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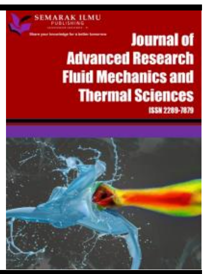

The Utilisation of Coconut Shell (Cocos Nucifera) as a Partial Aggregate Replacement on the Properties of Concrete in Terms of Thermal Behaviour

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ABSTRACT

Green environments or environmentally friendly buildings have increasingly captured the attention of researchers. This concept involves the reuse of waste materials to enhance or create new products. Accordingly, this study aims to investigate the utilization of fine coconut shell (FCS) as a partial substitute for sand, focusing on its applications with varying percentages from 10% to 100% on the properties of concrete in terms of thermal conductivity. The initial phase of the research concentrated on characterizing the properties of fine coconut shell and sand using methods such as sieve analysis, laser diffraction sieve technique, specific gravity tests, bulk density measurements, scanning electron microscopy (SEM), and water absorption tests. Subsequently, the mechanical properties of fine coconut shell in concrete, replacing sand partially, were evaluated through slump tests, compressive strength tests, flexural strength tests, modulus of elasticity tests, splitting tensile strength tests, water absorption tests, and water permeability tests. The second phase of the study focused on exploring the low thermal conductivity applications of fine coconut shell concrete, assessed through thermal conductivity tests (k-value) and thermal resistance (r-value) calculations. Upon collecting data, a relationship analysis was conducted to determine the optimal percentage of fine coconut shell replacement. Using this optimal percentage, wall panels were constructed to assess heat penetration into buildings, and the temperature data was validated using Autodesk Ecotect software. The findings indicated that fine coconut shell particles were finer (≤ 600 µm) compared to sand (4.25 mm - 150 µm). In terms of mechanical properties, concrete containing fine coconut shell as a partial replacement for fine aggregate demonstrated superior performance to normal concrete. Moreover, the thermal conductivity values of specimens containing coconut shell were lower than those of normal concrete. In conclusion, the study determined that replacing 50% of fine aggregate with fine coconut shell was optimal, meeting British Standard requirements and aligning with previous research findings.

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1. Introduction

Energy conservation is required in taking counted for the growing population and limited natural energy sources. According to Zhang *et al.,* [1] and Martínez-Molina *et al.,* [2], one third of the total energy consumption and 40% of greenhouse gas emissions are associated to building in the world. Since most of the people spend around 90% of their lives living indoors, energy conservation and thermal comfort in building had become a controversial and phenomenon topic discussed among researchers [3]. The energy required for building cooling and heating thermal comfort depend greatly on the thermophysical properties of the construction material and it is related to the conductive heat loss through walls, roof, windows and floors. Conductive heat transfer in solids is a mixture of molecular vibrations and energy transport by free electron [4]. Thermal conductivity (k-value) is a material's property that shows the heat conduction capability. The energy consumption of buildings depends in the thermal conductivity values of the building materials [5]. Commonly know that building was made by concrete and the material use inside the concrete need to be considered in order to maintain or lowered the energy consumption thus made a comfort situation to live in the building.

Concrete is one of the most widely used construction materials in the world. It is basically made from a mixture of cement, aggregates and water. One approach to enhancing the performance and quality of concrete is the use of additives as substitutes for cement or sand [6]. Recent years, there has been a growing emphasis on the utilization of waste materials and by-products in construction materials [7]. It is a part of the solutions to an environmental issue and ecological problems. Using this waste materials not only assists getting it utilized in construction material but also reduce the cost of concrete materials and also reduce the heat conductivity of a building. There are many types of waste materials from various sector in Malaysia that been used in research of improving the properties of concrete. One of the sectors that had been taken seriously in improving the properties of the concrete and solving the environmental issues in Malaysia are agricultural sector.

The agricultural sector is one of the most important sectors for a developing country like Malaysia. In fact, it is the most important feature that differentiates developing countries from developed countries. This sector is likely to have contributed to the foundation of the Malaysian economy in the post-independence era during which the majority of the population were focused on economic activities based on agriculture and mining. Due to rapid economic growth in recent years, the agricultural sector has been seen as an important sector for both continuous economic growth and improved living standards [8]. For over the last four decades, this sector had contributed to the growth and the development of the Malaysian economy.

However, the agricultural sector has also led to the production of many types of agricultural waste [9]. One of the examples of agricultural waste is coconut shells. As per the measurement reported by the Food and Agriculture Organization of the United Nations, 11,864,344 hectares of land are planted with coconut trees which produce 61,708,358 tonnes of coconut, equivalent to a yield of 5.20 tonnes per hectare [10]. Coconut is a natural resource that benefits mankind. Some of the advantages are high specific strength and modulus, low density, renewability, biodegradability and absence of health hazards [11]. The coconut fruit itself contains 3 layers called the exocarp, the mesocarp and the endocarp [12]. Figure 1 shows the cross section of the coconut fruit.

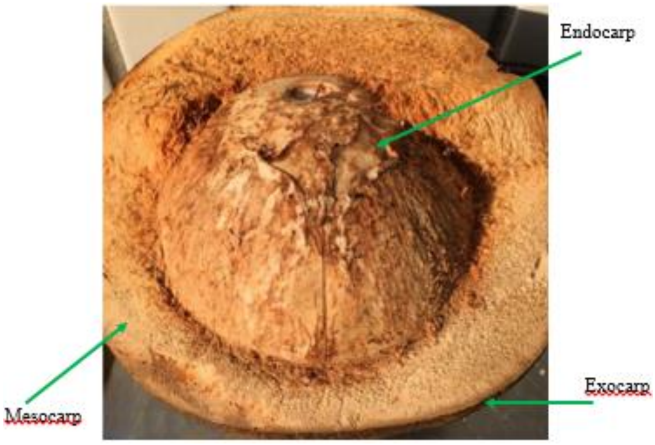

Fig. 1. The cross section of coconut fruit [10]

The endocarp, also known as the coconut shell, is discarded as waste after being scraped out [13]. Coconut shells are mainly used as ornaments, household utensils, and a source of active carbon [14]. Apart from the uses mentioned, most of the coconut shells are left to decompose on the fields [15]. Thus, this becomes an environmental issue. Therefore, the usage of coconut shells as a raw material in the industrial sector can help reduce pollution and transform waste into a valuable resource.

Recently, research on coconut shells has been extensively conducted for specific applications such as concrete material [16]. By adding coconut shells to concrete, environmental advantages such as less dependence on non-renewable energy or materials, lower pollution and reduced greenhouse emissions can be obtained [17]. Over the years, many researchers have used coconut shells as a partial or full replacement for coarse aggregates [18]. All the properties for the coarse aggregate replacement show promising results and it has been claimed to be a suitable material to be used in concrete [9].

However, there are limited research studies on the use of coconut shell as a partial replacement of fine aggregate and lowering the temperature of living house. Therefore, this study will mainly focus on fine coconut shell as a fine aggregate replacement. Coconut shells need to be ground into a fine powder so that it is similar or finer in size before it is used as a partial replacement. This is due to the contribution to the small area of the interface between the sand and cement matrix [19]. The smaller the interface, the stronger the concrete becomes. Apart from that, the structure of coconut shell itself that has pores and void had made it is suitable to decrease the ability of heat conductivity.

2. Methodology

A standard physical property testing for materials that include fine coconut shell and fine aggregate such as sieve analysis, scanning electron microscopy (SEM), specific gravity, fineness modulus and bulk density were conducted. The next phase of testing is for concrete properties that consist of slump test, compressive strength test, flexural strength test, modulus of elasticity test, splitting tensile test, water absorption test and water permeability test. The concrete was cast for gred 30 with a target mean strength for normal concrete is 43.12 MPa. By maintaining the concrete gred and its mixture, the coconut shell was used as a partial replacement of sand ranging from 10% to 100%. After identifying the concrete properties, the testing of thermal conductivity test and R-value calculation were conducted to identify the heat that penetrate the concrete. Next a series of relationship were done to determine the most optimum percentage of fine coconut shell that can be utilized and used in real monitoring situation. After determining the optimum percentage, a field work that include constructing a wall panel as in Figure 2 and validation using Ecotect software were conducted.

Fig. 2. Model house with a wall panel of normal and fine coconut shell concrete use in this study

3. Results

3.1 Material Properties

The material properties of fine coconut shell (FCS) and fine aggregate were simplified and conclude as in Table 1.

Table 1
Materials properties of fine aggregate and fine coconut shell

Properties	Fine Aggregate	Fine Coconut Shell
Figure		
Colour	White to light brown	Light brown to darker brown
Fineness Modulus	2.3	0.5
Bulk Density	1508.15 Kg/m^3	474.07 Kg/m^3
Specific Gravity	2.65	1.43
Water Absorption	5%	25.0%
Sieve Analysis	In the range of upper and lower limit	Less than 600 μm
SEM	Smooth surface	Rough surface

3.2 Mechanical Properties of Concrete

The mechanical properties of concrete containing fine coconut shell as a partial replacement of sand and normal concrete are discussed. These mechanical properties include slump test, density test, compressive strength test, splitting tensile strength test, flexural strength test, modulus of elasticity test, water absorption test, water penetration test and water permeability.

3.2.1 Workability (slump test)

A slump test determines the workability of a concrete mix. In this research, the slump test was used to determine the workability of concrete containing fine coconut shell and normal concrete. Higher workability results in a higher slump value. As mentioned in BS EN 12350-2:2009, (2009), true slump ranges between 75 mm ±25 mm or a range between 50 mm to 100 mm. Figure 3 shows the graph of slump test conducted.

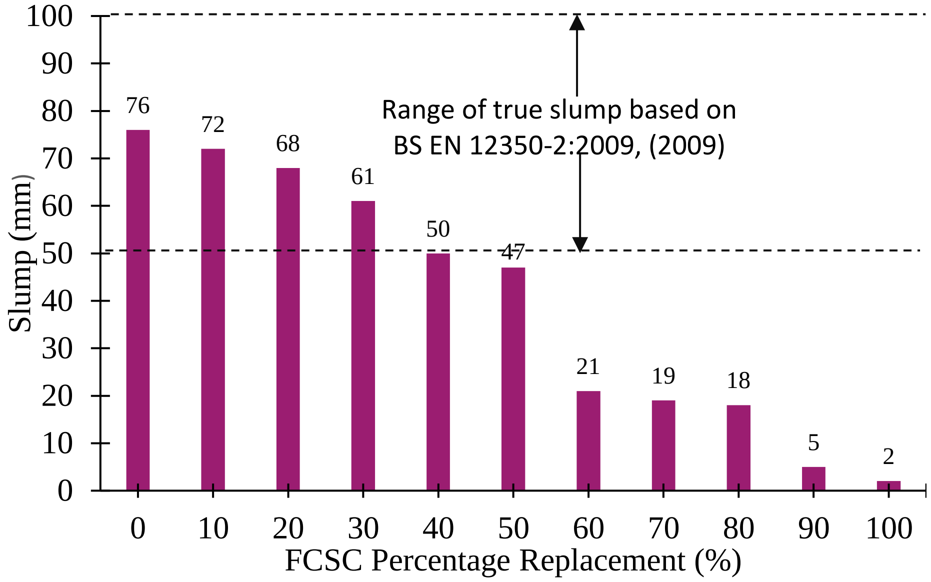

Fig. 3. Workability results

It can be concluded that, the higher the replacement of coconut shell, the lower the slump value. Factor like high water absorption of material, water cement ratio and the texture of material had affected the workability of concrete. However, other properties may have a better value than normal concrete.

3.2.2 Density of concrete

There are different opinions on the density of concrete. In the Engineering Handbook written by Dorf and Richard, normal concrete density is 2400 kg/m^3. Meanwhile, the Brooklyn Public Library Files 1999 stated that normal concrete density is 2300 kg/m^3. However, many researchers agree that normal concrete density lies in the range of 2300 – 2400 kg/m^3 [20]. Therefore, the aim of this study is to achieve normal concrete density using FCS concrete. Figure 4 shows the graph plotted for the density of concrete.

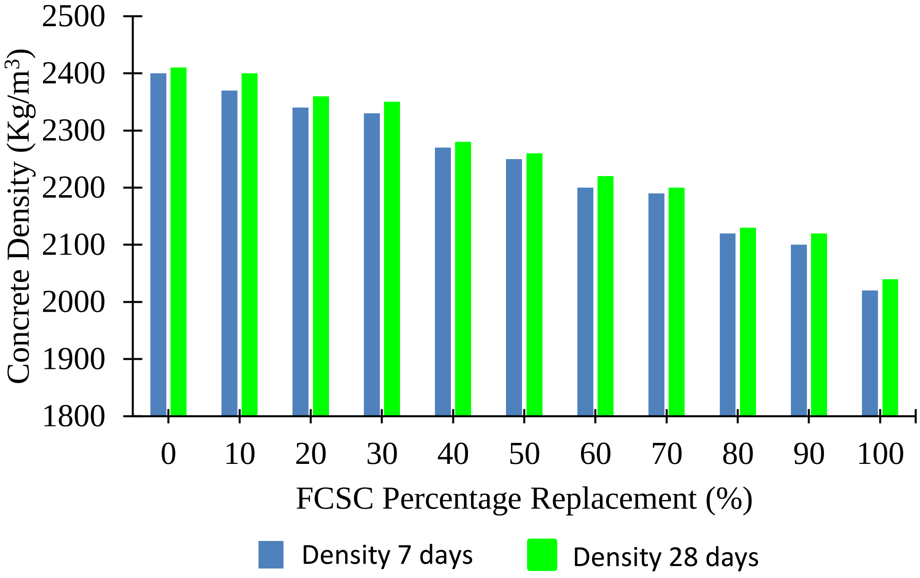

Fig. 4. Density results

The low density of the concrete with a higher replacement of coconut shell gives a lot of benefit to the construction industry. It is easier to handle and transport since less worker needed to handle the concrete. Furthermore, it is considered as lightweight concrete according to the standard and can save a lot of cost. Therefore, fine coconut shell can give a lot of advantages to the society and industries.

3.2.3 Compressive strength of concrete

Compressive strength is the most vital parameter as it indicates the quality of concrete. Figure 5 shows the compressive strength development of concrete mix. The cube specimens measuring 100 mm x 100 mm x 100 mm were immersed in water for 7 days and 28 days.

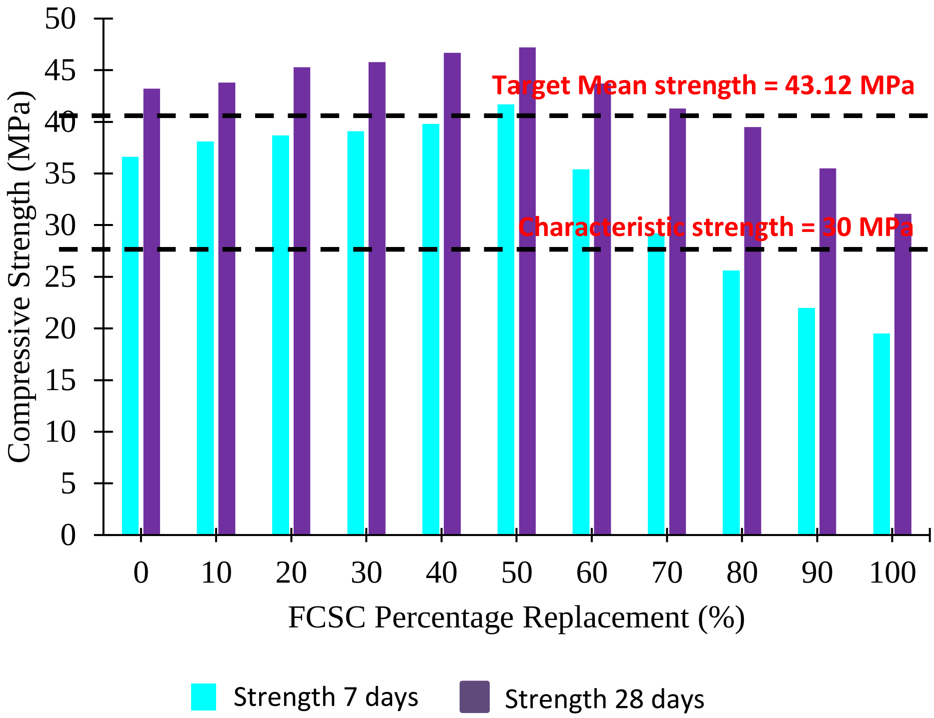

Fig. 5. Compressive strength results

3.2.4 Splitting tensile strength of concrete

The splitting tensile test was done because it yields a uniform value compared to other tests used to determine the tensile value [21]. Figure 6 shows the development of splitting tensile strength versus fine coconut shell percentage. The samples used for this test were cylindrical in shape with a diameter of 100 mm and a height of 200 mm.

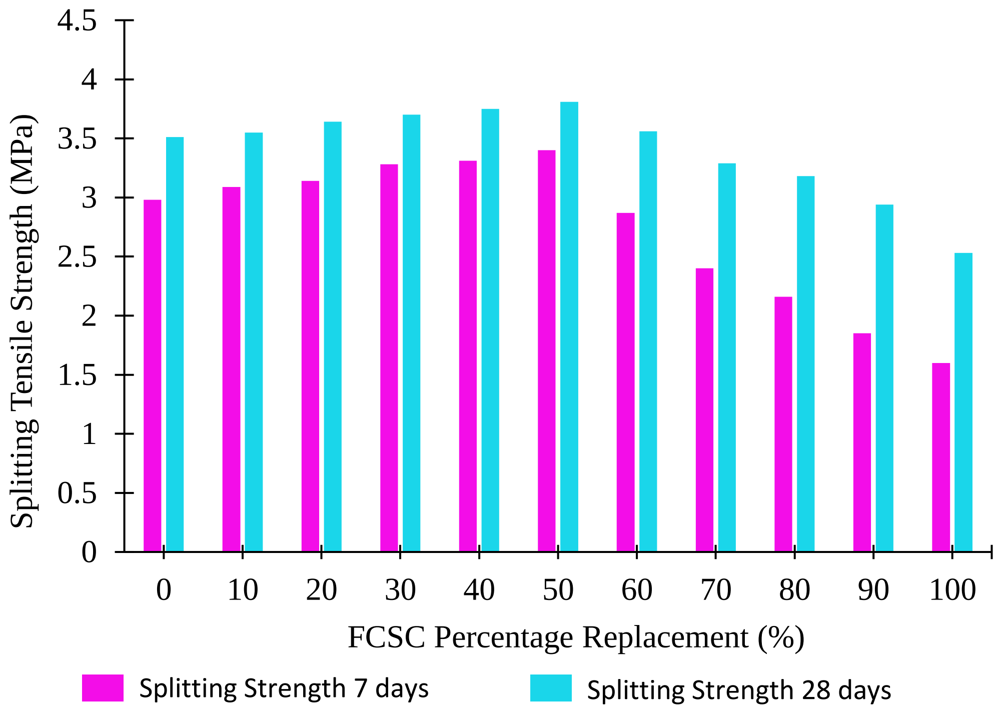

Fig. 6. Development of splitting tensile strength and fine coconut shell percentage

Splitting tensile strength is the ability of concrete to resist direct tension. Moreover, the concrete is very weak in tension due to its brittle nature. Hence, it is not expected to resist the direct tension. So, concrete develop cracks when tensile forces exceed its tensile strength. Therefore, it is necessary to determine the tensile strength of concrete to determine the load the concrete may crack. In this study, the testing was conducted according to the standard of BS EN 12390-6:2009 [22]. Referring to Figure 6, a trend of bell graph was recognized. The strength continues to increase with 10% to 50% replacement of fine coconut shell. According to Ealias *et al.,* [23], one of the factors that trigged the splitting tensile strength of coconut shell concrete to decrease are the pores and voids inside the concrete. The more the replacement of fine aggregate with fine coconut shell, the higher the pores and voids inside it. In this study, it is known that normal concrete is weak in tension, with the addition of voids and pores that come from the fine coconut shell, the concrete become weaker. Hence, the conclusion made by Ealias *et al.,* [23], can be accepted and used in this study.

3.2.5 Flexural strength of concrete

The maximum load that causes cracking can be determined through the flexural strength test. The flexural strength test is one of the critical tests for determining the strength of concrete. The flexural strength test was conducted on concrete prisms at the age of 7 and 28 days. The average data was illustrated as graph in Figure 7.

For the flexural test, prisms measuring 100 mm x 100 mm x 500 mm were used. The load was applied without shock and was gradually increased until the specimen failed.

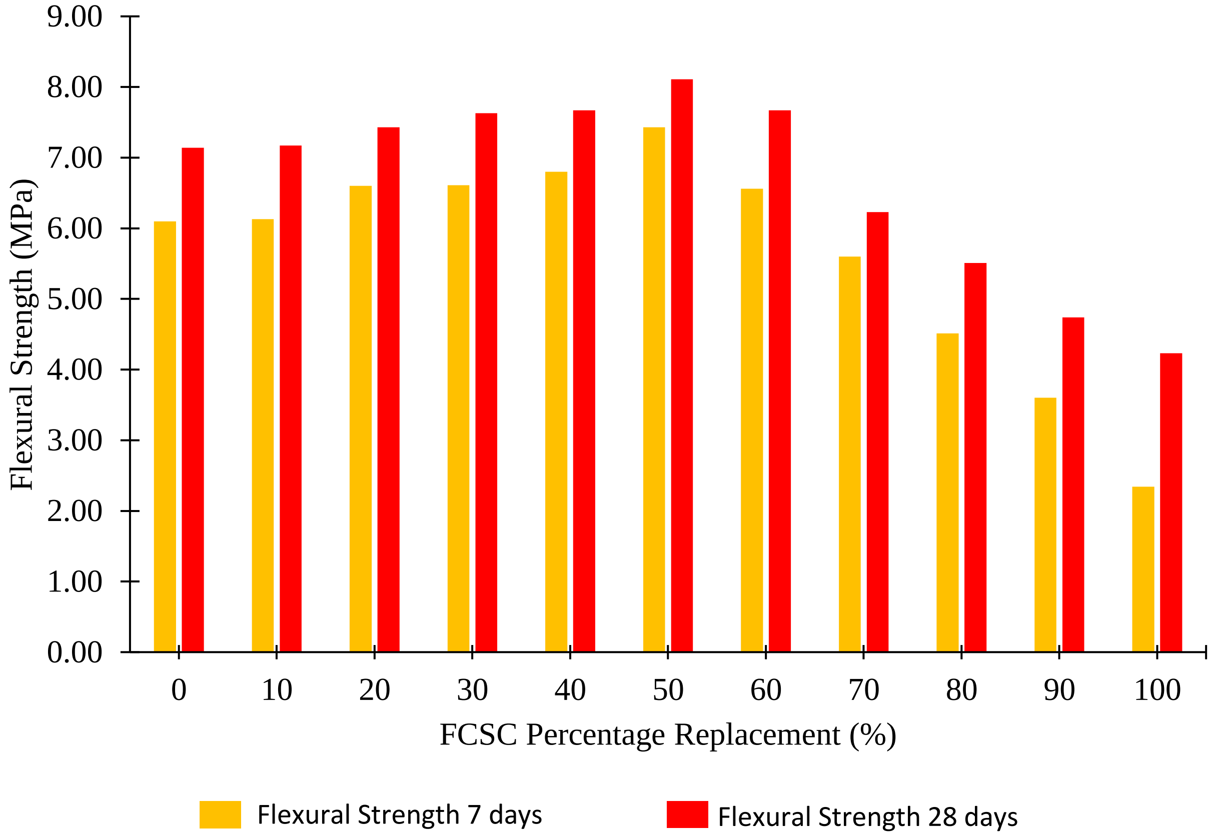

Fig. 7. Development of flexural strength vs. fine coconut shell percentage

Referring to Figure 7, a similar trend of bell curved graph was found as same as splitting tensile strength and compressive strength. The flexural strength increases from normal concrete to FCSC 50 with. It then decreases gradually from FCSC 60 to FCSC 100 respectively at 28 days. An increment of strength was seen from 7 days to 28 days of curing for every percentage replacement involve. It shows that the fine coconut shell has a good reaction inside the concrete with the other materials. The highest flexural strength was found at FCSC 50.

According to Kumar *et al.,* [24], the flexural strength gained from the research shows that the strength tends to increase from normal concrete to some point of replacement and then drop gradually but still satisfy the flexural strength of lightweight concrete. Kumar *et al.,*'s [24] findings were related and the same as this study where a pattern of increasing from normal concrete and started to decrease at FCSC 60 until FCSC 100. One of the reasons for the strength to drop is because the voids and pores that occurs inside the concrete. Kamal and Singh [25] mentioned that as the replacement of coconut shell increase, voids and pores also increase inside the concrete with an addition of the pores and voids of the materials itself. This situation made the concrete to become weaker. The statement from Kamal and Singh [25] also can relate to this study as the higher percentage replacement, the weaker the concrete become.

3.2.6 Modulus elasticity of concrete

Modulus of elasticity is defined as the ability of concrete to change shape when force is applied to it as well as its ability to retain its shape when the force is removed. This ability depends on the pores, voids, and microcracks inside concrete. The higher the MOE value, the better the quality of concrete. Figure 8 shows the data obtained.

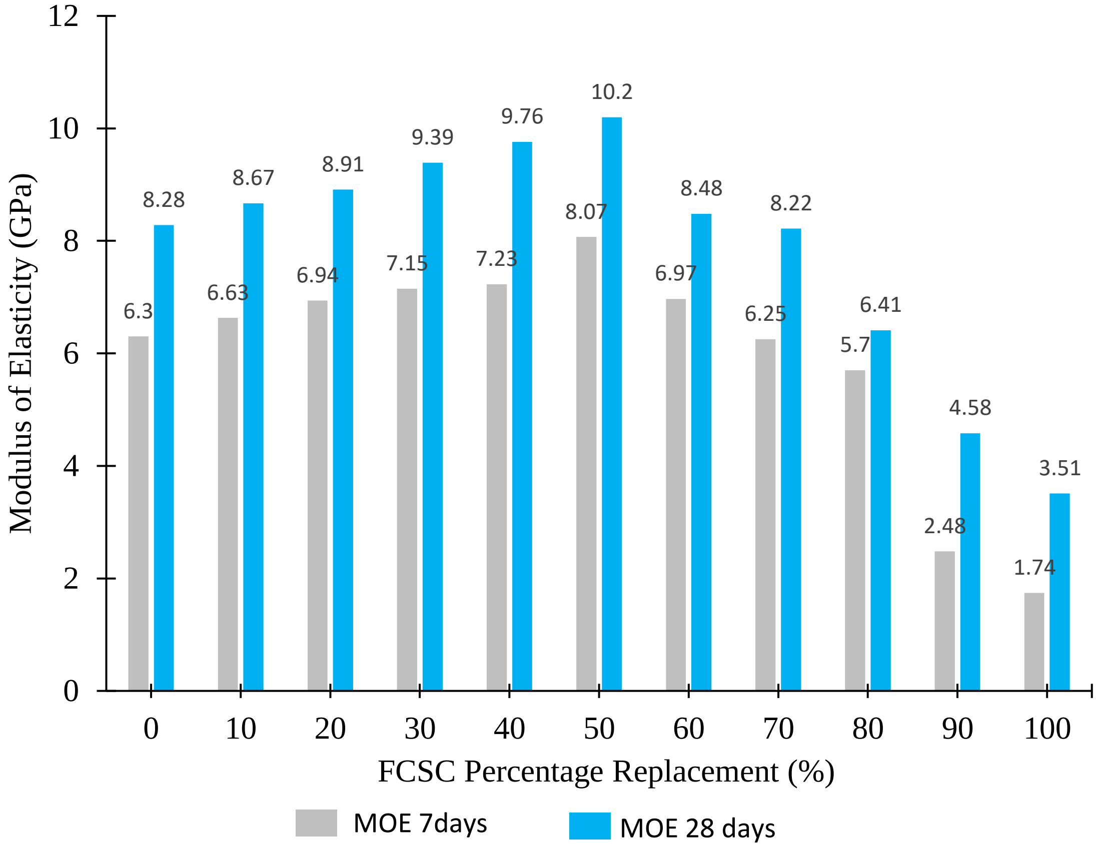

Fig. 8. Data modulus elasticity of concrete

The highest MOE value was found at the percentage replacement of 50%. It gained the highest value for both 7 and 28 days. According to Mehta and Monteiro [26], the highest modulus of elasticity can be obtained based on the reaction between the mix and the aggregate which then affects the stress-strain relationship.

3.2.7 Water absorption of concrete

Assessing the water absorption of concrete is one of the ways to assess its durability. Water absorption defines as the transportation of liquids in porous solids caused by surface tension acting in the capillaries. Neville [21] reported that the water absorption of concrete cannot be used as a measure of concrete quality. Neville also recommended that good concrete should have a water absorption of below 10% by mass. The results of the water absorption test are shown in Figure 9 in graphical form.

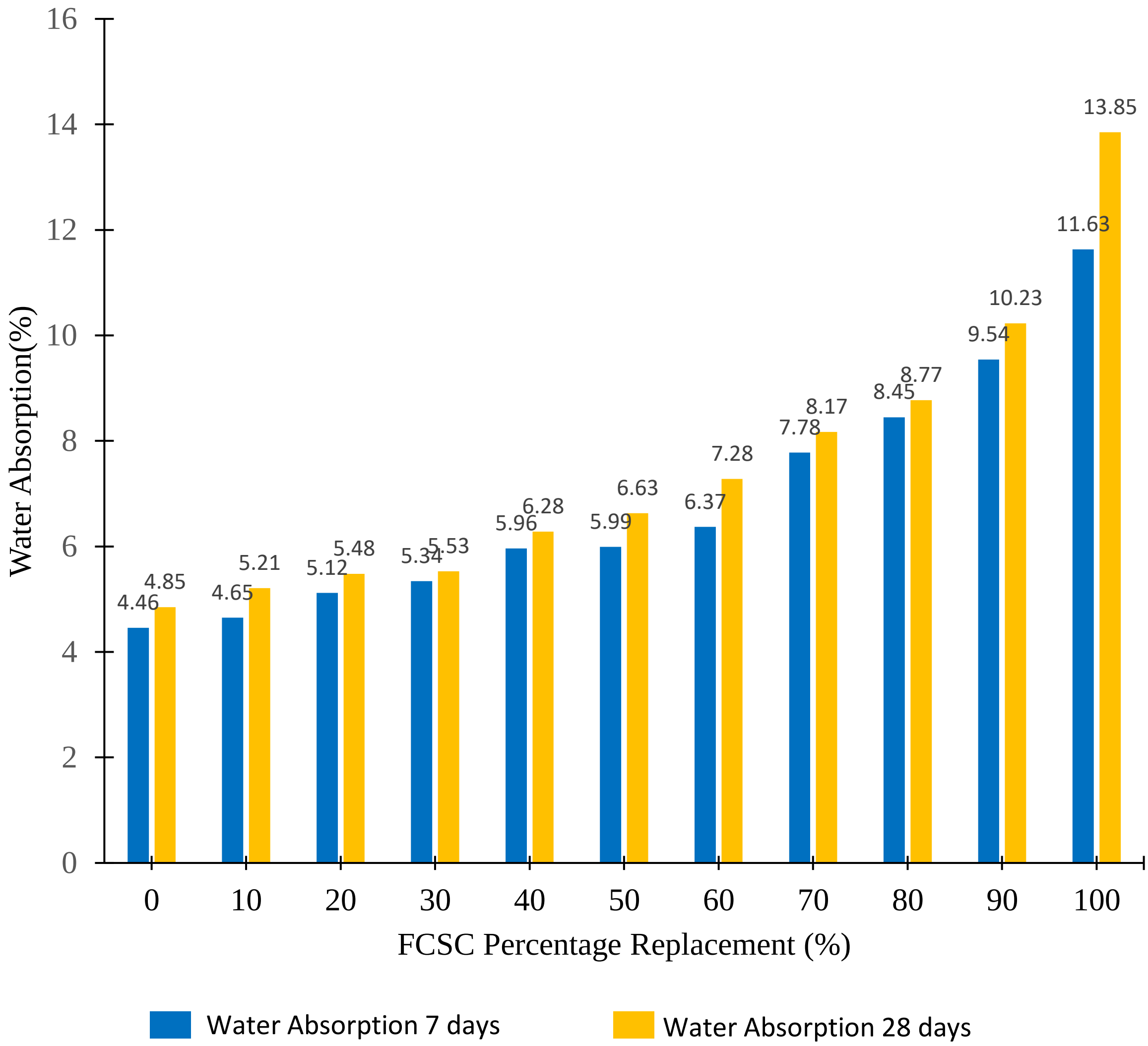

Fig. 9. Water absorption values for all mixes

Based on BS 1881-122, a good quality of concrete should have a water absorption value of less than 10% [27]. Therefore, FCSC 90 and FCSC 100 cannot be taken into consideration for optimum percentage as the value of water absorption are more than 10 %.

3.2.8 Water permeability of concrete

Water permeability determines the durability of concrete. This is because concrete that has high durability is normally impermeable. This water permeability test was conducted according to BS EN 12390-8:2009 [28]. Figure 10 shows the graph plotted from the data gained for 7 and 28 days curing period.

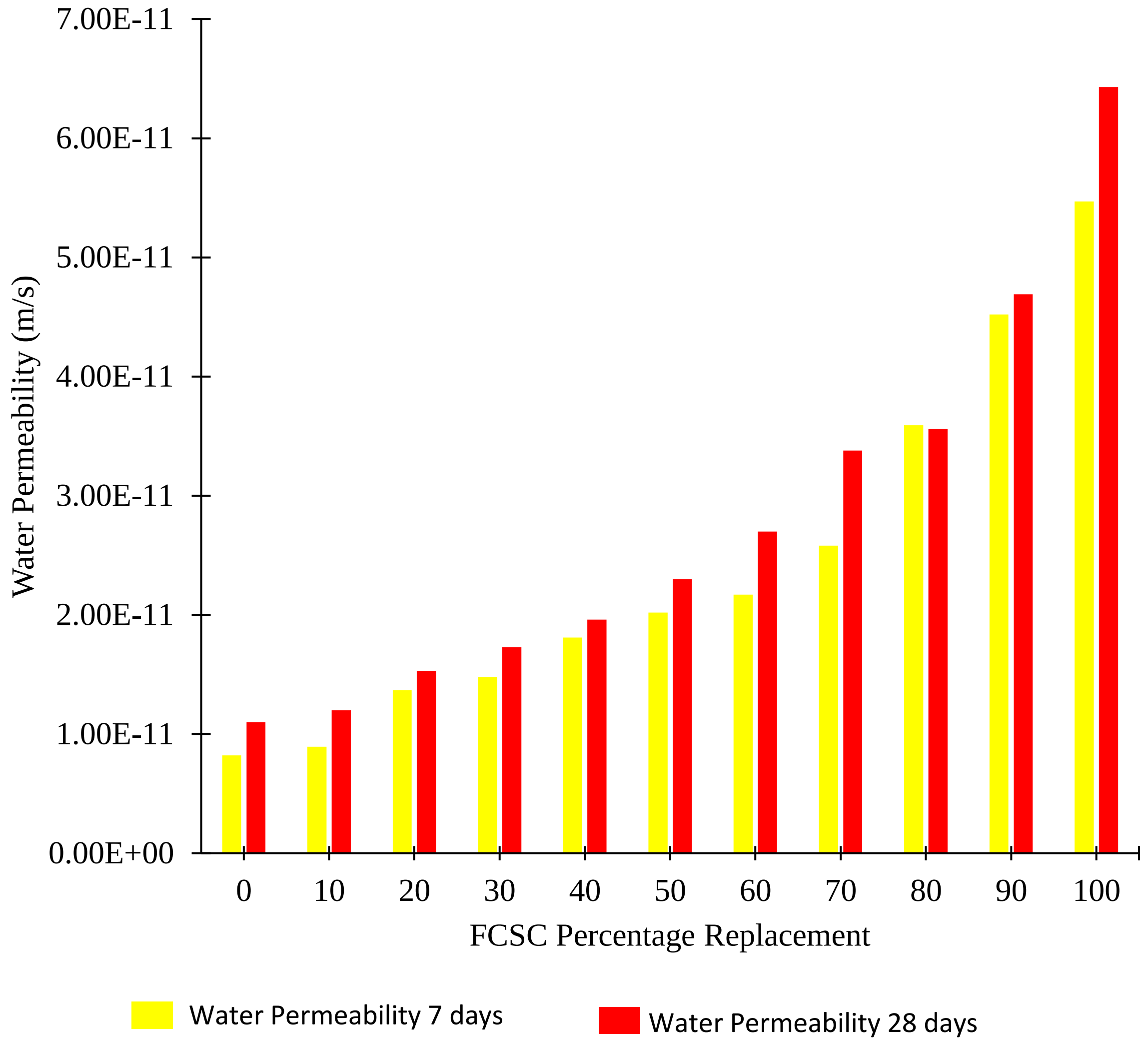

Fig. 10. Water permeability values for all mixes

From Figure 10, the water permeability was found to increase with the increase in FCS replacement percentage. Only a small portion of water is allowed to penetrate concrete in order to ensure that the concrete not crack because of the corrosion from the reinforcement bar. Apart from that, a higher water permeability will result in the leaking of concrete and makes the concrete continuously wet. If this happen, the concrete was not suitable to proceed as a construction of wall panel as it will make the house wet and the wall will fill up by moss as moss like a wet surface.

3.2.9 Thermal conductivity of concrete

Thermal conductivity specifies the conduction of heat through concrete materials. The test was conducted according to BS EN ISO 8990 [29]. Figure 11 shows the graph of thermal conductivity values of FCSC and conventional concrete. In this study, the thickness of the sample used was 100 mm which is based on the standard precast wall panel. For normal weight concrete, the thermal conductivity is normally having a value of 0.76 W/mK.

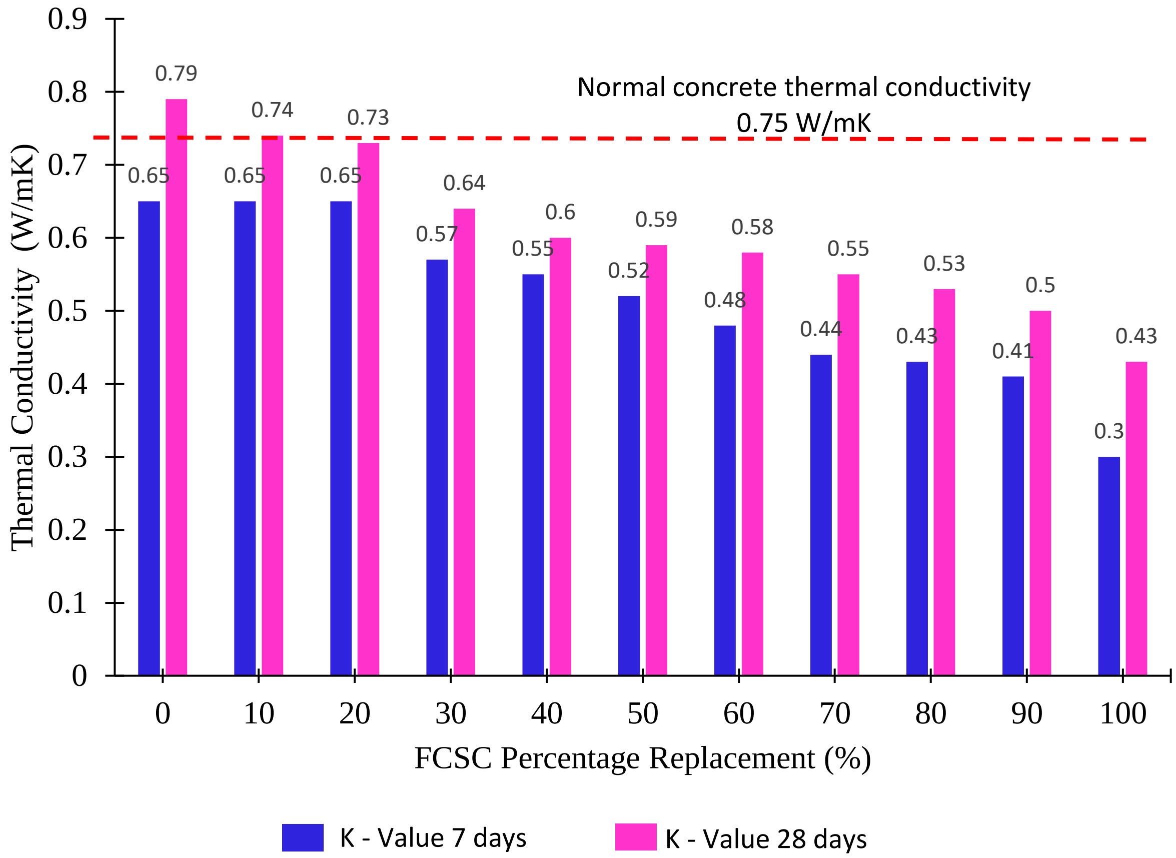

Fig. 11. Thermal conductivity at 7 and 28 days

Based on Figure 11, at 7 and 28 days a trend of decreasing thermal conductivity were seen from FCSC 0 until FCSC 100. This phenomenon is due to the porosity of concrete. Thermal conductivity very much depends on the porosity of concrete. If the concrete particles are packed, heat can penetrate concrete directly which results in a higher temperature. However, if the particles are losses, heat cannot penetrate the concrete directly as there are many voids between the particles. This produces a cooler temperature inside concrete. Olanrewaju also stated in his research that porosity was discovered to be one of the factors affecting the thermal conductivity of concrete [30]. Another factor that leads to lower thermal conductivity is the density of the concrete. The lower the density of concrete, the lower the thermal conductivity. However, other mechanical properties will be affected and so the relationship test were conducted to determine the most optimum percentage that can be used in real monitoring and situation.

3.2.10 R-value

Thermal resistance is one of the factors that connects the thermal conductivity of a material to its width. It is expressed in the form of resistance per unit area (m^2K/W). A higher thickness means less heat flow as well as lower conductivity. Higher thermal resistance indicates good insulation whereas lower thermal resistance indicates bad insulation. The test conducted using the standard of

BS EN ISO 8990:1996 [29]. By using Eq. (1). thermal resistance values can be obtained and plotted as shown in Figure 12.

$$R = \frac{l}{\lambda} \tag{1}$$

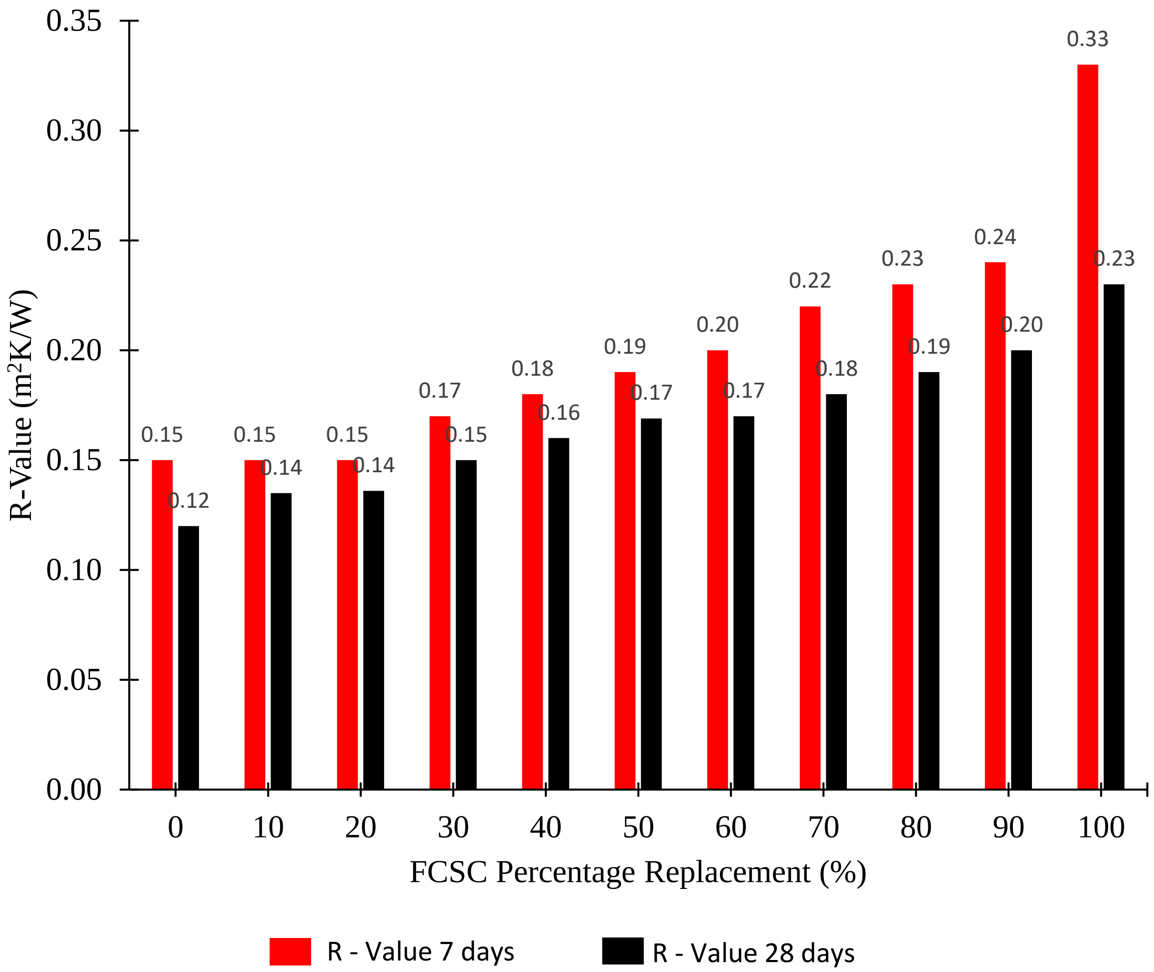

Fig. 12. Thermal resistance of fine coconut shell concrete

Figure 12 indicate the thermal resistance or R-value for each FCS concrete mix. The trend of thermal resistance increases as percentage replacement increase. Depending on the thickness and thermal conductivity value, FCSC 10 until FCSC 100 of fine coconut shell can be used as a partial replacement of sand in concrete due to its better performance in thermal conductivity and thermal resistance than normal concrete. However, a relationship analysis was done to determine the optimum value of replacement based on all the properties testing conducted.

3.3 Relationship Between the Properties of Normal Concrete and Fine Coconut Shell Concrete for the Determination of Optimum FCS Percentage

The relationship analysis between two tests in one graph are vital to know the crossing point of selected concrete that is suitable to use between two data. There are several relationships that need to be considered. It consists of relationship between slump and water absorption, relationship between compressive and density, relationship between compressive strength and water absorption, relationship between thermal conductivity and density, relationship between thermal conductivity and compressive strength, and relationship between thermal conductivity and water absorption. All the chosen data were related to the voids, pores and water absorption of the concrete. These three parameters play an important role to the concrete properties. Therefore, it is vital to ensure the optimum percentage of replacement in order to construct a wall panel for the field work. The relationship data were tabulate as in Table 2.

Table 2
Summary of all relationship data

Relationship Between Paramater	Optimum Percentage Replacement
Slump and Water Absorption	FCSC 50 and FCSC 60
Compressive and Density	FCSC 0 and FCSC 10
Compressive Strength and Water Absorption	FCSC 90 and FCSC 100
Thermal Conductivity and Density	FCSC 0, FCSC 20 and FCSC 50
Thermal Conductivity and Compressive Strength	FCSC 0
Thermal Conductivity and Water Absorption	FCSC 80

Based on Table 2, for parameter slump and water absorption, the optimum relation is at FCSC 50 and FCSC 60 while for relationship between compressive and density, the concrete that are consider to be good are FCSC 0 and FCSC 10. Another relationship for compressive strength and water absorption, the concrete that comply both parameters are FCSC 90 and FCSC 100. For thermal conductivity relationship with density, FCSC 0, FCSC 20 and FCSC 50 are considered to be good. Relationship between thermal conductivity and compressive strength and thermal conductivity with water absorption are FCSC 0 and FCSC 80 respectively. Therefore, there are 8 concretes namely FCSC 0, FCSC 10, FCSC 20, FCSC 50, FCSC 60, FCSC 80, FSCS 90 and FCSC 100 that can be considered as an optimum percentage for concrete that contain fine coconut shell.

First and foremost, FCSC 0 were neglected because it is the normal concrete that does not have fine coconut shell inside it. Hence FCSC 10, FCSC 20, FCSC 50, FCSC 60, FCSC 80, FSCS 90 and FCSC 100 that are left. In finding the optimum percentage, the most important things to be considered are the highest replacement of fine coconut shell as this study aims to reduce the wastage from the landfill. Next the slump value and water absorption were taken into consideration because the workability of concrete will affect the time and cost consume, so a concrete that is ease to handle need to be chosen. Apart from that, the thermal conductivity properties were seen as it will reduce the temperature inside the house after constructing the wall panel. The compressive strength is the last thing to be considered because wall panel does not need a highest strength because wall panel does not carry load from the structure. FCSC 90 and FCSC 100 cannot be chosen because the water absorption for this concrete is higher with a value of 10.23 % and 13.85 % respectively. This value has exceeded the value of standard BS 1881-122 that stated the value of water absorption should be less than 10 % of its mass [27]. The higher the water absorption will lead to a weaker concrete and also a bacteria or moss will be stated to breed because of the damp and wet place. Therefore, FCSC 90 and FCSC 100 can be neglected. Hence the concrete that are left are FCSC 10, FCSC 20, FCSC 50, FCSC 60, and FCSC 80.

The balance percentage replacement has passed the thermal conductivity properties and standard of BS EN ISO 8990 because the higher the replacement of fine coconut shell, the lower the thermal conductivity due to the porosity and void inside the concrete [29]. Next, the consideration of utilizing fine coconut shell waste at the highest value are located at FCSC 50, FCSC 60 and FCSC 80. Hence FCSC 10 and FCSC 20 were neglected because the percentage replacement is low. The utilization of coconut shell at the highest percentage helps to make the greener environment and also reduce the landfill consume.

Lastly, a standard of BS EN 12350-2:2009, that stated true slump lies between 75 mm ± 25 mm. this value of slump was needed as it is the workability of concrete to work with [31]. FCSC 50, FCSC 60 and FCSC 80 have a slump value of 47 mm, 21 mm, and 18 mm respectively. Although all three percentages replacement do not achieve the slump value as stated in the standard, FCSC 50 were considered as good to be used since it is only having a slightly difference rather than FCSC 60 and FCSC 80 that have a difference of 58 % and 64 % respectively and both concrete are hard to handle since the coconut shell materials itself has absorb more water. The fine coconut shell material in this study has a value of 25 % of water absorption. Therefore, during the mixing process, the higher the percentage replacement the slump become drier and harder to work with.

In a conclusion, FCSC 50 is chosen for the optimum replacement in this study. Table 3 shows the value of FCSC 50 achieved for each testing that were conducted for this study. Hence 50 % replacement of fine aggregate with fine coconut shell were choose to construct a wall panel and conducting a field work in order to determine the temperature that were experience inside the house. The field work data and discussion were discussed and also the temperature data were validated with Autodesk Eco-tect Software so that the temperature in field work and modelling simulation was almost the same.

Table 3
Summary properties value of FCSC 50 %

Parameter	Properties Value
Slump Test	47 mm
Density Test	2260 Kg/m^3
Compressive Strength Test	47.2 MPa
Splitting Tensile Strength Test	3.81 MPa
Flexural Strength Test	8.11 MPa
Modulus of Elasticity Test	10.20 GPa
Water Absorption Test	6.63 %
Water Permeability Test	2.30E-11
Thermal Conductivity Test	0.59 W/mK
Thermal Resistance Test	0.17 m^2K/W

3.4 Field Work and Validation of Data Using Autodesk Ecotect Software

Figure 13 shows the data in real monitoring for normal concrete wall panel while Figure 14. Shows the real monitoring on site from day until night or to be precise from 8.00 a.m to 12.00 p.m using the thermal infrared thermal imager and the data were recorded for fine coconut shell concrete wall panel at an optimum percentage of replacement. While Table 4 and Table 5 shows the validation reading using Autodesk Ecortect software of normal concrete wall panel and fine coconut shell concrete wall panel.

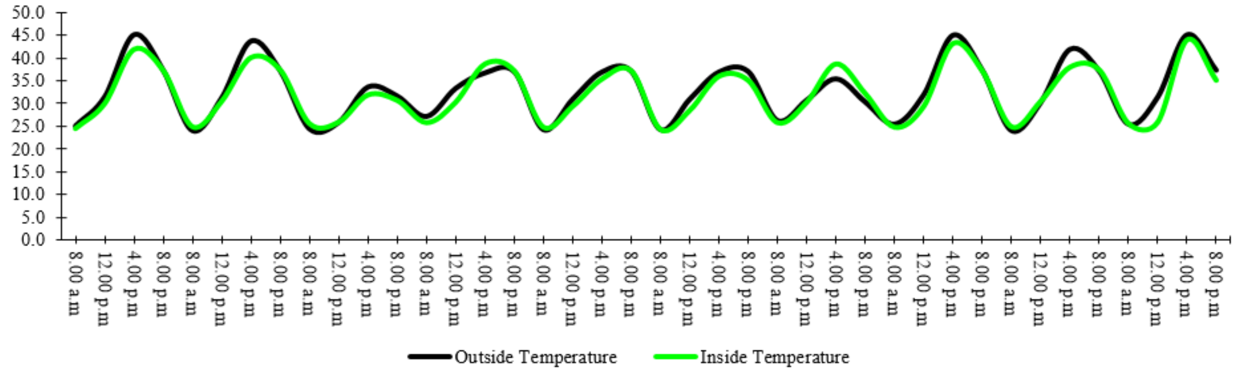

Fig. 13. Normal concrete wall panel temperature reading at real situation

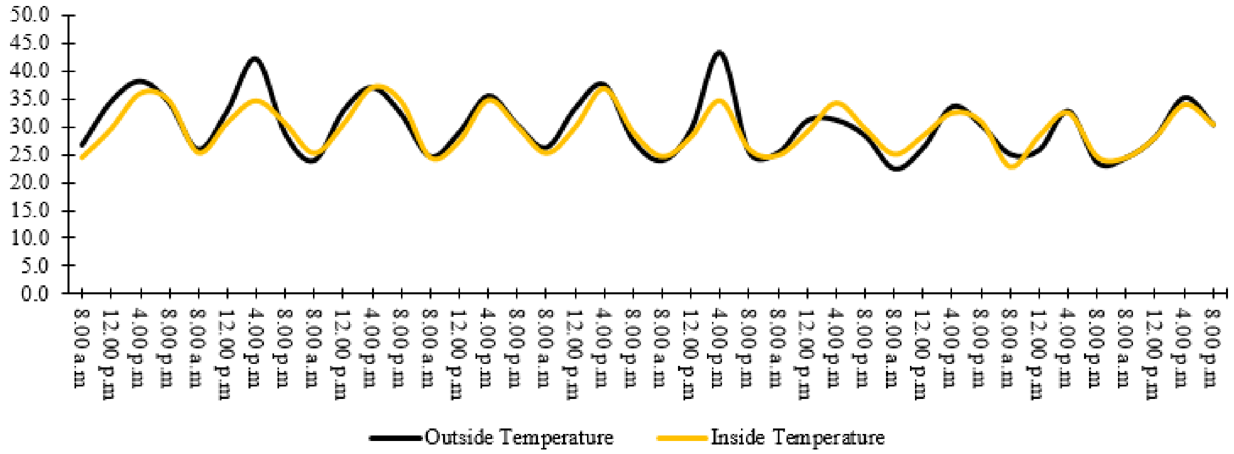

Fig. 14. 50% of fine coconut shell concrete wall panel temperature reading at real situation

By referring to both graphs, inside temperature of fine coconut shell concrete wall panel shows a lower reading compared to normal concrete wall panel. It shows that, the pores and void inside fine coconut shell wall panel have done a tremendous job by preventing the heat from sunlight to directly penetrate the concrete and make a cooler comfortable temperature inside the house.

Table 4
Data between software and real monitoring for normal concrete wall panel

Time	Outside Temperature (Software) °C	Inside Temperature (Software) °C	Difference Between Outside and Inside Temperature (Software) °C	Outside Temperature (Real Monitoring) °C	Inside Temperature (Real Monitoring) °C	Difference Between Outside and Inside Temperature (Real Monitoring) °C
0800	24.0	25.5	-1.5	24.3	24.9	-0.6
0900	25.2	25.6	-0.4	25.2	25.6	-0.4
1000	25.8	26.8	-1.0	26.5	26.6	-0.1
1100	28.4	26.1	2.3	28.9	28.7	0.2
1200	29.5	27.1	2.4	31.0	29.5	1.5
1300	30.5	28.3	2.2	32.0	31.7	0.3
1400	29.4	31.6	-2.2	32.8	32.9	-0.1
1500	30.1	29.5	0.6	36.9	34.6	2.3
1600	30.4	28.5	1.9	37.0	35.5	1.5
1700	27.5	28.4	-0.9	33.4	35.6	-2.2
1800	26.6	27.3	-0.7	33.4	36.3	-2.7
1900	25.6	26.5	-0.9	32.9	35.2	-2.3
2000	28.3	25.6	2.7	31.7	30.8	0.9
2100	27.4	25.2	2.2	31.4	30.3	1.1
2200	27.0	25.0	2.0	29.6	29.1	0.5
2300	24.8	26.6	-1.8	25.1	25.7	-0.6
0000	24.0	26.3	-2.3	24.5	26.1	-1.6

Table 5
Data between software and real monitoring for FCS concrete wall panel

Time	Outside Temperature (Software) °C	Inside Temperature (Software) °C	Difference Between Outside and Inside Temperature (Software) °C	Outside Temperature (Real Monitoring) °C	Inside Temperature (Real Monitoring) °C	Difference Between Outside and Inside Temperature (Real Monitoring) °C
0800	24.0	25.2	-1.2	25.3	24.7	0.6
0900	25.2	26.8	-1.6	24.0	26.3	-2.3
1000	25.8	28.4	-2.6	27.2	27.2	0
1100	28.4	29.5	-1.1	29.7	28.9	0.8
1200	27.7	30.5	-2.8	31.0	29.4	1.6
1300	28.4	31.6	-3.2	33.3	32.2	1.1
1400	29.0	30.6	-1.6	37.7	34.6	3.1
1500	29.5	29.5	0	33.3	35.0	-1.7
1600	29.8	28.5	1.3	31.1	34.9	-3.8
1700	30.0	27.5	2.5	30.8	33.7	-2.9
1800	29.8	26.6	3.2	31.5	33.6	-2.1
1900	29.4	25.6	3.8	32.3	33.4	-1.1
2000	28.9	25.4	3.5	28.3	30.2	-1.9
2100	28.4	25.2	3.2	28.4	28.7	-0.3
2200	28.1	26.1	2.0	27.5	27.8	-0.3
2300	27.8	24.8	3.0	24.8	26.7	-1.9
0000	27.6	24.0	3.6	24.3	26.1	-1.8

Autodesk Ecotect Software does not give the exact same value of outside temperature due to the weather casting data. During the data taken on real monitoring, it is during a haze session and therefore the highest point of temperature is 37.7 °C while in the software, the highest point of temperature is 30 °C. Even though, the temperature is different, both situation shows a difference between temperatures are in the range of 3.8 °C. The value is higher compared to normal concrete wall panel that only have a difference of 2.7 °C. It reflects that fine coconut shell concrete wall panel have a higher resistance that prevent the heat to directly penetrate inside the building. Therefore, a reason and statement that said fine coconut shell concrete have more voids and pores that prevent a direct penetration of heat and release less heat to the other side of concrete compared to normal concrete are true. Therefore, the data gained is valid and the replacement of 50 % fine coconut shell inside concrete are good to be used.

4. Conclusions

Based on all the experiment conducted, it is found that the replacement of 50% sand with fine coconut shell gives a better result in term of concrete properties and thermal properties and can be used in real situation. It shows that the coconut shell from a waste can be used and the waste can be reduced due to the usage in the concrete. The thermal comfort also can give a better result to human being as a difference in 1^{0}C can give a comfortable situation to the user.

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