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Mechanical Properties of Concrete Block Containing Recycled Paper Sludge (RPS) as Replacement Material

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Abstract: The use of waste and recycled materials in construction and block production is one of the current investments made by all construction industries and the issue related to the waste paper is paper pollution. The main objective of this study is to investigate mechanical properties of recycle paper sludge as replacement material of sand in the concrete block and it can be proof by the data and result obtained from density test, water absorption test, sound absorption coefficient and thermal conductivity test. The main material are cement, sand, water and paper sludge as replacement material. The percentage of RPS used in this study consist 5%,10% and 15%. The use of 5% RPS is the best effective proportion of concrete block with percentage of water absorption at 12.24%, the thermal conductivity value is 0.25 W/m°C (1.17 W/mK) (BS EN 1745) with density value at 2457.71 kg/m3 (1850 – 2100 kg/m3) (ASTM C90). With the data obtained from the tests, it can be concluded that the use of RPS in concrete block can be a good by-product material to use in construction as internal partition wall, inner and outer leaf of external cavity walls and block and beam floor infill and it is eco-friendly and sustainable.

Keywords: Concrete Block, Recycled Paper Sludge (RPS), Replacement Material

1. Introduction

Concrete blocks are a form of building material that is extensively utilised in the construction of constructions such as buildings. They are often moulded into a range of shapes and sizes to suit different building purposes and are formed from a mixture of cement, water, and aggregate, such as sand and gravel. Concrete blocks are utilised in a wide range of building projects, including residential, commercial, and industrial structures. They are well-known for their strength, durability, and fire resistance, making them an excellent choice for a variety of building applications.

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The technology of stabilised earth masonry blocks is based on the use of an activated industrial by-product (recycle paper sludge) and natural earth. The use of a by-product material in the formulation is expected to reduce the final pricing of the stabilised earth masonry building block. The additional environmental benefit of utilising industrial by-products available in the country will improve the sustainability profile of masonry block production even further. The use of a sand replacement material which is recycle paper sludge with a lower environmental burden offers opportunities for significant reductions in energy use and carbon dioxide emissions. Energy consumption and pollution are the two important environmental and cost concerns related to the block industry. [1] Three replacement ratios of cement with recycle paper sludge (5, 10 and 15% by weight) and coarse aggregate with recycled cement aggregate (RCA) (25% and 50% by volume) were considered. Results demonstrated that the highest enhancement in compressive strength compared with the reference mix (without replacement) was achieved for a mix containing 50% RCA and 5% recycle paper sludge.[2]

Paper sludge can be used in place of sand in the manufacture of concrete blocks. Paper sludge, when combined with cement and water, can aid in the creation of a concrete mix appropriate for use in the construction of buildings and other structures. Using paper sludge as a partial replacement for sand in concrete blocks has the potential to reduce the environmental effect of sand mining. Sand is a significant element in the manufacture of concrete blocks, and extracting sand from natural sources can have severe environmental consequences such as habitat loss and river contamination. The use of paper sludge as a partial substitute for sand can assist to lessen the environmental effect of sand mining. Furthermore, the substitution of paper sludge for sand lowered the cost of concrete blocks since sand is a rather expensive material in the manufacturing of concrete blocks, and utilising paper sludge as a partial replacement can assist to reduce the cost of these goods. Last but not least, concrete blocks built with paper sludge as a partial replacement for sand can be more sustainable than regular concrete blocks since they utilise a resource that would otherwise be squandered and have a lesser environmental effect. From all of these potential benefits, it clearly answered the sustainable development goal number 9,11,12 and 13 respectively.[3]

The significance of this study is to discover the optimum percentage for the ratio of common block mixture that have high workability by using the friendly replacement material like paper sludge against fine aggregates. It is due to the function of the paper sludge as a replacement to the sand can make a huge impact from the cost of production of common block as it is a waste and recycle paper sludge from the paper factory and will provided new fresh technology of waste material used in the construction industry. The main advantage from this study is that the use of recycled paper using environmentally friendly concepts will protect our environment from environmental pollution and so on and is guaranteed to benefit humans and the earth as followed in the Sustainable Development Goal. The use of recycled paper such as Recycled Paper Sludge (RPS) in the concrete block mixture is expected to be cost-effective in terms of manufacturing as well as the production of this type of block. Furthermore, the use of recycled paper sludge to replace the main material in the concrete block mixture can improve the mechanical properties such as strength of concrete block which is an idea as well as the best proposal that can be used in improving the construction industry all over the world.

2. Methodology

2.1 Material

2.1.1 Cement

The cement used for each mix in this research was Ordinary Portland Cement (OPC) and in accordance with the standards prescribed by MS 522 Part 1: 1997. The cement crystallizes in the presence of water, forming calcium silicate hydrate (CSH) and calcium hydroxide (Ca(OH)2),which has a strong crystalline bond structure. Besides, cement is a binder to components in concrete due to its bonding agent nature when wet. Figure 1 has shown the Portland cement that was used in the concrete mix.

Figure 1: Ordinary Portland Cement (OPC)

2.1.2 Sand

In this study, the sand that was used in this experiment is sand that passes as the requirement needed for concrete mix. Usually, the sand used consists of the unmilled type. This sand should be free of contaminants and in a clean condition. Figure 2 shows the sand used in concrete mixes.

Figure 2: Sand

2.1.3 Water

Water used in concrete mixes must be from a clean and approved source. In addition, the water used should be free from contaminants such as floating solids, organic matter, and so on. Therefore, in this study, tap water is used in the concrete block mix.

2.1.4 Recycle Paper Sludge (RPS)

In this experiment, recycled paper sludge (RPS) is employed to substitute sand. A total percentage of RPS that was used in this study as many as 5%,10% and 15%. The recycle paper has been collect from SWM Environment Sdn. Bhd.

Figure 3: Recycle paper from SWM Environment Sdn. Bhd

2.2 Sample Preparation

The prepared combination's design is utilised to generate samples for this experiment. Concrete block mixing is performed on both standard concrete samples and concrete samples adding varying amounts of Recycled Paper Sludge (RPS)

2.2.1 Concrete block sample

The number of concrete block sample that will be used in this project was 24 samples for 7 and 28 days as represented in Table 1. In this test, the block sample has been used in density and water absorption test and each of the block is 390 mm x 190 mm x 90 mm in size. The concrete block put in the curing tank provided by the laboratory for 7 and 28 days. The percentage of RPS that were used in this test at 0%,5%,10% and 15% to replace sand or fine aggregates in the mixture.

Table 1: Number of Concrete Block Sample for Different Percentage of RPS

Percentage of Recycle Paper Sludge (%)	**Quantity of Sample**	
	7 Days	**28 Days**
0	3	3
5	3	3
10	3	3
15	3	3
Total	24	

2.2.2 Sound absorption sample

The number of cylinder sample that will be used in this project was 8 samples as represented in Table 2. In this test, the cylinder sample has been used in sound absorption coefficient test and each of the cylinder is 90 mm x 30 mm in size. The percentage of RPS that were used in this test at 0%,5%,10% and 15% to replace sand or fine aggregates in the mixture.

Table 2: Number of Cylinder Sample for Different Percentage Of RPS

Percentage of Recycle Paper Sludge (%)	Quantity of Sample
0	2
5	2
10	2
15	2
Total	8

2.2.3 Thermal conductivity sample

The number of thermal conductivity sample in size of slab that will be used in this project was 12 samples as represented in Table 3. In this test, the slab sample has been used in thermal conductivity test and each of the slab is 300 mm x 300 mm x 30 mm in size. The percentage of RPS that were used in this test at 0%,5%,10% and 15% to replace sand or fine aggregates in the mixture.

Table 3: Number of Slab Sample for Different Percentage Of RPS

Percentage of Recycle Paper Sludge (%)	Quantity of Sample
0	3
5	3
10	3
15	3
Total	12

3. Results and Discussion

3.1 Density

According to the Figure 4, the control concrete block for 28 days has the value of density at 2582.09 kg/m^3. Meanwhile, for 5% RPS used in concrete block has increasing of value of density with 2452.74 kg/m^3 to 2457.71 kg/m3 respectively for 7 days to 28 days. Next, for 10% RPS used as replacement, the density of concrete block is increasing from 2390.55 kg/m^3 to 2479.60 kg/m^3. Last one is for 15% use of RPS in concrete block get the value which is decreasing from 2492.54 kg/m^3 to 2482.59 kg/m^3 for 7 days and 28 days respectively. The standard value for density of solid concrete block should not less than 1800 kg/m^3. This indicates that when there is an increase in the use of RPS in the block, it will result in a high percentage of water content in the block. It is due to the porous nature of RPS which induces more pores in the fresh mix. The high of use of RPS make the block lighter compared to the control block.

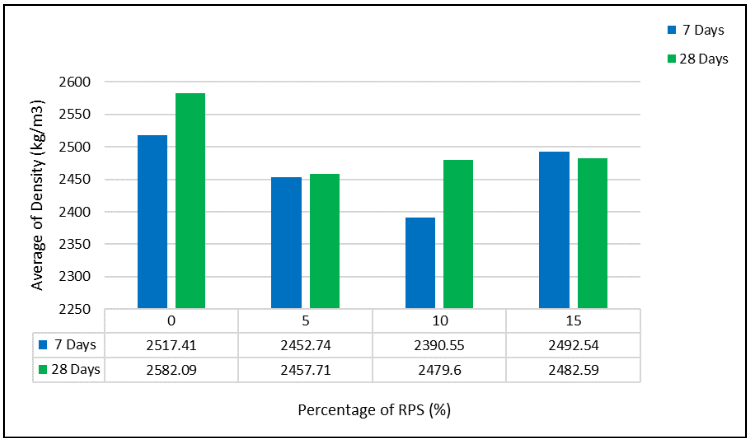

Figure 4: Density for different percentage of RPS

3.2 Water Absorption

As shown in Figure 5, the histogram graph shows that the highest value of water absorption is 12.76 % for 15% use of RPS while the lowest percentage of water absorption is 12.16% when use 5% of RPS. According to the (ASTM C90) it should not be more than 10% by average of three blocks. Based on the result obtained, it shows that 15% of RPS used in concrete block have the highest percentage of water absorption. It is due to the high RPS content and high-water content in paper sludge cause a lot of water infiltration compared to others. There is also a probability that the block has high porosity or presence of void on the surface that allow water to seep into the block. Furthermore, the nature of the paper itself that absorbs water plays a role in determining the percentage of water diffusion rate into the block.

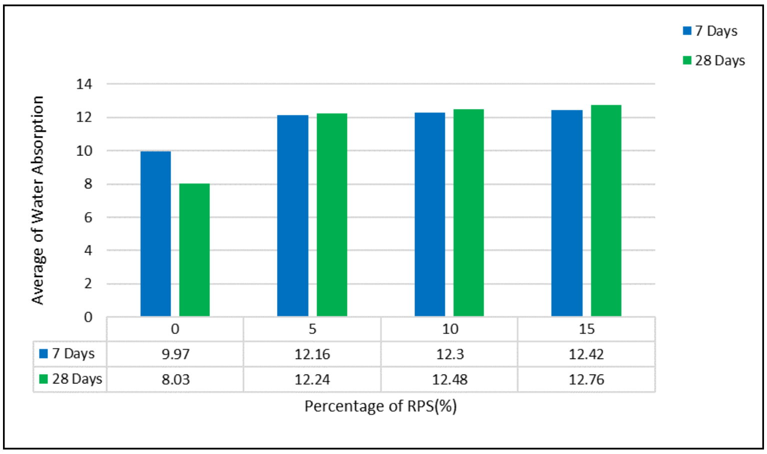

Figure 5: Water Absorption for different percentage of RPS

3.3 Thermal Conductivity

Based on Figure 6, the highest value of thermal conductivity was 5% use of RPS in concrete block with value of 0.42 W/m°C. Besides, the lowest value is when use 10% of RPS with value 0.25 W/m°C. It shows unstable value of thermal conductivity due to a few factors such as the preparation of sample, the mixture and probably the size and quantity of RPS use to replace the sand. It should have decreased value of thermal conductivity as the percentage of RPS used increased.

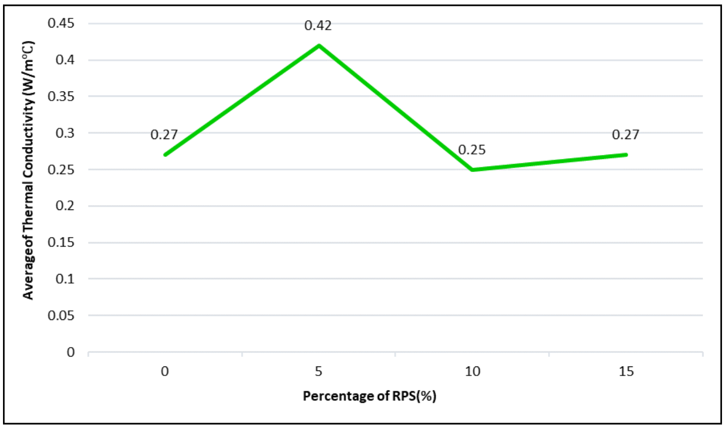

Figure 6: Thermal conductivity for different percentage of RPS

3.4 Sound absorption coefficient

From the Figure 7 showed that the sound absorption coefficient of RPS for control concrete block is at 0.01 to 0.02 with frequency range at 1000-1250 Hz. According to the ASTM E1050 the sound absorption coefficient for concrete is 0.02 while 0.98 is reflected. So, it is proof that for control concrete block it gets the exact value of the absorption. When replace the aggregate with RPS, the amount of sound that can be absorbed at range 1000 – 1250 Hz, 5% RPS get the value at 0.02. While the 10% RPS only get the value of 0.02 at 1000 Hz. The maximum value of sound absorption in this test was at 15% RPS at frequency 3150 Hz.

It is due to the RPS content was high and make the block less weight and the high of porosity in it make it absorber to the sound compared to other percentage of RPS. It's concluded that from the data that obtained in this test shows that replacing fine aggregates in concrete mixes with RPS can absorb sound effectively with low RPS content at optimum frequency which is at range 1000-1250 Hz and more RPS use, higher value of sound absorption than normal concrete block due to less of weight and porosity of the block.

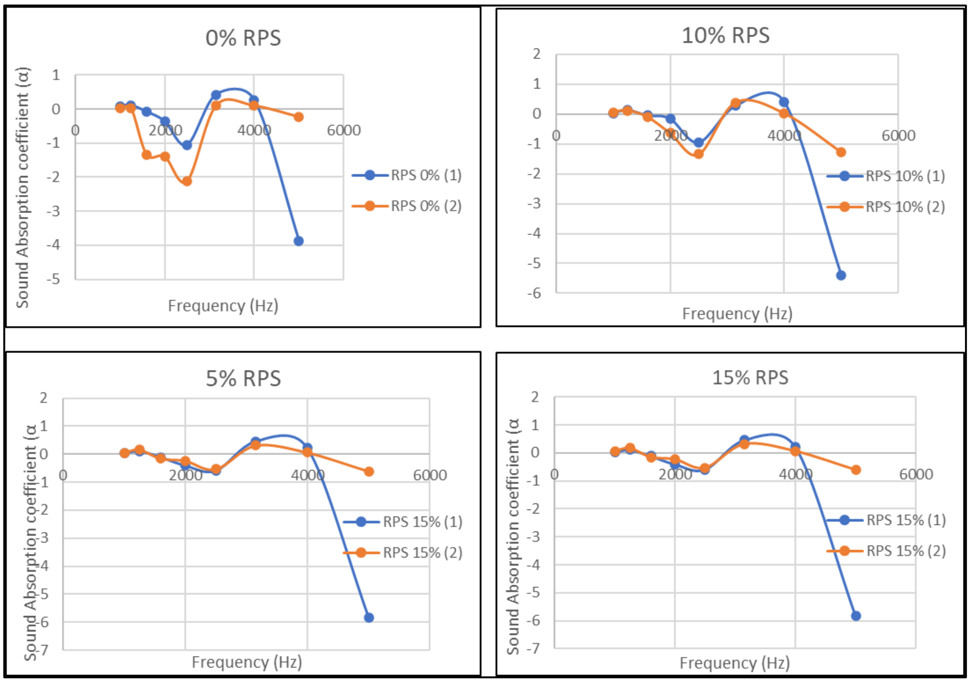

Figure 7: Sound absorption coefficient for different percentage of RPS

4. Conclusion

Overall, the range between 5% RPS is the best effective proportion of concrete block with percentage of water absorption at 12.24%, the thermal conductivity value is 0.25 W/m℃ (1.17 W/mK) (BS EN 1745) with density value at 2457.71 kg/m3 (1850 – 2100 kg/m3) (ASTM C90) and concluded in the range of solid dense concrete block. It is good to be used as internal partition wall, inner and outer leaf of external cavity walls and block and beam floor infill. This study also achieves the sustainable development goals as it can produce eco-friendly block and great innovation product to be used in construction industry in the future.

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