REDUCING ENERGY CONSUMPTION BY USING CIGARETTE BUTTS AS WASTE MATERIAL IN CONCRETE BUILDING MATERIALS

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Due to a large amount of waste associated with cigarette smoking, it is suggested that they are used as waste material in the deformation of concrete building materials. Therefore, the aim of this research is to determine the thermal properties of the enhanced concrete building materials and to find the amount of their impact on reducing electrical energy consumption for cooling purposes. This study was performed in the city of Baghdad (Latitude 33.2 No) using three different forms of cigarette butts to combine with the concrete mixture; namely, small pieces, filament mesh, and a mixture of both forms, by ratios between 1- 5 % of the cubic weight. The results of this research show that a mixture of both forms of cigarette butts delivers optimal results. Using small pieces of cigarette butts at a ratio of 5% within five layers of the filament mesh achieved a reduction in the amount of electrical energy spent for seasonal conditioning by 28.6 kWh per square meter of the test wall. Further, the percentage of energy reduction when compared to a traditional wall was 45.7%, in addition to, a decrease of 38% in compressive resistance. These results are overlooked when considering the construction of load-bearing walls.

Keywords: Concrete building materials, low density materials, electrical energy, cigarette butts, energy saving

1. Introduction

Iraq is located in the Northern semi-tropical region and is affected by semi-desert climate, clear skies 260 days / year with an average of 15 hours/day of sunlight in the summer and 9 hours/day in the winter. The environment air temperature in the summer can reach up to 50 °C with an average 900 watts per square meter of solar radiation (340 watts in the winter) [1]. Thus, the external shells of the city buildings are exposed to huge heat waves. The most common method of construction for most Iraqi cities is using three layers of materials.

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Common fired bricks with a thickness of 240 mm in the core, outer layer cladding with a cement mortar thickness of 20 mm, and an inner layer cladding of gypsum plaster with a thickness of 25 mm. Accordingly, the overall heat transfer coefficient (U) of this system is 1.514 watts/square meter, Kelvin [2], with a required cooling load of 10.5 tons of refrigeration during the summer [3]. This method has been adopted since the 1930s despite the presence of many alternatives that are available. Therefore, the quantities of electrical energy that are consumed by the air-conditioning units used in traditional buildings to provide comfortable thermal conditions for the people in them are estimated at about 70% of the total consumption of the Iraqi family [4]. In order to reduce the electrical energy spent for air conditioning purposes, it is necessary to take into account the principles of rationalizing consumption within those buildings, which can be achieved in two axes. The first is to reduce the environmental impact on the entire building by using the shading method for walls with trees or climbers [5-8]. Shading the building in general [9], increasing the reflection coefficient of solar energy for packaging materials used for building facades [10-12], ventilating the building structure [13-15], or the use of nanoscale materials (Nano-Bio) used in the manufacturing of building materials or finishing [16-17], changing the amount of heat energy stored in walls [18], using two-phase materials [19], reducing the amount of heat released within building sections [20] and using thermal insulation materials [21]. The second of these trends is the manufacturing of sustainable building materials using agricultural or industrial wastes, and sometimes constructional ones added to the mixture during the formation process [22-26]; or, the use of cigarette butts in the manufacturing of bricks [27-36]. The World Health Organization [37] estimates that the number of individuals who smoke worldwide reached 1.1 billion, and in Iraq about 7 million (within the age groups 18-60 years) in 2019, and that the annual average consumption per capita was in the range of 1,083 in the world. In Iraq the average is 1,184 cigarettes smoked per year. The estimated quantities of the butts that are thrown into the environment annually are in the range of 88,156 tons worldwide, while in Iraq, 612.8 kg are discarded as violations of the waste. Therefore, in this study cigarette butt waste has been used and adding it in its natural form to concrete mixtures. This have would result in enhanced concrete building materials with acquired characteristics of reduced both thermal conductivity and density, which led to reduced energy consumption.

The novelty of this research represented energy consumption has been reduced by adding cigarette butt waste.

2. Materials and Methods

The material characteristics used in this research should be noted and studied. Thermal properties of concrete were estimated after adding cigarette butts with different methods. The experimental work in this study has been done by using two concrete cubes with different dimensions. The first cube had dimensions of 150×150×150 mm used for compressive strength. Testing was performed using E.L.E. International-2007/UK/A.D.R.- 2000 - standard machine – instrument. British specifications (882-B.S./1992) were used by mixing a ratio of (1:2:4) of mass while the water ratio was kept fixed in all mixtures at 0.5 (following standard curing protocol). Portland ordinary cement (type 1) along with Karbala area sand and Salah-Alden area crush coarse (river stone) aggregate (widely used in Iraqi construction) were used in the mixing formulation following Iraqi specifications (M.Q.A 5/1984). The aggregate materials were washed using the standard course of treatment, then dried and mixed. The graduated limits of the crush coarse and sand were corresponding with Iraqi specifications. The second cube ~~has~~ had dimensions of 200×200×200 mm that was used for thermal examination. A cigarette butt in its original shape before using is shown in Fig. 1. Cigarette butts were added to the cement by two methods. The first is cut into small pieces with dimensions of 5-8 mm in length, 2-4 mm in width, and 1 mm of thickness., as shown in Fig. 2. The other method used butts formed into a filamentous mesh with dimensions of 120 mm in length and a diameter of 20 micrometers, as shown in Fig. 3.

Fig. 1. Cigarette butt in original size and shape,

Fig. 2. Cigarette butts cut into small pieces

Fig. 3. Cigarette butts as filamentous mesh

Cigarette butts were added to the concrete mixture by ratios of 1%, 2%, 3%, 4% and 5% of cubic weight. The concrete was consisted from cement, sand, and aggregate as the ratio 1:2:4 and water 0.5. This mixture was done by electrically stirring to allow for equal distribution and good mixing of all materials. The mixture was placed into the test cubes and allowed to cure (following standard curing protocols). For the purpose of studying the thermal behavior, a test room was used, located on the third floor of an apartment building in Baghdad (Latitude 33.2 °N) with inside dimensions of 1 × 1 × 2 m and, as shown in Fig. 4, all the internal surfaces of the room were covered except for the test wall using polystyrene boards with a thickness of 200 mm. The testing wall (1 × 2) m facing the eastern direction used in this study is constructed using concrete materials whose thermal performance is required to be measured. The room is equipped with a window type air conditioning unit with a capacity of 3.5 kilowatts (1-ton refrigeration) for the purpose of providing standard thermal conditions (26.5) °C [38].

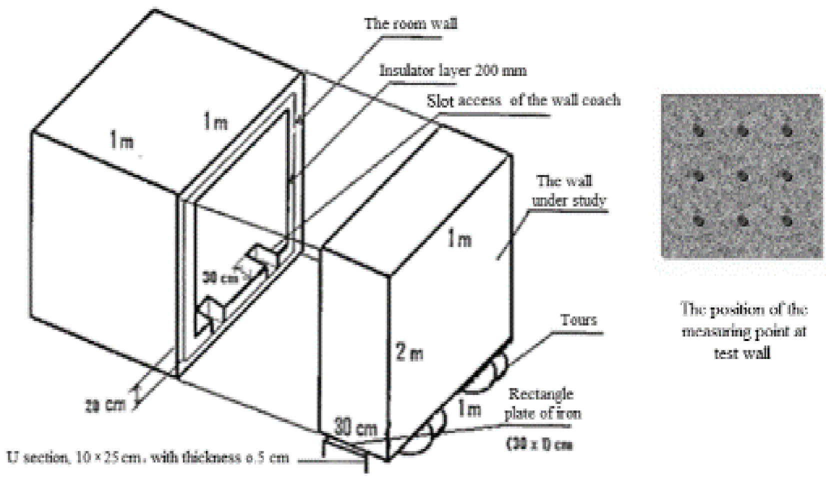

Fig. 4. Schematic illustration of the details of the test room

Digital thermometers with calibrated thermocouples were used to measure both temperatures of room air (Tr) and interior surface of the testing wall (Ti). In addition, an intelligent auto digital thermometer was used to measure the environment temperature in the shade (Tsh) and the external surface of the testing wall (To). The experimental readings were recorded on the 21st day of all summer months (May - September) /2019 from 6 AM to 6 PM. Moreover, the amount of electrical energy consumption was measured in kWh using an electrically power measurement device, which connected to the room electrical energy directly. The inner natural heat transfer convection coefficient (in turbulent flow) (h) of the inside test room surface was estimated from equation (1) [39].

$$h = 1.31(\Delta t)^{1/3} \quad (1)$$

Then the heat gain (Q) was calculated by equation (2). Where temperature difference denoted (Δt) is the difference between standard room air temperature (Tr) and the temperature of the inner surface for the tested wall (Ti).

$$Q = h.A.\Delta t \quad (2)$$

3. Results and discussion

The thermal behavior of the building materials that used cigarette butts with the three different methods under study and traditional building materials are shown in Figs. 5 and 6, respectively, for the summer month of June.

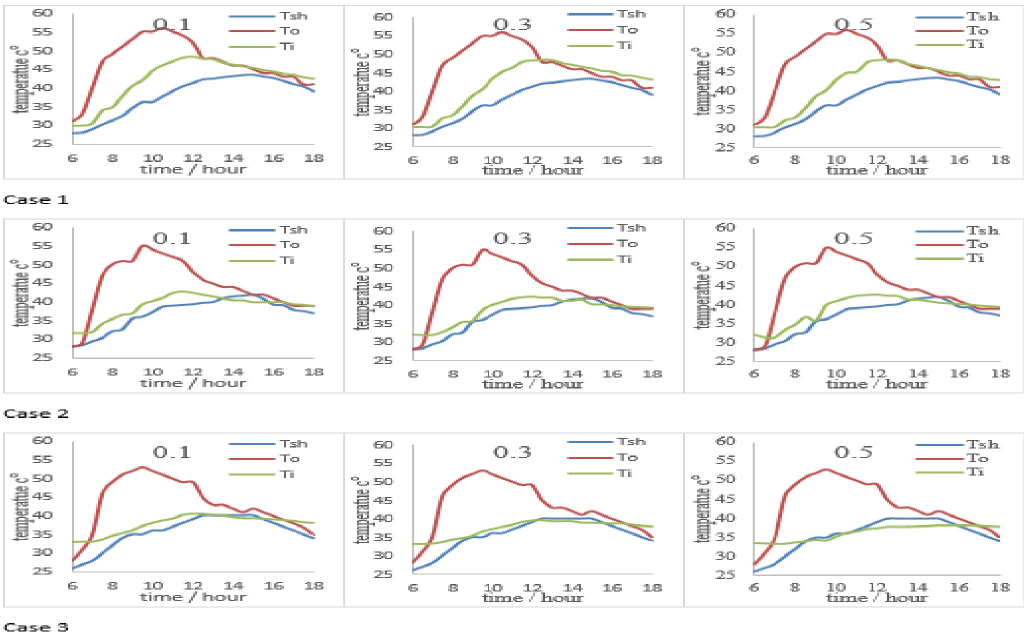

Fig. 5. Thermal behavior of building material used cigarette butts / June

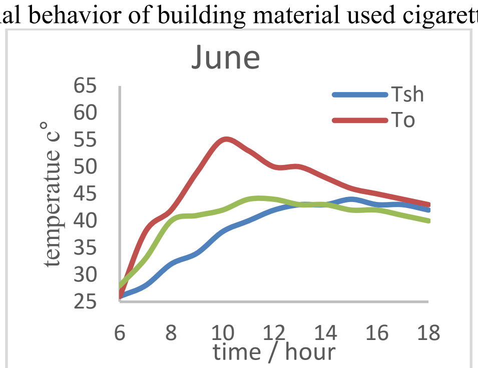

Fig. 6. Thermal behavior of traditional building material / June

These are shown as a model of practical experiments during the summer months, while the values of the overall heat transfer coefficient (based on thermal conductivity values measured by the hot wire and hot plate methods) for the sections of the walls under study are shown in Table 1. Finally, the constructional results are denoted in Figs. 7 & 8. Below is a discussion of the research variables and results in detail.

Thermal properties:

It is observed that the values of the overall heat transfer coefficient (U) have been decreased by adding cigarette butts when compared with the traditional building materials (before addition) as shown in Table 1. The overall heat transfer coefficient (U - factor) of concrete building materials after adding the cigarette butts was reduced by (8.15 - 14.28) % by using the 1st method (butt as pieces), while the values became (19.6 - 31.1) % when using the 2nd method (butt as a screen). The 3rd method (butt as a compound of pieces and screen) gave the most promising results and reduced the U factor by (27.7 - 37) % when adding at the optimal ratios. Thus, the first goal of the research is achieved by producing concrete materials with low insulation.

Interior surface temperature (Ti):

The temperature of the building material surface facing the room, is called inner surface temperature. The inner surface temperature of the test wall with the three different cases changed depending on which method was used for adding cigarette butts. Each case which contains five types depending on the percentage of added butts is shown in Fig. 7.

Table 1

Thermal and constructional resultant for walls Studied

Types of adding	Percentage of adding butt (%)	Density (kg/m^3)	Overall heat transfer coefficient (U) (W/m^2. K)		Absorption %	Slump mm	Compressive strength N/mm^2
			Hot wire	Hot plate			
	No addition	2300	2.74	2.613	1.6	11	24
1st method butt as apart	1 %	2230	2.4	2.35	1.65	13	23.6
	2 %	2190	2.38	2.3	1.7	13	23.1
	3 %	2110	2.31	2.21	1.7	13	22.5
	4 %	2100	2.29	2.19	1.7	14	22.0
	5 %	1950	2.24	2.13	1.7	14	21.4
2nd method butt as a screen	1 layer	2010	2.1	1.94	1.7	14	22.4
	2 layers	1940	2.04	1.88	1.75	15	21.6
	3 layers	1910	1.97	1.80	1.75	15	20.7
	4 layers	1865	1.87	1.67	1.75	15	19.8
	5 layers	1820	1.80	1.6	1.75	15	19.0
3d compound part and screen	1 % + 1 layer	1810	1.89	1.7	1.8	16	20.6
	2 % + 2 layers	1765	1.82	1.67	1.8	16	18.5
	3 % + 3 layers	1725	1.78	1.57	1.8	16	17.0
	4 % + 4 layers	1700	1.73	1.52	1.9	16	15.3
	5 % + 5 layers	1690	1.65	1.42	1.9	17	14.8

The inner surface temperature is a function of the nature of the change of environmental thermal conditions. That is, the increase in the temperature of the surface of the wall facing the environment (outer surface temperature) will cause the transfer of heat through the components of the structural section after a period of time that may be lengthened or shortened depending on the thermal properties of the materials that make up the wall and thus the temperature of the surface facing the room will change. As shown in Fig. 7, it is observed that the use of cigarette butts in the form of small pieces at a rate of 1% has reduced the inner surface temperature of the building material, which is facing the room (Ti), from 42 °C (in the case of traditional construction) to 40.8 °C.

The degree of decreased surface temperature correlated with an increase in the added percentage of cigarette butts, where it became 39.8 °C when the added percentage was 5%. This comes from the fact that cigarette butts have higher insulation compared to traditional concrete, so its presence in the concrete mixture will increase the isolation of the mass in general while its resistance to the passage of heat increases and increases with the increase of the added percentage.

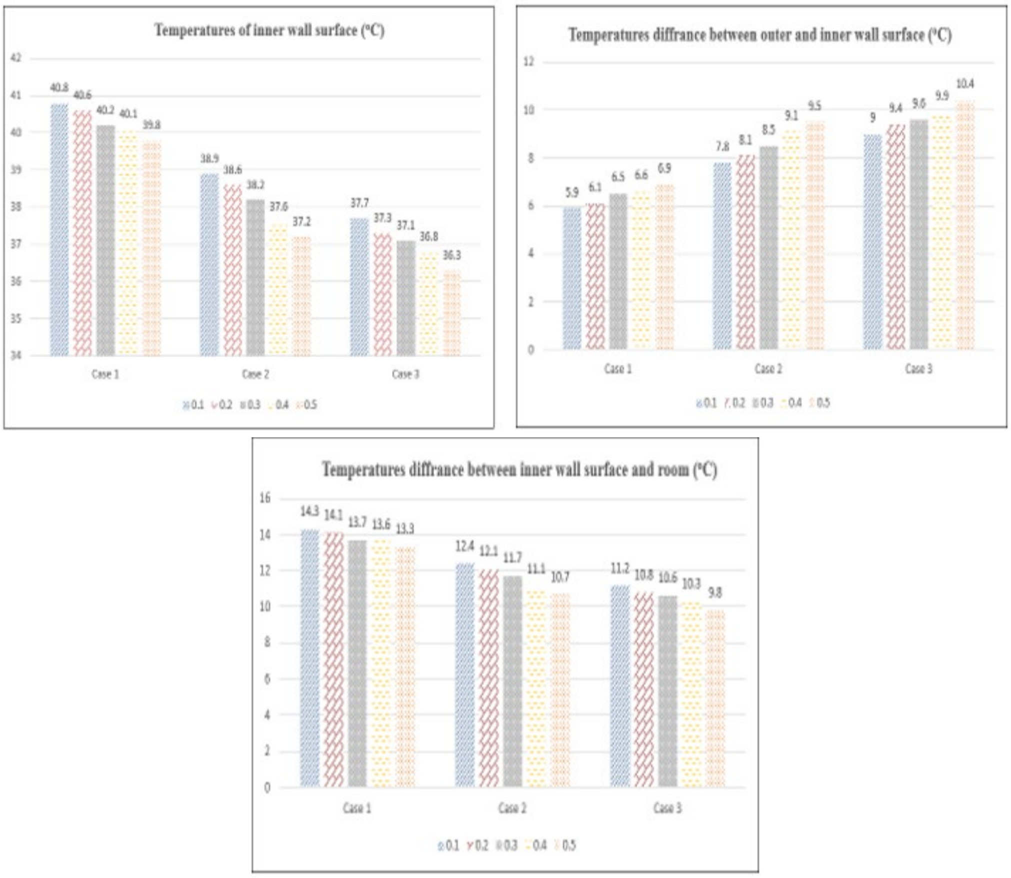

Fig. 7 Inner surface temperature and temperature differences

The addition of using the second method for the butts, which were in the form of a filamentous mesh layer of tissue, has achieved a greater improvement in the insulating properties of the concrete material due to its lattice shape that covers a larger area We note that the presence of a single layer has reduced the temperature of the surface facing the room to 38.9 °C, and that by increasing the number of layers, the thermal resistance increases and the thermal conductivity decreases (high insulation).

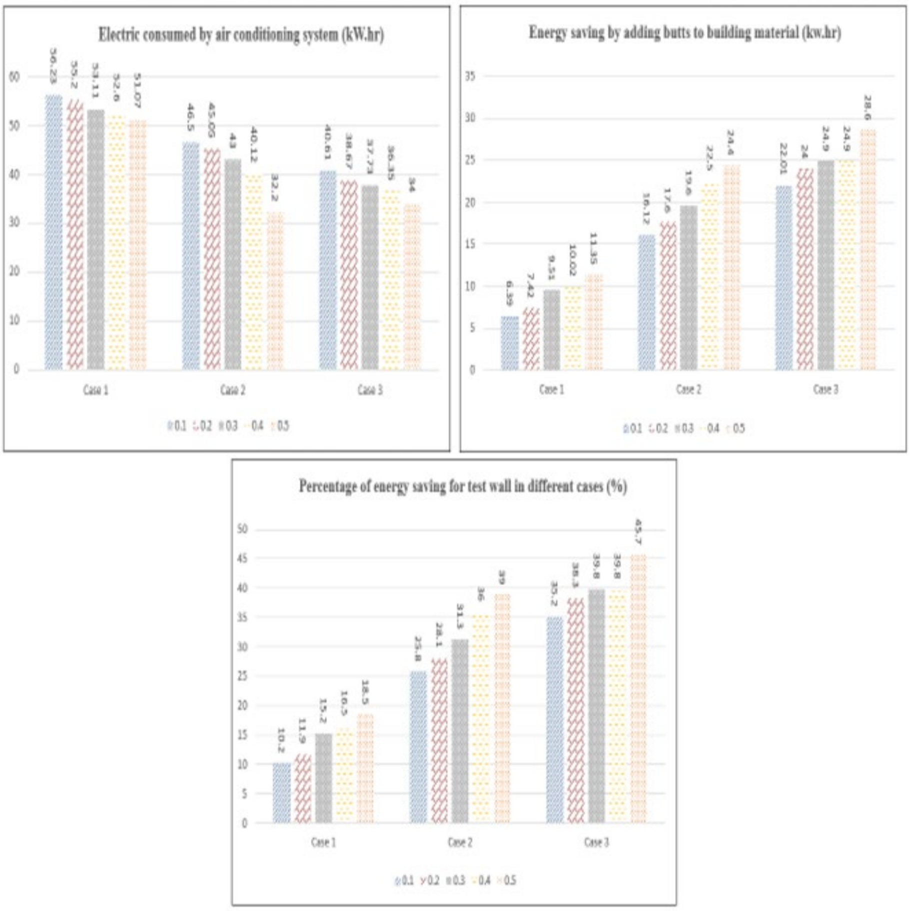

Fig. 8 Electrical consumption, electrical saving amount and percentage for Studied walls

We note that the temperature is recorded at 37.2 °C when the number of layers is 5. When using additive with a ratio of 5% pieces and 5 layers, the surface temperature of the building mass reached 36.3 °C and the percentage of surface temperature reduction approached 14% when compared to what is provided by traditional materials.

Temperature difference (ΔTo-i), (ΔTi-r):

As shown in Fig. 7, the use of the 1% mixture of the cigarette butts in a cut way led to the temperature difference between the two surfaces of the material (facing the environment and facing the room) to be 5.9 °C, while for the traditional wall it was 4.7 °C. In addition, this difference increased and became 6.9 °C when the additive percentage was 5% pieces. Using the second method of addition in the form of a filamentous mesh, the temperature difference was in the limits of (7.8- 9.5) °C depending on the number of layers. As for the use of the third method of addition, the combined method of cutting and screening, the temperature difference was in the limits of (9- 10.4) °C depending on the number of layers and the percentage of cutting. The percentage increase in the difference of temperature values at the two ends of the building mass was within (24) % when compared with what was the difference in the case of using traditional construction. As for the temperature, the difference between the surface temperature of the material facing the room and the standard air temperature inside the room (provided by the use of the air conditioning unit) was (26.5) °C, while, the traditional wall was (15.5) °C. It became in the limits of (14.3- 13.3) °C according to the amount of added cut percentage, and it became in the limits of (12.2- 10.7) °C according to the number of filament fabric screen used. Upon joint use, the difference became in the limits of (11.2- 9.8) °C. Hence, a reduction of 36.8% in the temperature difference when compared to what it is when using the traditional wall.

The amount of electrical energy consumed:

As a result of reducing the temperature difference between the surface of the internal building material (facing the room) and the design room air temperature, the amount of heat caused by the environment through the building shell, which requires disposal through the work of the air conditioning unit used in the room, will be less and will hence reduce the working period of the air conditioning unit, thus reducing the amount of electrical energy consumed for the purposes of providing thermal comfort, as seen in the data in Fig. 8. The amount of air conditioning load for the traditional wall will be in the limits (28.08) Ton Refrigeration per square meter of the façade wall for the summer season, but when you add the cigarette butts to the concrete mixture, the cooling load will be reduced to the limits of (25.22- 22.9) Ton Refrigeration according to the percentage of addition of cut pieces (the first method of adding cigarette butts). The cooling load of the wall when using the second method of the filament fabric mesh was in the boundaries of (20.85- 17.13) Ton Refrigeration, depending on the number of mesh layers added. Finally, using the third method, which combines between pieces and mesh, the cooling load was observed at the limits of (18.21 - 15.24) Ton Refrigeration. This has definitely led to a reduction in the quantities of electrical energy consumed by the air-conditioning unit, as indicated in Fig. 8, which are in the limits of (6.39-11.55) (kWh) when using the first method (cutting method), (16.12-24.4) kWh when using the second method (screen method) and (22.01-28.6) kWh when using the third method (combination of pieces and mesh grids).

Energy saving:

It is clear from the results shown in Fig. 8, that the percentage of reduction in the level of electrical energy consumption for seasonal air conditioning purposes and for every one square meter of the outside wall when constructing it with the concrete materials under study compared with the energy consumed when building with conventional materials was (10.2-18.5) %. When using the first method (cutting), it was in the limits of (25.81 - 39) %. When using the second and third methods (screen and compound), it was (35.2 - 45.7) %.

Density of building materials:

It is evident from Table 1 that adding the cigarette butts to the concrete mixture to form the building mass has led to a decrease in the density of the mass after drying. The reason for this is due to the difference in the density of the heels compared to the density of the concrete, in addition to the cavities that will cause water to withdraw from the heel itself during the drying phase. It is also noted that increasing the percentage of the added butts in the form of small pieces (the first method) will reduce the amount of clumping density even more. The percentage of reducing the amount of density was in the range of (3- 15.22) % according to the amount of addition. When using the second method (filamentous web), it was in the limits of (12.6-20.8) % depending on the number of layers added. Finally, the change in the values will be in the limits of (21.3- 26.52) % according to the percentage of cut pieces and the number of screen mesh. With this we can say that the second goal of this research of reducing the density of concrete was achieved.

Absorption and Compressive Strength:

As shown in Table 1, the amount of water absorption recorded an increase when the butts were added to the concrete mixture during the formation of the building mass, and that the percentage of the increase in absorbance was within the limits of (3.13 - 6.25) % when compared with the absorbance of traditional materials in the case of using the first method (cutting method). However, when adding the textile filament nets (the second method), a higher rise was recorded which was in the limits of (6.25-9.4) % depending on the number of layers. Finally, by use of the compound (the third method), the increase was in the limits of (12.5-18.8) % when compared with traditional materials. As for the compressive strength, it recorded a decrease compared to what it was in the case of conventional materials. The decrease was in the limits of (1.7- 10.8) % when using the first method (cutting) and, when using the second method (layers), the decrease was higher and reached the limits of (6.7-20.8) % depending on the number of layers. Finally, when using the third (combined) method, the decrease was in the boundaries of (16.7 - 38.3) %. The reason for this is that the butts are used in the form of pieces that are distributed within the building mass and because it is less dense it is made of concrete and is flexible, so the resistance of the materials to compression decreases with the increase in the presence of these pieces in them, that is, by increasing the added percentage. While using the butts in the form of a filamentous web, it will expand on the entire cross-sectional area of the building material and lead to a decrease in its resistance to compression, but with the increasing use of the framing method in construction, we do not find any harm from adopting this material and the decrease in its resistance to the compression can be overlooked.

4. Conclusion

From the above, it is clear that:

- Adding cigarette butts to the concrete mixture via any of the three methods used will reduce its density and increase its resistance to heat transfer through it.
- The use of cigarette butts in small pieces at a rate of 1% will save 6.29 kWh electrical energy, and the percentage of savings when compared with the traditional wall was 10.2%. However, when the mixing percentage increases, the savings will increase and reach 18.5 kWh. The percentage of savings can reach 18.5% at a mixing amount of 5%.
- The use of cigarette butts in the form of a single filamentous web will save energy in the limits 16.1 kWh and the percentage of savings will be 28.8 %. When the number of layers increase, the saving will increase to 24.4 kWh and the percentage of saving will be within the limits of 39%.
- The joint use of parts and screen leads to achieving greater savings. The amount of rational energy saved when adding 5% with 5 layers was 28.6 kWh and the percentage saving was in the limits of 45.7% of what is consumed of energy in traditional construction.
- The resulting materials will decrease in density by increasing the percentage of addition, which means reducing the dead weights of the wall and thus leads to a reduction in the dimensions of the building's foundations. As a result, the other works used to support the building will decrease.
- The compressive strength of the concrete materials in which cigarette butts have been added decreases. Therefore, it is not recommended to use them in the case of the construction of load-bearing walls, but by increasing the use of structural

buildings, we do not find harm from their use because the constructed wall can only bear weight.

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