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A Research on the Usage of Corn Cob in Producing Lightweight Concrete

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Abstract

In this study, the possibility of using corn cobs as an organic aggregate in producing lightweight concrete has been investigated. First, some important physical properties of corn cob have been determined in the laboratory. These properties are as follows: weight to volume ratio (unit weight), water absorption rate and granulometric analysis. Later on, 4 concrete mixtures have been prepared according to the workability of concrete and standards specified in Turkey. After that, unit weight, heat transmissibility coefficient and 28-day pressure strength of these 4 concrete samples have been determined using machines measuring these properties. The 28-day pressure endurance value has been found between 1.4 - 56.25 kgf/cm^2, heat transmissibility coefficient has been found between 0.19 - 0.35 Kcal/m·h·˚C and unit weight of samples have been found between 800 - 1520 kg/m^3. Lastly, these properties of concrete samples have been compared with other lightweight materials being used in the construction of buildings.

Keywords

Ground Corn Cob, Lightweight Concrete, Aggregate, Granulometric Analisi, Pressure Strength

1. Introduction

Our country, Turkey has got a great corn production capacity in relation to land, water and climate conditions. The yearly corn production area of Turkey is 575,000 hectares and mean year of corn is 3900 kg/ha. The greatest corn producing provinces are as follows; Samsun, Trabzon, Rize, Kocaeli, Ordu, Bursa, Tekirdağ and Edirne [1]. Corn that if left after graule corns are separated is called corn-cob and there is an abundant quantity of corn cob in our country. That's why we intended to use this corn cob in using light weight concrete. The

usage of organic material in producing lightweight concrete is very new and usage of the unnatural lightweight material such as volcanic ash, diyatomit, and pumice are common [2]. Paramaswaran [3] points out that the usage of organic material as a construction material is rare and states that linen, hemp which is being produced profoundly in countries such as Thailand, Indonesia and Malaysia can be used in construction.

Wills, points out that these lightweight concretes have a high void proportion and low durability [4].

Today the usage of lightweight concrete as a construction material is very important. Lightweight concrete can be used in places where lightness and heat isolation is important besides the pressure strength of construction materials. Their unit weight can vary between 400 and 2000 kg/m^3 The main objective of producing lightweight concrete is to produce a material that is high and has got good isolation properties. Lightweight materials can decrease the load carried by buildings. Considering normal concrete, this load will equal the moving loads carried by buildings. In normal concrete usage, the materials cannot be used economically and loads carried by the building foundation will increase. Lightweight concrete is useful in that respect. Although they are far from obtaining mechanical endurance they are useful with respect to the horizontal load bearing strength of buildings [5].

The usage of organic and inorganic materials in producing concrete as a void creator is not very old. Theoretically, these types of materials that are left in farms such as corn cob and plant residues can create environmental problems. While farmers burn these residues they can be harmful to environment. Besides burning these residues is an illegal practice. These light plant residues can be versitile because they are light, have got high isolation abilities, they are resistant to frost and chemical effects, they have enough pressure strength, they retain plaster and they are cheap [6].

In our country Turkey there are some studies related to the usage of lightweight aggregate in building agricultural construction. While these studies concentrate on inorganic materials, the usage of ground corn cobs in producing lightweight concrete is new and also economic.

In this research, the possibility of using ground corncob in producing lightweight has been dealt with. In this regard, some physical properties of ground corn cobs and properties such as pressure endurance and unit weight of produced concrete samples have been determined.

2. Materials and Methods

In this research to produce lightweight concrete samples groung corn cob (20 kg), 324 portland cement, sieve series compatible with DIN 1045, cement mold, Instron 1114 pressure—pulling measurement machine, Shorterm QTM-D2 Heat Tramsmissibility Measurement Instrument, iron saw, mold oil, shovel labels have been used.

After grinding the corncobs by using grinding machine used in farmers the produced groundcobs have been sifted out to six different diameter sizes by using sifting series as follows: larger than 15 mm, 7 mm - 15 mm, 3 mm - 7 mm, 1 mm - 3 mm, 0.2 mm - 1 mm and smaller than 0.2 mm.

Pressure endurance of concrete samples has been found by using Instron 1114 machine and to test the isolation properties of ligthweight concrete samples the Shoterm QTM-D2 Heat Transmissibility Measurement Instrument have been used.

2.1. Calculation of Unit Weight of Corn-Cob

To find unit weight of corn cob, one unground corn cob has been coated with parafin [7]. First, one uncoated corn cob has been weighted and its mass has been determined ($P1$). Later this corn cob has been coated with parafin ($P2$). The coated corn cob has been sank into a measuring cylinder some of which is filled with water. Its volume has been determined as the rising water level of cylinder ($V1$). By using parafin's specific weight parafin's volume has been calculated ($V1 - V2$) and later corncob's volume has been determined ($V1 - V2 = V3$). Corn cob's unit weight calculated as follows:

$$\Delta = \frac{P1}{V3} \tag{1}$$

Δ = Corn cob's unit weight (gr/cm^3);

$V3$ = Corn cob's volume (cm^3);

$P1$ = Corn cob's weight (gr).

2.2. Ground Corn Cob's Water Absorption Rate

While determining the corn cob's water absorption capacity DIN 1045 German sleek series was used and after dividing the ground corn cob into six granule parts they were put into water for 6 days [8]. According to this:

Water Absorption Rate (%):

$$\frac{\text{Wet Corncob's Weight} - \text{Dry Corncob's Weight}}{\text{Dry Corncob's Weight}}$$

In this research, DIN 1045 German Norm sleek series have been used to sift out sand that is compatible with TSE 707. These siftings have been realized in the Laboratories of Irrigation and Drainage Department of Agean University's Agricultural Faculty.

2.3. Preparation of Concrete Mixtures

While preparing concrete mixtures "one part cement, 2.5 parts sand, 3 parts gravel and 0.5 part water" principle has been used [9]. According to this principle sand and gravel have been replaced with ground corn cob and water has been added concidering water absorption capacity of corn and water content of concrete samples. By making these mixtures, suitable concrete consistencies have been determined. While preparing two different mixtures, first mixture had

lower cement amount and ground corn cob amount have been decreased by 50 per cent to substitute with sand. In the second mixture, there was a great amount of cement and ground corn cob amount was decreased by 50 per cent and later by 60 per cent to mix with sand.

Using four mixtures, concrete samples have been evaluated according to their 28-day pressure endurance, transmissibility and unit weight properties. These features of concrete samples have been tested in Dokuz Eylul University's Machine Engineering Department's Laboratories.

3. Results and Discussions

Unit weight of unground corn cob has been found as 0.57 gr/cm^3 according to Formula (1).

Ground corn cob's water absorption rates have been given in Table 1.

To prepare mixtures that are compatible with TS 707 [10] standards and to align granulametric line of ground cobs with reference lines of TS 707 standards a concrete mixture comprising 60 per cent sand and 40 per cent ground corn cob has been prepared.

This mixture and the granulometric line of sand and ground corn cob mixture's granulometric line have been shown in Table 2 and Figure 1.

Lightweight concrete samples that have been mixed by using ground corn cob, cement, sand and water are shown in the following Table 3.

Table 1. Water apsorption rate of ground corn cobs of different diameters.

Ground Cor cob's Granule Diameter (mm)	Water Absorption According To Weight (%)
>15	166
15 - 7	149
7 - 3	168
3 - 1	196
1 - 0.2	140

Table 2. Sieve analysis results of sand and ground corn cobs.

Sieve Diameter (mm)	Passing Granule Per Cent (%)		
	Sand	Ground Corn Cob	Mixture (60% Sand and 40% Corn Cob)
16	100	100	100
8	100	30	72
4	95	10	61
2	83	4	51
1	56	2	34.4
0.5	20	0.5	12.4
0.25	4	0.36	5.54
Under sieve	0	0	0

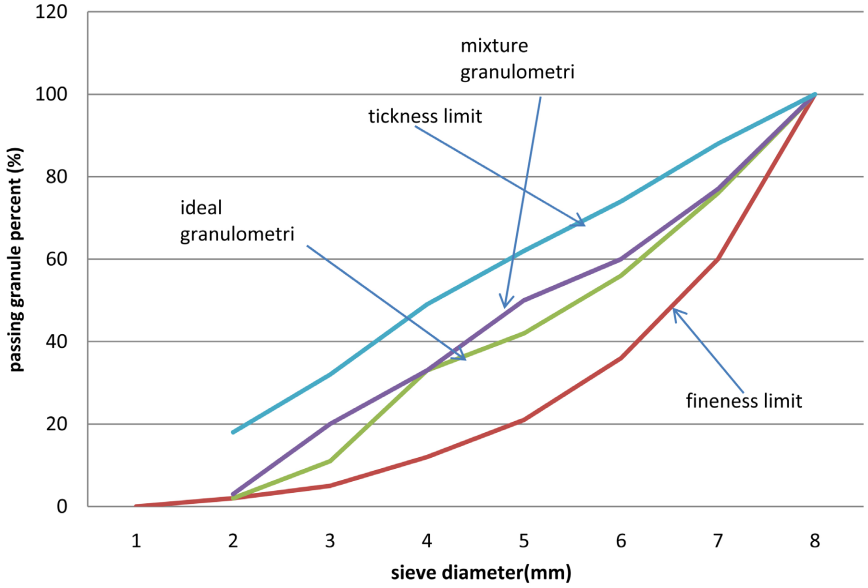

Figure 1. Granulometric line of sand and ground corn cob's mixture.

Table 3. Concrete samples that have been prepared.

Mixture Number	Content of Mixture				Water Cement Ratio
	Ground Corn Cob (gr)	Cement (gr)	Sand (gr)	Water (gr)	
1	400	885	-	684	0.77
2	200	885	200	564	0.63
3	200	1200	200	560	0.46
4	240	1200	200	530	0.44

Unit weight, pressure endurance and heat transmissibility of 4 concrete mixtures are given in Table 4.

As can be seen in Table 4 the amount of sand and cement has a serious effect on pressure endurance of mixtures. If we compare first and second mixtures we can see that by adding sand pressure enduranced properties of samples have increased 15 fold. If we decrease the ground corn cob amount by 50 percent the heat transmisibillity coefficient has risen from 0.19 Kcal/m·h·˚C to 0.31 Kcal/m·h·˚C. Because corn cob is a bad insulator, heat transmissibility coefficient has risen. Unit weight value has risen by adding sand and risen from 0.8 gr/cm^3 to 1.26 gr/cm^3. In mixtures 2 and 3 while ground corn cob and sand amounts were the same, cement amount has risen from 885 gr to 1200 gr. With this change, pressure endurance of sample has risen one and a half and unit weight value also has risen from 1.26 gr/cm^3 to 1.52 gr/cm^3. If we compare number 3 and number 4 mixtures we can see that if we use the same amount of cement and increase the ground corn cob amount from 200 gr to 240 gr we reached a pressure endurance value of 56.25 Kcal/m·h·˚C.

With increasing ground cob amount the heat transmissibiblity coefficient droped from 0.34 Kcal/m·h·˚C to 0.33 Kcal/m·h·˚C. Unit weight value of number

Table 4. Physical and mechanic properties of concrete samples.

Mixtures	Obtained Values of Concrete Mixtures		TSE 453 Standart Limit Values [11]		
			Pressure Endurance (khf/cm^2)	Heat Transmisibility Coefficiency (Kcal/m·h·˚C)	Unit Weight (gr/cm^3)
1	Pressure Endurance (khf/cm^2)	1.4	15 - 75	0.14	0.4 - 0.8
	Heat Transmisibility Coefficiency (Kcal/m·h·˚C)	0.19			
	Unit Weight (gr/cm^3)	0.8			
2	Pressure Endurance (khf/cm^2)	21.12			
	Heat Transmisibility Coefficiency (Kcal/m·h·˚C)	0.31			
	Unit Weight (gr/cm^3)	1.26			
3	Pressure Endurance (khf/cm^2)	31.50			
	Heat Transmisibility Coefficiency (Kcal/m·h·˚C)	0.34			
	Unit Weight (gr/cm^3)	1.52			
4	Pressure Endurance (khf/cm^2)	56.25			
	Heat Transmisibility Coefficiency (Kcal/m·h·˚C)	0.33			
	Unit Weight (gr/cm^3)	1.30			

3 mixture which has a lower proportion ground cob is 1.52 gr/cm^3. And this value of number 4 mixture has risen to 1.3 gr/cm^3 because of the increase in corn cob amount. With the increase of ground corn cob amount the unit weight values of mixtures have increased proportionally.

Comparison of Light Weight Concrete with Other Construction Materials

To make this comparison, some other lightweight construction materials' properties have been given in Table 5.

The first material to be used in comparing is adobe. Adobe is mixed with straw by farmers it resembles the concrete samples produced in this research with this respect. The mean pressure strength od adobe is 31.50 kgf/cm^2 and this value is 31.50 kgf/cm^2 and 56.25 kgf/cm^2 for number 3 and number 4 lightweight concrete samples. These concrete samples as a substitute for adobe in contructing agricultural buildings.

The second material to be used in comparison is brick. Balaban and Şen [13] states that the pressure strength of brick is between 30 kgf/cm^2 and 50 kgf/cm^2. The number 4 concrete sample produced has a pressure strength of 56.25 kgf/cm^2 and irresembles to brick in that respect. Because unit weight of brick is very low when compared with concrete, its insulation abilities are high. If it is used like brick it occupies less building area compared with Stone brick and it gives rice to an increase in useful building space.

Table 5. Properties belonging to some materials.

Meterial	Properties		
	Unit Weight (kg/m^3)	Pressure Endurance (Kgf/cm^2)	Heat Transmisibillity Coefficient (Kcal/m·h·˚C)
Volcanictuff concrete*	1300 - 1800	52 - 204	-
Pumice concrete*	1800 - 2000	102 - 459	-
Perlit concrete*	400 - 500	12 - 30.6	-
Vermiculit concrete*	300 - 700	2 - 10.6	-
Brick***	-	30 - 50	-
Adobe***	-	33.5	-

*CEB, FIB [12]. ***Balaban and Şen [13].

Another material to be used in comparison is aerated concrete. Aerated concrete can be produced with different strength classes according to TS 453 and has got pressure strength values between 15 kgf/cm^2 and 75 kgf/cm^2 ant it has heat transmissibility values varying between 0.17 Kcal/m·h·˚C and 0.23 Kcal/m·h·˚C. Because these values are paralel with the values of concrete samples produced in this research they can be used like aerated concrete.

When we compare the pressure strength of lightweight concrete produced by using perlitte and vermiculite we can say that the concrete samples 3 and 4 can be used as an alternative to perlite concrete and it is thought that they can be useful when used as dividing walls of agricultural buildings considering heat insulation benefits.

Heat transmissibility coefficient of insulation concrete varies between 0.06 Kcal/m·h·˚C and 0.25 Kcal/m·h·˚C. Because these values are parallel with the values obtained in this research they can be used as insulation floor and roof coatings [14].

4. Conclusions

In this research, the possibility of using ground corn cob in producing lightweight concrete has been investigated. By mixing sand, ground corn cob, cement and water in four different mixtures, pressure endurance property, heat transmissibility coefficiency and unit weight of concrete samples have been obtained. Different concrete samples' pressure endurance values ranged between 1.4 - 56.2 kgf/cm^2 and teat transmissibility coefficient values ranged between 0.19 - 0.34 Kcal/m·h·˚C while unit weight of samples changed between 800 - 1520 kg/m^3.

The obtained samples can be used as insulation materials and decorative materials. By increasing cement amount, concrete samples can be used for load carrying purposes in construction. If we increase the ground corn cob quantity, water absorption of concrete will also increase. That is why concrete samples must be coated with plaster coating in using construction. Because of the presence of ground corn cob, the concrete samples absorbed water amounting to 2

or 18 percent of their weights that's why the concrete samples must not be used in damp environments.

In addition, the usage of lightweight concrete for decorative purposes like thin brick can be possible.

Turkey produces a lot of corn and usage of corn cob in producing lightweight concrete instead of burning them can be more economical. But grinding the corn cob necessitates fabrication. Because the water absorption rate of concrete samples increases with increasing cor cob quantity it is not suitable to use it in construction materials that can absorb water quickly. It is also not suitable to use these lightweight concrete samples without coating them with a protective substance such as emulsified asphalt. Because the specific weight of corn cob has not been found, this weight must be calculated and this research must be developed in this regard.

To withstand the pressure being applied to buildings, how much cement must be added to mixtures can be another research topic. Because corn cob is an organic material, organisms living, inside it is another aspect that must be taken into consideration. This research which used ground corn cob in producing lightweight concrete can be developed by inspection of physical and mechanical properties of produced concrete samples further.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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