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EFFECTS OF ORGANIC WASTE (RICE HUSK) ON THE CONCRETE PROPERTIES FOR FARM BUILDINGS

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Abstract

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The objective of this research was to investigate physical, mechanical and thermal properties of concrete produced by using organic waste (rice husk). Concrete with a dosage of 300 was produced by adding various amounts of rice husk into the normal aggregate (5, 10, 15, 20, 25 and 30%). The compressive strength and unit weight of the samples were determined after 7 and 28 days, and the water absorption rate, freezing-thawing resistance and thermal conductivity were determined after 28 days. According to the experimental results, the compressive strengths and unit weights of the concrete ranged between 17.6 and 37.5 MPa and between 1797 and 2268 kg/m^3, respectively. All concrete produced were resistant to freezing. The concrete water absorption rates were below 5.5%. In addition, thermal conductivities varied between 1.53 and 0.79 W/mK. In conclusion, rice husk had potential as a material to produce lightweight concrete when considering its strength, resistance and insulation properties, and to be used in agricultural buildings

Key words: farm buildings, concrete, lightweight concrete, organic waste, physical and mechanical properties, thermal properties

Introduction

Presently, the energy needed to provide comfortable conditions in buildings is the most costly component. Therefore, component for future consideration in construction design should be heat isolation. To provide the needed thermal comfort in shelters such that temperature effects do not negatively affect buildings and living beings are relaxed and comfortable, it is necessary to consider the heat isolation properties when constructing building (Ozturk and Bayrak, 2005).

Several factors must be considered in building construction. Material selection is the most important factor. The proper selection of the construction materials serves to ensure that the building functions as expected and helps economic construction. Isolation and low-cost construction are particularly important for agricultural constructions, because, in general, farm buildings are one or two floors and carry low loads. Therefore, the strength of constructed buildings is not as important as heat isolation and construction cost (Orung, 1995; Karaman et al., 2006).

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Due to their low unit weight and high porosity, lightweight concrete elements are preferred as isolation materials. Comfort temperature values with lower energy consumption are possible by using lightweight concrete in construction elements. Since the early 1980s, due to the superiority of lightweight concrete, the production in this field has increased, and important industries have developed in that area (Rossingnolo and Agnesini, 2001). The greatest advantages of lightweight concrete are its low density, allowing for construction on the ground with only moderate bearing capacity, the use of less reinforcement, the ability to construct taller structures, greater economy in lifting and the use of more thermally efficient material (Gunduz and Ugur, 2004).

The unit weight of concrete can be lowered by either using porous, therefore lightweight, aggregates instead of ordinary ones, introducing air into the mortar or removing the fine fraction of aggregate, and then by partially compacting the concrete. In all cases, the main goal is to introduce voids into the aggregate and the mortar or between the mortar and aggregate. A combination of these methods can also further reduce the weight of the concrete (Gunduz and Ugur, 2004).

To produce lightweight concrete, numerous methods can be used. The most popular method is the use of natural, synthetic or organic lightweight aggregates. Examples of lightweight aggregates are pumice, coal slag, flying ash, rice husk (RH), straw, sawdust, cork granules, wheat husk, coconut fiber and coconut shell. The organic waste used in lightweight concrete is mainly of plant origin and includes RH, straw, sawdust, cork granules, wheat husk, coconut fiber and coconut shell (Khedari et al., 2001; Manan and Ganapathy, 2002).

By using plant waste that is abundantly found in rural areas, it may be possible to construct cheaper and good quality agricultural constructions. With the developments in technology and material science after the 20th century, the importance and usage of composite materials has grown.

Generally, concrete with a unit weight of less than 2000 kgm^{-3} is classified in the lightweight concrete class. Lightweight concrete, manufactured from either natural or artificial aggregates, is classified by the American Concrete Institute (ACI) Committee into three categories according to its strength and density. The first category is termed low strength, corresponding to low density, and is mostly used for insulation purposes. The second category is moderate strength and is used for filling and block concrete. The third category is structural lightweight concrete and is used in reinforced concrete (Sari and Pasamehmetoglu, 2004). The compressive strength and unit weight values for the lightweight concrete categories are given in Table 1.

RH, as an organic waste, is a significant problem in rice-cultivating areas because it is not used profitably and is generally burned after harvest, which causes environmental problems. More than half of the rice production in Turkey occurs in the Thrace region. Farmers claim that after rice production has finished, RH is their main problem in preparing seed beds for future crops to be grown. Use of RH in concrete production may solve this environmental problem and provide an advantage in producing lightweight and low-cost concrete. The aim of this study is to examine the effect of RH on the engineering properties of concrete.

Table 1

The lightweight concrete categories according to ACI (Sari and Pasamehmetoglu, 2004)

Properties	Lightweight concrete category		
	Low	Moderate	Structural
Unit weight, kg/m^3	< 1000	1000–1500	1500–2000
Compressive strength, MPa	0.70-2.00	2.00-15.00	16.00-42.00

Materials and Methods

The main material used in this study was RH, which was the paddy waste produced in the Thrace region. Furthermore, mixed coarse aggregate passed through an 8 mm sieve, natural river sand and ASTM Type I (PC 42.5) Portland cement were used as binding materials. The chemical composition and physical properties of the aggregate and cement used in this study are given in Tables 2 and 3, respectively.

To prepare the lightweight concrete material samples, nominal mixing techniques were applied because of the organic origin of RH (BS 5328, 1976). Organic material contents of the aggregate decrease the compressive strength (Ozturk and Bayrak, 2005). Therefore, the RH ratio of the mix was fixed at values less than 30%. The RH was obtained from the Ipsala region in the Thrace region. The RH used in the mixtures was soaked with water for approximately 30 min because the RH had high water absorption.

Based on weight the ground river sand and coarse aggregate were mixed thoroughly in a dry

Table 2
Chemical composition and physical properties of the natural aggregates

Material properties	Natural aggregate	
	Slight	Coarse
SiO_2, %	89.82	43.64
CaO, %	0.10	18.49
Fe_2O_3, %	0.48	12.84
Al_2O_3, %	4.89	10.22
K_2O, %	2.95	0.03
MgO, %	0.39	7.82
Loose unit weight, kg/m^3	1540	1462
Condensed unit weight, kg/m^3	1635	1619
Specific gravity, kg/m^3	2700	2790
Water absorption, %	1	0.6

Table 3
Chemical composition and physical and mechanical properties of the cement

Chemical composition		Physical and mechanical properties		
Component	%			
Insoluble residue	0.52	Specific gravity, g/cm^3		3.14
		Setting time	Initial, min	137
SO_3	3.11		Final, min	194
		Soundness (Le Chatelier - mm)		1
Loss on ignition	1.25	Specific surface, cm^2/g		3700
		Compressive strength, MPa	day 2	26.6
cr	0.0385		day 7	40.8
			day 28	55.8

state. Then, the natural aggregate was replaced with the RH at ratios of 0 (CRH0), 5 (CRH5), 10 (CRH10), 15 (CRH15), 20 (CRH20), 25 (CRH25) and 30% (CRH30) by volume. The CRH0 concrete class was the control concrete. The cement dosage and water-cement ratio in the mixture for all concrete classes were kept constant at approximately 300 kg/m^3 and 0.6, respectively.

Concrete test samples were 15 cm x 15 cm x 15 cm cubic samples. All the test samples were molded and held for 1 day and then cured in a water tank at 20 ± 2ºC until the 6th and 27th days (TS EN 12390-2, 2002). For each stage, samples for each concrete class were tested and examined for physical and mechanical properties. The compressive strength (TS EN 12390-3, 2003) and unit weight of the samples (TS 3624, 1981) were determined after 7 days and 28 days, and the water absorption rate (TS 3624, 1981), freezing-thawing resistance (Ekmekyapar and Orung, 2001) and thermal conductivity (TS EN 1946-1, 2000) were determined after 28 days. To evaluate the reproducibility of the results, all measurements were conducted on three samples.

Results and Discussion

The experimental results on the characteristics of the fresh and hardened concrete are presented in Tables 4 and 5. Seven different mixture compositions (CRH0 to CRH30) were examined in this study, and their mixture proportions and fresh concrete consistency are given Table 4. The microscopic image of hardened concretes (CRH0 and CRH30) is presented in Figure 1.

Consistency

The slump results are given in Table 4. The slump values of the samples increased with the amount of RH in the mixtures. This increase in the slump values resulted from the 30 min water soak performed on the RH. The slump values varied between 8.0 and 10.4 cm. The fresh concrete produced in this study was in the plastic consistency condition, and CRH25 and CRH30 were in the S3 class while all others were in the S2 consistency class (TS 11222, 2001).

Unit weight

According to the obtained data, the unit weight of the 7- and 28-day hardened samples decreased with increasing RH content because the specific gravity of RH was lower than that for the natural aggregate (Table 5). The highest unit weight at day 28 was 2268 kg/m^3 for the CRH0 mixture, and the lowest value was 1797 kg/m^3 for the CRH30 mixture. The relationship between the unit weight and the amount of RH is shown in Figure 2. The unit weight decreased linearly with an increase in the RH amount in the mixture. The concrete

Table 4
Mixture proportions

Mixture	Cement, kg/m^3	Coarse aggregate, kg/m^3	Sand, kg/m^3	RH, L/m^3	Water, kg/m^3	W/C	Slump, cm
CRH0	300	766.52	1188.10	-	180	0.6	8.0
CRH5	300	728.15	1128.72	35.48	180	0.6	8.2
CRH10	300	689.88	1069.63	70.96	180	0.6	8.7
CRH15	300	651.60	1009.88	106.47	180	0.6	9.1
CRH20	300	613.33	950.62	141.98	180	0.6	9.6
CRH25	300	574.81	891.11	177.53	180	0.6	10.0
CRH30	300	536.54	831.60	213.09	180	0.6	10.4

Table 5
Physical and mechanical properties of the concrete

Mixture		CRH0	CRH5	CRH10	CRH15	CRH20	CRH25	CRH30
Unit Weight,	7 day	2228	2125	2003	1947	1845	1798	1762
kg/m^3	28 day	2268	2172	2077	1992	1918	1849	1797
Compressive strength, MPa	7 day	30.3	27.1	24.6	22.1	19.7	17.1	14.2
	28 day	37.5	33.8	30.3	26.8	23.4	20.5	17.6
Water absorption %		3.03	3.45	3.93	4.36	4.77	5.12	5.48
Freezing-thawing resistance (Compressive strength after freezing-thawing) (MPa)		35.9	31.8	27.7	23.8	21.1	18.7	16.1
Thermal conductivity W/mK		1.535	1.290	1.126	0.990	0.88	0.79	0.71

with more than 15% RH in the mixture could be classified as lightweight concrete, with respect to their unit weights.

Compressive strength

The compressive strengths of the samples on days 7 and 28 ranged from 15.2 - 31.3 MPa and 18.1 - 37.5 MPa, respectively, indicating that in the first 7 days, the concrete attained about 81% of the strength at day 28 (Table 5). Typically, in the first 7 days the normal weight concrete achieved 70–80% of the strength at day 28 (Lo and Cui, 2004). The development of the initial concrete strength was a little higher than the normal weight concrete due to the use of the PC 42.5 cement in the mixture.

The relationship between the RH content and the compressive strength is shown in Figure 3. The compressive strengths of the samples on days 7 and 28, by unit weight, decreased with increasing RH content in the mixtures. Using aggregate

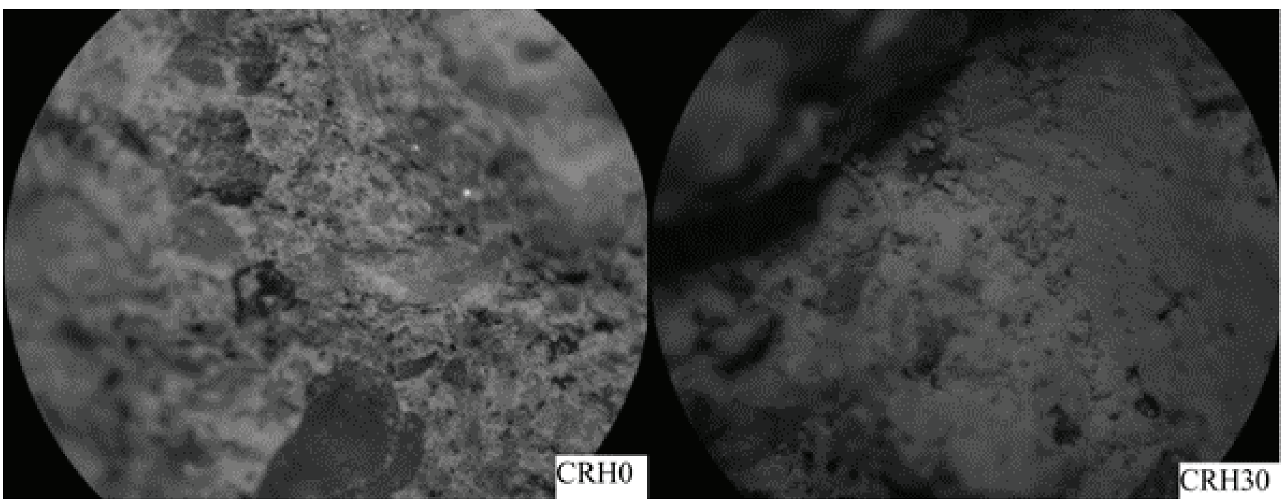

Fig. 1. The microscopic image of the hardened concretes

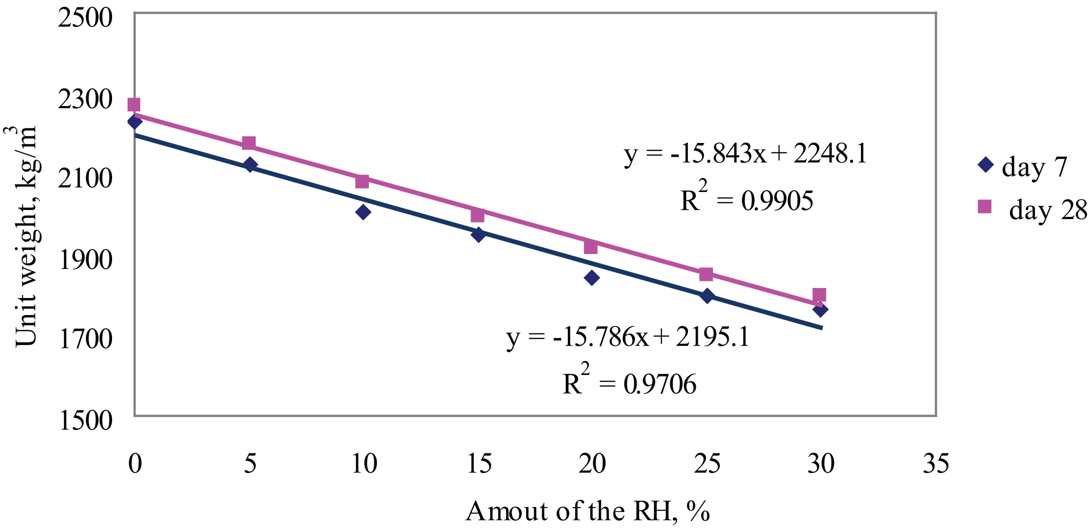

Fig. 2. The unit weight versus the amount of RH

replacement with RH contents of 5, 10, 15, 20, 25 and 30% decreased the 7 day compressive strength by 10, 9, 10, 11, 13 and 16% and the 28 day compressive strength by 9, 10, 11, 12, 13 and 14%, respectively.

The relationship between unit weight and compressive strength after 7 and 28 days is shown in Figure 4. The compressive strength increased linearly with an increase in unit weight.

The concrete produced in this study was classified as structural lightweight concrete with respect to their unit weight and compressive strength. Structural lightweight concrete is defined by a minimum compressive strength of 16 MPa and a unit weight less than 2000 kg/m^3 (Kosmatka and Panarese, 1992).

Water absorption

The water absorption of the samples on day 28 ranged between 3.03 and 5.48% (Table 5). The minimum water absorption value was 3.03% for CRH0, and, as expected, using the RH as an

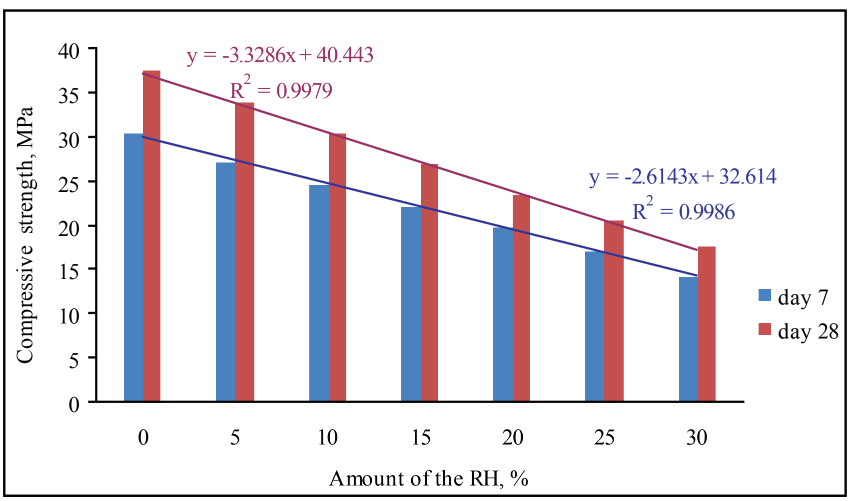

Fig. 3. The effect of RH on the compressive strength

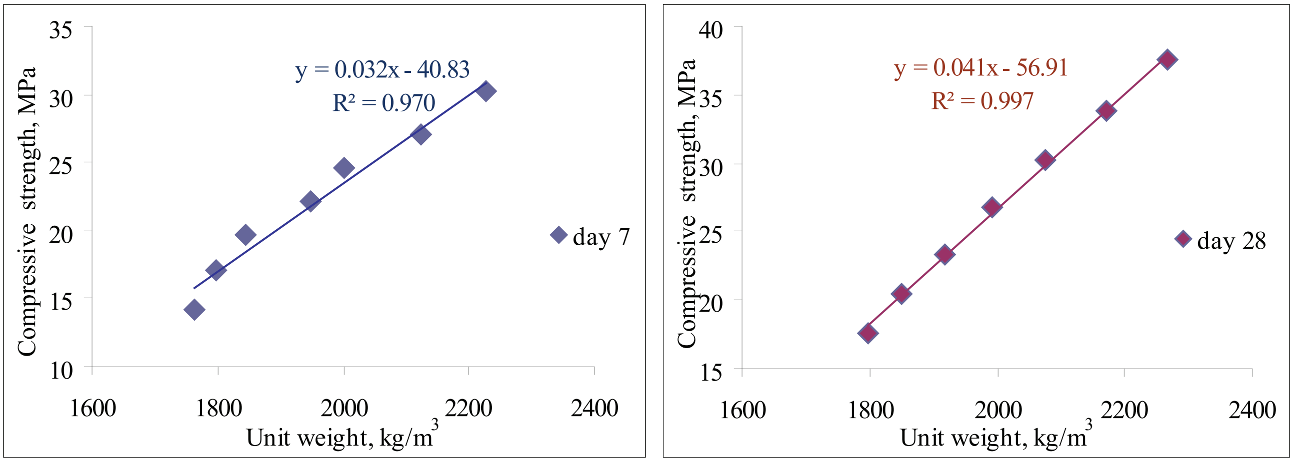

Fig. 4. The compressive strength versus unit weight

aggregate replacement resulted in an increase in sample water absorption. Figure 5 reveals that water absorption increased linearly with decreasing unit weight.

Freezing-thawing resistance

The resistance of concrete to freezing-thawing was determined by examining the changes in the compressive strength. For this reason, compressive strength tests were conducted after each freezing-thawing cycle. The results are presented in Table 5.

As the RH content increased in the mixture, the compressive strength values decreased; this behavior paralleled the resistance behavior before the freezing-thawing cycles. The decrease in compressive strength was greatest (10.9%) for CRH15 while the decrease was least (4.2%) for CRH0. Considering all of the results together, losses in compressive strength due to freezing-thawing cycles remained well below the maximum losses reported by Erdogan (2004) for concrete. Therefore, according to the standard specifications that state the loss in compressive strength must be less than 20%, it may be concluded that all concrete samples can be qualified as suitable.

Thermal conductivity

Table 5 shows the variation in thermal conductivity with RH ratio. The thermal conductivities of the samples were 1.53, 1.29, 1.12, 0.99, 0.88, 0.79 and 0.71 W/mK with RH aggregate replacement values of 0, 5, 10, 15, 20, 25 and 30% by aggregate volume, respectively. These results are due to the fact that the thermal conductivity is a function

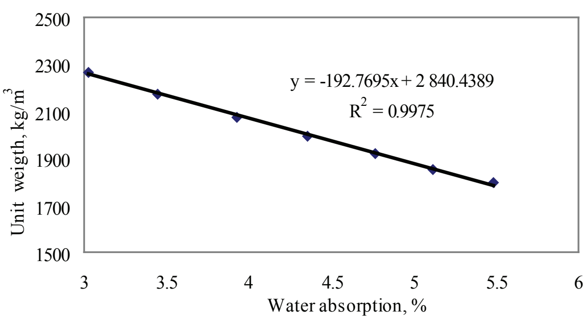

Fig. 5. The relationship between water absorption and unit weight

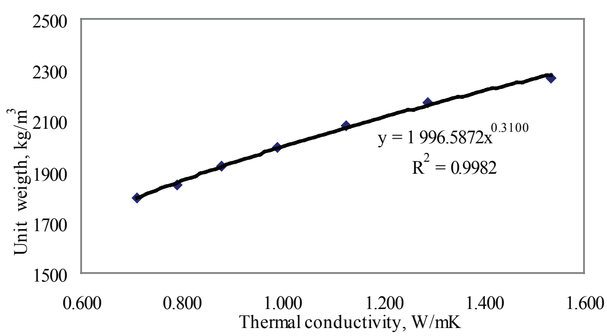

Fig. 6. The relationship between thermal conductivity and unit weight

of unit weight. Steiger and Hurd (19789, Lu-shu et al. (1980), Blanco et al. (2000) and Uysal et al. (2004) reported this relationship between the thermal conductivity and the unit weight of lightweight concrete. They experimentally derived a correlation between the thermal conductivity and the unit weight for lightweight concrete and also reported that the thermal conductivity increased with increasing unit weight. Figure 6 shows the variation in thermal conductivity with the unit weight.

Using an aggregate replacement with RH contents of 5, 10, 15, 20, 25 and 30% decreased the thermal conductivity by 16, 13, 12, 11, 10 and 10%, respectively.

Conclusions

The results indicate the following:

- The unit weight of the produced concrete samples varied between 2268 and 1797 kg/m^3. When the RH amount in the mixture was greater than 15%, concrete could be classified as lightweight concrete with respect to their unit weights.

- The compressive strengths of the samples at days 7 and 28 ranged from 15.2-31.3 MPa and 18.1-37.5 MPa, respectively. The concrete produced in this study were defined as structural lightweight concrete when considering their unit weight and compressive strength.

- The water absorption of the samples on day 28 varied between 3.03 and 5.48%, and the use of RH as an aggregate replacement increased the water absorption.

- The thermal conductivity decreased with increasing RH content. The thermal conductivity varied between 1.53 and 0.79 W/mK. This research showed that the thermal conductivity of the RH aggregate concrete was approximately two times lower than that of an equivalent normal weight concrete.

According to the experimental results, it can be concluded that structural and insulating concrete can be produced using RH to meet the strength, resistance and insulation requirements, and the produced material can be used especially in agricultural buildings. Because farm buildings are one or two floors and they carry low load, isolation and low cost are more important than other properties of the concrete such as strength.

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