Jordan Journal of Civil Engineering, Volume **7**, No. **1**, **2013**

Research into Artificial Limestone Composites with Cotton Waste

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ABSTRACT

In this study, artificial limestone composites are produced by using cotton and limestone powder wastes. The thermo-elastic properties of produced composite specimens in various cotton waste amounts are investigated. At 40% cotton waste replacement with limestone powder waste in the composite specimen, the thermal conductivity and unit weight values are effectively reduced. The reduction in the thermal conductivity and unit weight values of the composite specimen at 40% cotton waste replacement with limestone powder waste is about 51% and 29% as compared with the control specimen. The energy conservation in buildings by using limestone powder waste and cotton waste composites having low thermal conductivity can reduce energy requirements. A strong relationship is also found among the thermal conductivity, unit weight and ultrasonic pulse velocity values of composite specimens produced.

KEYWORDS: Limestone dust, Waste cotton, Masonry, Thermo-elastic properties.

INTRODUCTION

Energy conservation is an important part of any national energy strategy. In the underdeveloped countries with inadequate resources, it is even more important (Hasan, 1999). Using natural waste materials with low thermal conductivity in building masonry units improves insulation of buildings by providing an energy efficient solution. The increase in the popularity of using environmentally friendly and lightweight construction materials in building industry has brought about the need to investigate how this can be achieved by benefiting to the environment as well as maintaining the material requirements affirmed in the standards.

The demand for natural cotton fibres and poly/cotton blend fibres has increased significantly in the past decade (World Bank, 2004). The development of new areas for cotton in Brazil, Africa and Turkey is contributing to the rise in world production, such as the expansion of irrigation in South East Turkey (GAP region) which now accounts for 500000 tons of production, compared with 164000 tons in 1995 (OECD, 2004). Approximately 20.5 million tons of cotton were grown by about 80 producing countries in 2004 for the fibre production (OECD, 2005). The waste from cotton processing is a mixture of stems, leaves, soils and lint. Cotton waste (CW) used in this research is generated from the mechanical processing of raw cotton in the spinning process. Because of the differences in the types of manufacturing facilities, it is difficult to determine the quantity of cotton waste generated. According to the experience of the cotton manufacturers in GAP region, approximately 7% of cotton ends up as waste produced in spinning. Therefore, it may be estimated that 1.5 million tons of cotton waste, not including lint content, were generated worldwide by the fibre manufacturers in 2004.

Another not effectively used industrial waste is limestone powder waste (LPW) that is also excessively available in large amounts from limestone processing

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Accepted for Publication on 14/11/2012.

factories worldwide. The processing of limestone which includes crashed limestone production results in approximately 20% LPW. The estimated LPW of 21.2 million tons in the UK (Manning, 2004) and 18 million tons in Greece is reported (Galetakis and Raka, 2004). Disposal of LPW causes dust, environmental problems and pollution because of its fine nature.

In a previous work (Algin and Turgut, 2008), the physico-mechanical properties of CW-LPW satisfied the standard specifications according to TS 705, ASTM C140, BS 6073 and ASTM C129 for load and non-load-bearing concrete masonry units to be used in buildings. The CW-LPW combinations as an aggregate in its natural form have allowed producing economic, lighter and environmental-friendly new composite materials. In this study, thermo-elastic properties of CW-LPW combinations as a composite material are investigated.

EXPERIMENTAL PROGRAM

MATERIALS AND FABRICATION OF SPECIMENS

CW used in this research is generated from the mechanical processing of raw cotton in the spinning process. The large amounts of secondary wastes (containing a mixture of stems, leaves, soils and lint) from the spinning process of cotton string manufacturers in the GAP region are currently disposed into the uncontrolled open waste pits. The CW used in the specimens is taken from its disposal area nearby the cotton string manufactures in the GAP region. LPW used in the composite specimens is produced during quarrying operations in the region. The results of chemical analysis and physical analysis of LPW, CW and cement used in this study are given in (Algin and Turgut, 2008).

Five different types of mixtures are prepared in the laboratory trials. All types of mixtures are prepared according to the requirements of BS 6073. The details of mixes are given in Table 1. The cement and water proportions in the mixes are taken as constant to determine the effect of various CW-LPW combinations.

Since the cotton wastes are of higher volume content**,** the replacement ratios between CW and LPW are taken as volumetric. For instance, the 20% replacement of CW means that 20% of the corresponding LPW volume is replaced by CW in the LC-20 specimens (see Table 1). The CW replacement in terms of the cement used can also be defined in this way, such that LC-10, LC-20, LC-30 and LC-40 mixes contain 8.5 %, 17.3%, 25.8 % and 34.6 % CW of the cement weight, respectively. The details of mixing, production and curing procedures of specimens are given in (Algin and Turgut, 2008). All of the specimens are tested after 28 days of curing period.

Table 1. Mixture proportions for (105×75×225) mm specimens

Mix no.	Cement (g)	Water (g)	LPW (g)	CW (g)	Total (g)
Control mix	376	188	2936	-	3500
LC-10	376	188	2706	32	3302
LC-20	376	188	2405	65	3034
LC-30	376	188	2117	97	2778
LC-40	376	188	1804	130	2498

A total of 15 specimens with dimensions of (105×75×225) mm are prepared for thermo-elastic properties. After ultrasonic pulse velocity (UPV) test is performed on these specimens, the specimens with dimensions of (20×60×100) mm are prepared for thermal conductivity test by cutting these specimens with a diamond saw. The cylindrical specimens with dimensions of ϕ 50×80 mm for testing elastic properties are also obtained by using a diamond saw.

TEST METHODS

Thermal conductivity (*k*) is the most important thermal property in relation to heat transfer problems, because it is necessary to know this property for energy analysis in buildings. A shotherm-QTM unit (Showa Denko) quick thermal conductivity meter based on ASTM C1113 hot wire method is used in the present study. Measurement range is 0.02-10 W m^{-1} K^{-1}. Measurement precision is ±5% of the reading value per reference plate. Measurement temperature is -100 to 1000°C. Three specimens of (20×60×100) mm per mix are used for testing thermal conductivity. Measuring time is standard (100-120s). This method has wide applications in determining thermal conductivity of refractory materials (Daire and Downs, 1980; Willshee, 1980; Sengupta et al., 1992).

The UPV measurements are performed on the specimens with dimensions of (105×75×225) mm by using TIKO make Pundit Plus equipment according to BS 1881. Three specimens per mix are used to test the UPV. The UPV through a material is a function of the elastic modulus and density of the material. The UPV value of specimens is determined by placing a pulse transmitter on one face of the specimen and a receiver on the opposite face. A timing device measures the transit time of the ultrasonic pulse through the specimen. Then the UPV can be calculated from the path length divided by the transit time. The path length is measured through the specimen length of 225 mm.

The specimens with a diameter of 50 mm and a height of 80 mm are used for testing the modulus of elasticity and Poisson ratio. The modulus of elasticity and Poisson ratio values are calculated according to ASTM C469. The modulus of elasticity and Poisson ratio are calculated as the average of three specimens. The end faces of the specimens are ground by using an end-face grinder and then checked for evenness and perpendicularity with respect to the vertical axis. At the mid-height of each specimen, two small strain gauges are attached: one along of length (vertical) and one along the circumference (horizontal). The strain gauges are of FLA-6-11 type (Tokyo Sokki Kenkyujo, Japan).

Table 2. Physical and thermal properties for masonry units studied

Mix no.	**Unit weight, (g/cm^3)**	**Porosity, (%)**	**UPV, (km/s)**	***k*, (W$m^{-1}K^{-1}$)**	**Modulus of elasticity, (MPa)**	**Poisson ratio**
Control mix	1.88	23.3	2.72	0.984	14934	0.20
LC-10	1.70	21.5	2.58	0.984	11489	0.22
LC-20	1.65	24.4	2.14	0.764	5746	0.22
LC-30	1.51	26.3	1.77	0.592	5081	0.25
LC-40	1.34	36.4	1.45	0.483	Failed	Failed

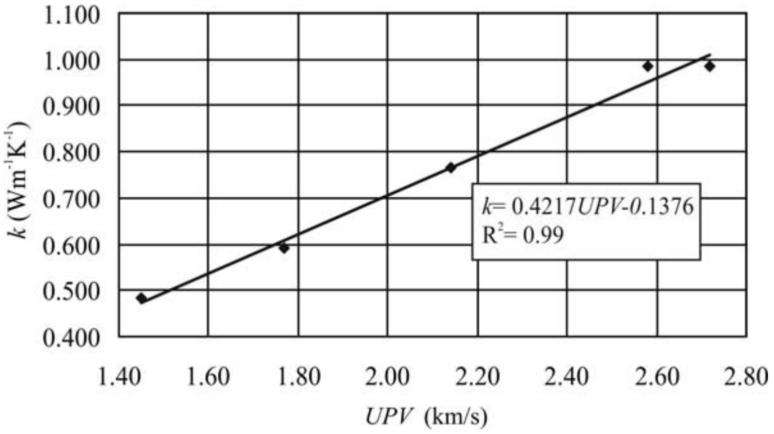

Figure 1: Relationship between thermal conductivity and UPV

TEST RESULTS AND DISCUSSION

Table 2 shows the averaged results obtained from the tests. The test results confirm that the thermal conductivity values are inversely proportional with the percentage CW replacement with LPW content. It ranges from 0.483-0.984 W m^{-1} K^{-1}, depending on the CW level. It is seen that thermal conductivity values of the specimens are as small as those of common brick materials used in buildings. There is no significant reduction in the thermal conductivity of LC-10 specimen as compared to the control mix obtained from the 10% CW replacement. But, in the 20%, 30% and 40% CW replacements, there is a significant reduction of thermal conductivity of LC-20, LC-30 and LC-40 specimens as compared to the control mix. At the 20%, 30% and 40% CW replacements, the reduction in the thermal conductivity of LC-20, LC-30 and LC-40 specimens as compared to the control mix is 22%, 40% and 51%, respectively.

The graph of thermal conductivity *versus* the UPV is presented in Figure 1. From the graph, it can be seen that the UPV of all specimens is directly proportional to thermal conductivity. The relation of thermal conductivity *versus* the UPV has the best correlation (R^2=0.99). This is nearest to unity. This means that the thermal conductivity (k) of any specimen can readily be calculated from laboratory determined UPV. The prediction from UPV is easier than measuring thermal conductivity on (20×60×100) mm plates, which takes longer time. In conductivity tests, it takes a longer time to reach steady-state conditions. However, the effectiveness in the other porous materials of this relationship should be investigated.

Figure 2 and Figure 3 show the relationships between thermal conductivity and porosity (P), UPV and P, respectively. It is an interesting result that the correlation coefficients of the thermal conductivity-porosity and UPV-porosity are approximately equal as shown in Figure 2 and Figure 3. In fact, this is an expected result for porous materials. This situation can be put in the following way. The voids of porous materials are filled with air. The thermal conductivity value of air is low, because air is not a good conductor. Thus, the thermal conductivity value of porous materials is lower than that of solid materials. The movement of sound in porous materials is slower than in solid materials because of air. The UPV values of porous materials are usually low. The test results confirm that the thermal conductivity and UPV values are inversely proportional with porosity.

The modulus of elasticity (E) and Poisson ratio (γ) values of specimens with CW and the control specimen are given in Table 2. As seen in Table 2, the modulus of elasticity values of specimens with CW are decreased as compared with the control specimen. The decreases in the modulus of elasticity at 10, 20 and 30% CW replacement are 23.0, 61.5 and 66.0%, respectively, as compared with the control specimen. The Poisson ratio values of specimens vary between 0.20 and 0.25. The effect of 10 to 30% CW replacements in CW-LPW matrix does not exhibit a sudden brittle fracture even beyond the failure loads and indicates high energy absorption capacity because of low modulus of elasticity of CW specimens.

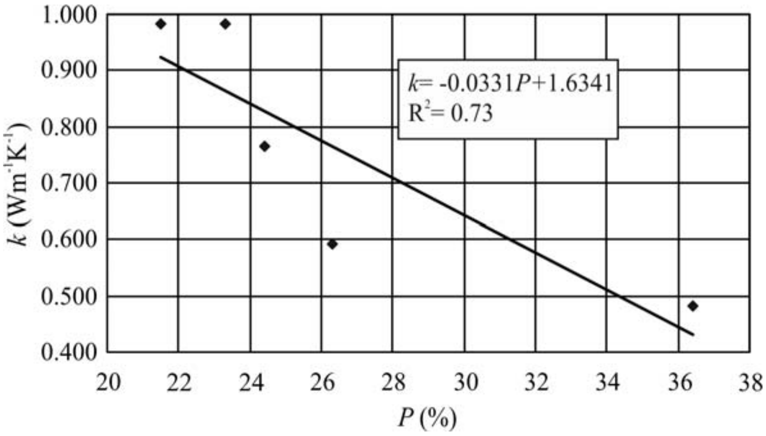

Figure 2: Relationship between thermal conductivity and porosity

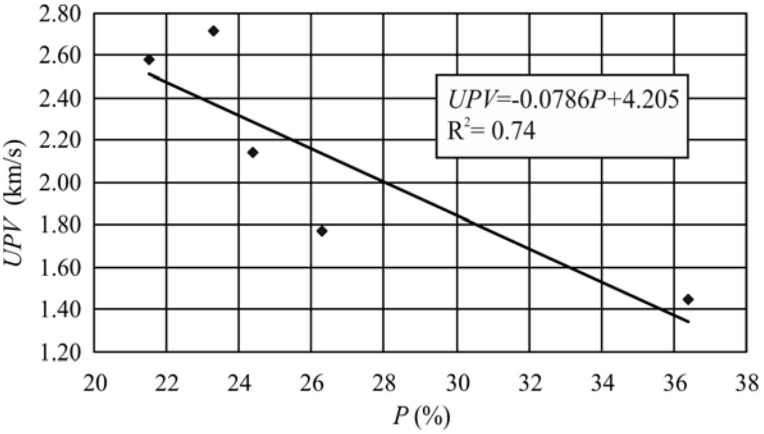

Figure 3: Relationship between UPV and porosity

CONCLUSIONS

Based on the experimental investigation reported in this paper, the following conclusions are drawn:

(1) At 40% cotton waste replacement with limestone powder waste, the reduction in the thermal conductivity and unit weight values of specimens was 51 and 29%, respectively, as compared with the control specimen.

(2) There was a strong relationship among the thermal conductivity, ultrasonic pulse velocity and unit weight values of specimens produced in this study. The effectiveness in the other porous materials of this relationship will stay as a future research.

The test results showed that the CW-LPW combinations have a potential to be used in the production of a new lighter composite.

Acknowledgement

The author would like to thank Miss Tanay Atasoy for her helpful comments on the preparation. This work is supported by IZAMER Construction and Building Materials Company.

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