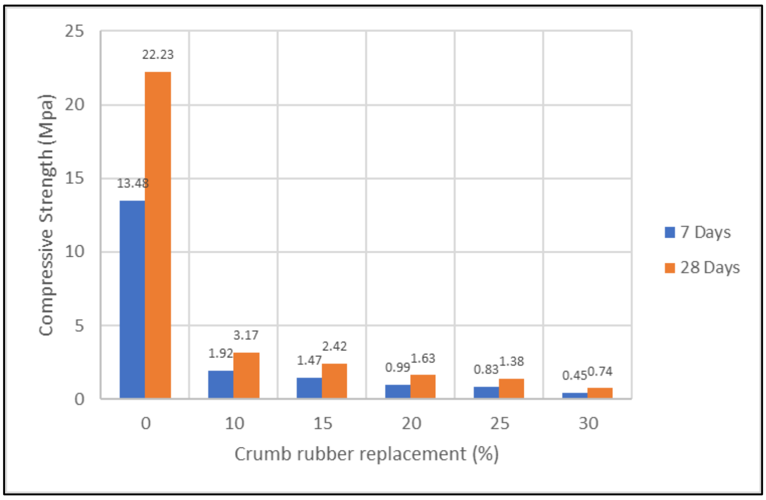


Fig. 6: Result for Compressive Strength

According to fig 5, the sand brick with crumb rubber has a lower average compressive strength than the control. When 30% of the sand is replaced, the strength decreases by 96% for 7 days and 97% for 28 days when compared to the control. Specimen 10% at day 28 is 3.17 which achieved the requirement strength for non-load bearing. Slightly decreasing strength crumb rubber contained compared with control because of the cement, sand, and crumb rubber not properly bonding due to the surface of crumb rubber itself. Crumb rubber has a smooth surface and does not adhere to cement [6] and, the rubber particles are much weaker than the surrounding matrix. Therefore, cracks formed quickly around the rubber particles in the mixture, which is an accelerated part of the deterioration of concrete [20].

3.2 Density

The density test results are displayed in Table 2. According to the ratio of blended additives, Figure 7 displays the densities of conventional sand cement bricks and sustainable bricks on days seven and twenty-eight. The findings demonstrated that on the 28 day, the density of sand cement bricks dropped.

Table 2: Result for Density at 7 days and 28 days

	Density (kg/m³)	
Specimens	Day 7	Day 28
0%	2307.69	2183.15
10%	1300.85	1247.86
15%	1225.89	1186.81
20%	1186.81	1162.39
25%	1076.92	1052.50
30%	935.29	876.68

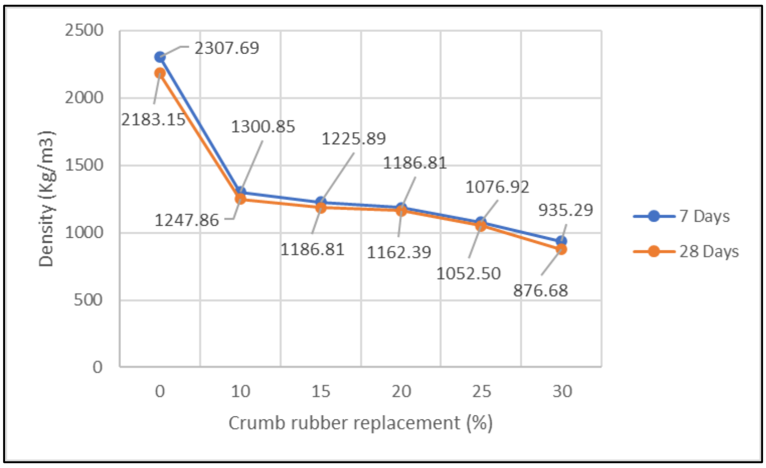


***Fig. 7*: Result of Sand Brick Density**

The density of sand brick with crumb rubber is displayed in Fig 6. According to the results, sand bricks with crumb rubber had lower average densities than control bricks when 30% of sand is substituted, the density decreases by 59% for the 7-day sample and 60% for the 28-day sample as compared to the control brick. Increasing the rubber content to replace sand will further decrease the density because the rubber material has less density than sand [11].

3.3 Water Absorption

Data was collected utilizing 24-hour submersion and after 28 days of cure. The average water absorption of sand brick with crumb rubber is displayed in Fig 8, where the water absorption characteristic of sand brick was enhanced by the presence of crumb rubber. The graph illustrates the relationship between crumb rubber replacement percentage and water absorption percentage. As the crumb rubber replacement increases from 0% to 30%, the water absorption also increases progressively. At 0% crumb rubber replacement, the water absorption is recorded at 8.31%. With a 10% replacement, the value rises to 12.71%, followed by 14.42% at 15%, 15.51% at 20%, 17.23% at 25%, and finally reaching 18.86% at 30%. This data shows a clear trend where an increase in crumb rubber replacement leads to a corresponding increase in water absorption, suggesting that higher crumb rubber content contributes to greater water permeability or retention. The observed augmentation in water absorption might perhaps be attributed to the expansion of crumb rubber, resulting in the formation of micro-cracks inside the samples [12].

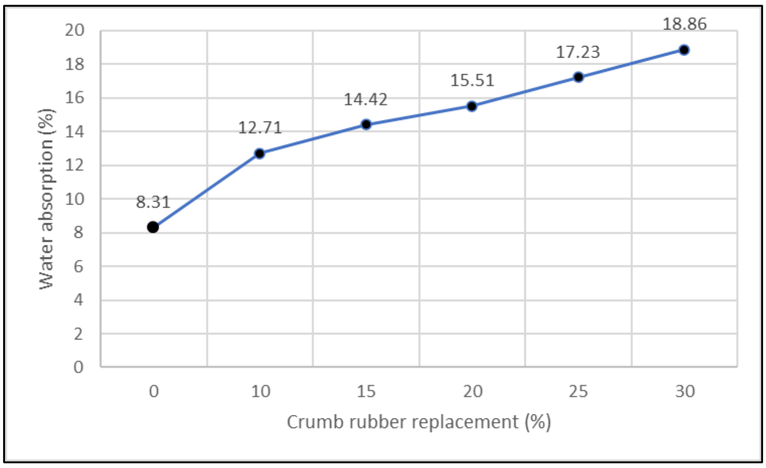


Fig. 8: Result of Water Absorption

3.4 Acoustic test

In compliance with ISO 10534-2, an experimental sound absorption test was conducted. Using an impedance tube (Model: AED1000), the sound absorption coefficient (α) was calculated. Two microphones were installed in the experimental setup to examine the crumb rubber sand brick's capacity to absorb sound.

3.4.1 Low Frequency

Sound absorption was carried out in the high-frequency band, as shown in Fig 9. A comparison of the sound absorption coefficients of the six test samples for low frequency. The graph shows the relationship between frequency (Hz) and the sound absorption coefficient for different percentages of crumb rubber replacement (0%, 10%, 15%, 20%, 25%, and 30%). The sound absorption performance varies with frequency and crumb rubber content. At lower frequencies (0–600 Hz), the absorption coefficients are generally low across all replacement levels, with peaks appearing at specific points. The 20% crumb rubber replacement achieves higher absorption coefficients in the mid-frequency range (400–700 Hz), peaking above 0.6. At higher frequencies (800–1600 Hz), the 25% and 30% replacements show superior absorption performance, with coefficients reaching close to 0.7, indicating better sound absorption. Meanwhile, the 0% and 10% replacements exhibit lower absorption values across most frequencies. The 15% replacement shows inconsistent behavior with relatively low absorption values throughout. Overall, increasing crumb rubber content improves sound absorption, especially at mid-to-high frequencies, with the 25% and 30% replacements performing best.

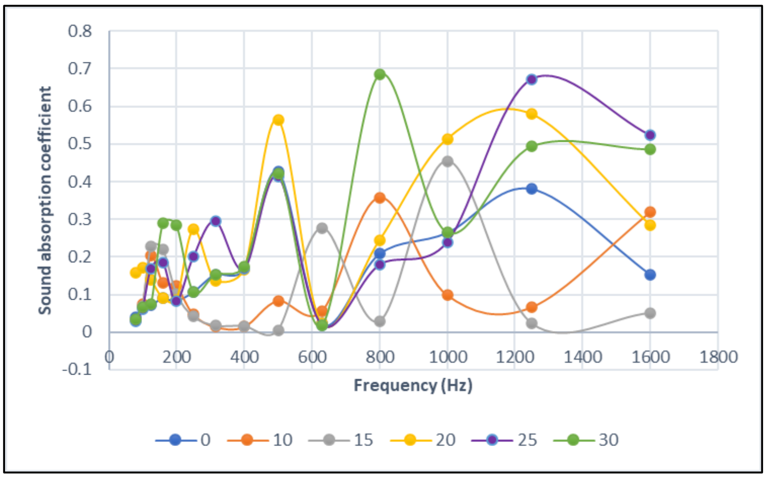


Fig. 9: Result for Sound Absorption Coefficient at Low Frequency

3.4.2 High Frequency

Sound absorption was carried out in the low-frequency band, as shown in Fig 10. A comparison of the sound absorption coefficients of the six test samples for high frequency. The graph presents the sound absorption coefficient across frequencies ranging from 0 to 6000 Hz for six different conditions or materials labeled as 0%, 10%, 15%, 20%, 25%, and 30%. At low frequencies (below 1000 Hz), materials show significant peaks in absorption, with conditions 0%, 20%, and 25% achieving coefficients above 3. However, absorption rapidly decreases for all materials beyond these peaks. In the mid-frequency range (1000–3000 Hz), absorption values generally stabilize at lower levels, showing smaller fluctuations, with condition 25% maintaining slightly higher performance. In the high-frequency range (3000–5000 Hz), some materials, such as conditions 20%, 25%, and 30%, demonstrate improved absorption with noticeable peaks, whereas others, like condition 0%, have relatively low absorption coefficients. Overall, the data reveals that materials labeled 20%, 25%, and 30% perform better across wider frequency ranges, particularly at low and high frequencies, while others like 0% and 10% have inconsistent or lower absorption efficiency. This is because the sample developed trapped air with holes as the rubber content increased. Due to these features, the sample possesses the qualities of a dissipative or porous absorber material. When sound strikes these materials, air molecules vibrate in the porous material's gaps. When the incident sound frequency is high, a significant amount of energy is lost due to the vibrations of air molecules [10].

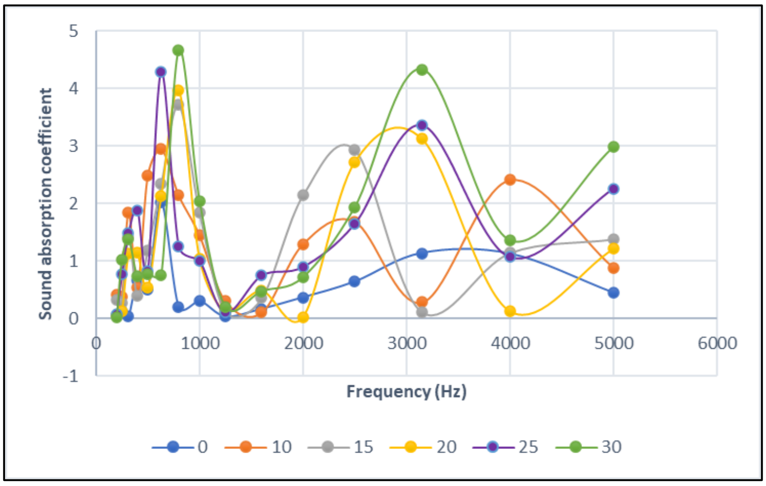


Fig. 10: Result for Sound Absorption Coefficient at High Frequency

3.5 Thermal Conductivity

Thermal conductivity is important to understand the thermal insulation of crumb rubber sand brick. Fig 11 shows the relationship between crumb rubber replacement percentage and thermal conductivity (W/m°C). As the percentage of crumb rubber replacement increases from 0% to 30%, the thermal conductivity consistently decreases. At 0% replacement, the thermal conductivity starts at 0.08 W/m°C. With increasing replacement, the values gradually decline to 0.07 W/m°C at 20%, and further to 0.06 W/m°C at 25% and 30%. This indicates that incorporating crumb rubber into the material reduces its thermal conductivity, suggesting improved insulation performance with higher percentages of crumb rubber replacement. There are several causes for the decrease in heat conductivity. In the first place, rubber has low thermal conductivity (0.16) and is thermally insulating, but sand has a higher thermal conductivity (1.5 W/mK) than rubber [6]. As a result, using rubber instead of sand lowers the sand brick's overall heat conductivity. Second, the quantity of cavitation in the concrete block increases as the rubber content rises. Compared to the control mixture, which has a thermal conductivity of 1.7 W/mK, air has a lower thermal conductivity of 0.025 W/mK [6].

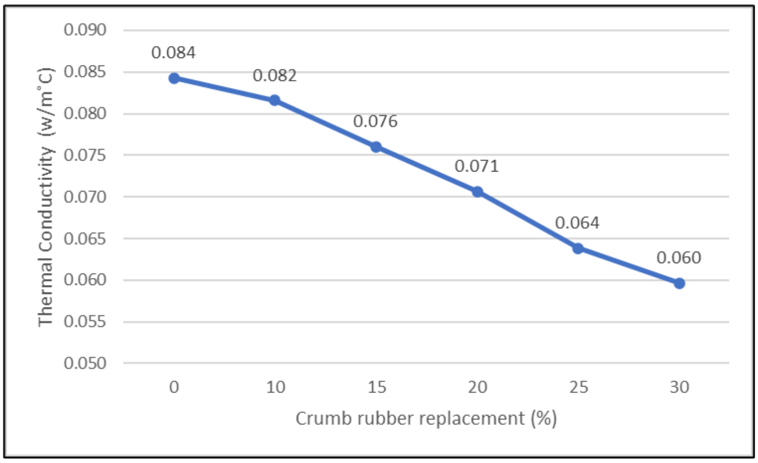


Fig. 11: Result for Thermal Conductivity

4. Conclusion

By analyzing the density, water absorption, compressive strength, acoustic, and thermal conductivity of different mixtures, this study achieved the aims to determine the ideal ratio of sand brick with additional crumb rubber which 10% containing crumb rubber has better thermal conductivity and can be applied in construction for non-load bearing. Properties of alternative sand brick has been analyses which, density is decreased during the production process when rubber is used. But in this investigation, water absorption was higher than with the control brick. There is a decrease in compressive strength. It results from the cement paste and rubber particles' poor adherence to one another. A rise in rubber content was followed by such a drop. The thermal conductivity of crumb rubber sand brick is lower than that of control brick. As the amount of rubber grows, the heat conductivity gradually drops. This is more environmentally friendly since it enables air conditioners in tropical areas to use less energy. By adding rubber to the mixture, echo noises are lessened and noise is avoided. Sand brick made of crumb rubber is appropriate for building walls, particularly external ones. Fabrics, sponges, and foams are the most absorbent materials; therefore, they are not heat or moisture resistant. As a result, it makes sense to use crumb rubber while making bricks for walls. This type of sand brick is considered to be lighter and more flexible than regular sand brick. They also have the capacity to absorb waste, significantly lower noise levels, and are resistant to heat entering high-rise buildings. The present study highlights the potential use of crumb rubber bricks for non-load-bearing structures, where high strength is not a primary requirement. It is comparable to previous studies in that it confirms that increasing the amount of crumb rubber results in a significant reduction in compressive strength due to poor bonding between the rubber particles and cement matrix. Previous studies also established that crumb rubber bricks exhibit improved thermal insulation and sound absorption properties. These results are supported by this study, which shows that the material becomes more energy-efficient for buildings as the amount of rubber increases. Furthermore, by performing a thorough examination of sound absorption across several frequency ranges, it builds on earlier research and demonstrates that bricks with a higher crumb rubber content reduce noise more effectively. This study offers a more thorough assessment of crumb rubber bricks for sustainable construction applications by focusing more on the trade-offs between strength, thermal insulation, and acoustic qualities than previous research, which was mainly concerned with mechanical performance.

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