Thermo-Elastic Properties of Artificial Limestone Bricks with Wood Sawdust

Paki Turgut, Mehmet Gumuscu

Abstract—In this study, artificial limestone brick samples are produced by using wood sawdust wastes (WSW) having different grades of sizes and limestone powder waste (LPW). The thermo-elastic properties of produced brick samples in various WSW amounts are investigated. At 30% WSW replacement with LPW in the brick sample the thermal conductivity value is effectively reduced and the reduction in the thermal conductivity value of brick sample at 30% WSW replacement with LPW is about 38.9% as compared with control sample. The energy conservation in buildings by using LPW and WSW in masonry brick material production having low thermal conductivity reduces energy requirements. A strong relationship is also found among the thermal conductivity, unit weight and ultrasonic pulse velocity values of brick samples produced. It shows a potential to be used for walls, wooden board substitute, alternative to the concrete blocks, ceiling panels, sound barrier panels, absorption materials etc.

Keywords—Limestone dust, masonry brick, thermo-elastic properties, wood sawdust.

I. INTRODUCTION

Energy conservation is an important part of any national energy strategy and energy conservation in underdeveloped countries with inadequate resources is even more important [1]. To an increasing extent, energy usage, and more particularly, energy wastage is receiving close examination at present. Using natural waste materials with a low thermal conductivity in building masonry units improves insulation of buildings by providing an energy efficient solution.

Accumulating of unmanaged wastes especially in developing countries has resulted in an increasing environmental concern. The increase in the popularity of using environmentally friendly, 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. Since the large demand has been placed on building material industry especially in the last decade owing to the increasing population which causes a chronic shortage of building materials the civil engineers have been challenged to convert the industrial wastes to useful building and construction materials [2].

When Many previous researches [2]-[14] undertaken are obtained valuable results to use the industrial wastes in various forms of concrete production. For instance, the use of waste rubber, glass powder and paper waste sludge in concrete mix has received considerable attention over the past years. Although these researches provided the encouraging results, the brick mixes having both WSW and LPW combination hitherto was not investigated so much. These utilizable wastes presented in this research are widely available in large amount from the forest and limestone industries. Wood product and furniture manufactures generate sawdust, offcuts and dust. Sawdust is generated from cutting, drilling and milling operations where wood is removed from a finished product. Wood dust is very fine particles and generated during sanding or other machining operations. It is often collected in filter bags or dust collectors. On average, 48 million m³ of timber is consumed annually in the UK and the wood processing results in 5 to 10% sawdust and dust wastes [15]. The processing limestone which includes crashed limestone production is resulting approximately 20% LPW. The estimated LPW of 21.2 million tons in the UK [16], 18 million tons in Greece is reported [13]. Disposal of LPW causes dust, environmental problem and pollution because of its fine nature.

In the previous work [2], the physico-mechanical properties of WSW-LPW satisfied the standard specifications according to TS 705 [17], ASTM C 140 [18], BS 6073 [19] and ASTM C 129 [20] for load and non-load-bearing concrete masonry units to be used in buildings. The WSW-LPW combinations as an aggregate in its natural form have allowed producing economical, lighter and environmental-friendly new composite brick material. In this study, thermo-elastic properties of WSW-LPW combinations as a brick material are investigated.

II. EXPERIMENTAL PROCEDURE

A. Materials and Fabrication of Samples

WSW used in this research is generated from the mechanical processing of raw wood in the sawing process. WSW is used in its original form and taken from its disposed area nearby the timber manufactures in the local region. LPW used in the brick samples is produced during quarrying operations in the region. The results of chemical and physical analysis of LPW, WSW and cement used in this study are given in [2].
WSW used in this study is categorized as LWF (fine), LWC (coarse) and LWM (mixed) in terms of their particle sizes. The particle sizes of LWF, LWC and LWM are 0-0.6mm, 0.6-1.18mm, and 0-1.18mm, respectively. The grading properties of the LPW and WSW are given in [2]. Ten different types of mixtures are prepared in the laboratory trials. The details of mixes are given in Table I. The cement and water proportions in the mixes are taken as constant to determine the effect of various WSW-LPW combinations.

The replacement ratios between WSW and LPW are taken as volumetric in the mix design. For instance, the 20% replacement of WSW means that the 20% of corresponding LPW volume is replaced by WSW in the LWF-20 samples (see Table I). The percentage weight replacements between WSW and LPW in the mixes are also provided in Table I. The details of mixing, production and curing procedures of samples are given in [2]. All of the samples are tested after 28 days of curing period. A total of 30 brick samples with dimensions of $105\times75\times225\text{mm}^3$ are prepared for thermal conductivity test by cutting with diamond saw of these brick samples. The cylindrical samples with dimensions of $\phi50\times80$ mm for testing elastic properties are also obtained by coring the brick samples. The end faces of the samples 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 sample, two small strain gauges are attached: one along the length (vertical) and one along the circumference (horizontal). The strain gauges are the GFLA-6-50 type (Tokyo Sokki Kenkyujo, Japan).

### III. Test Results and Discussion

Table II shows the averaged tests results obtained from the tests. The test results confirm that the thermal conductivity values are inversely proportionate with the percentage WSW replacement with LPW content (see Fig. 1). It ranges from 0.601-0.9803 Wm$^{-1}$K$^{-1}$ depending on the WSW level. It is seen that thermal conductivity values of the samples are as small as that of common brick materials used in buildings.

About 19.9% reduction in the thermal conductivity of LWF-10 sample compared to control sample is obtained from the 10% fine WSW replacement. This is an expected result owing to the low thermal conductivity nature of wood. The thermal conductivity value of pine is about 0.11 Wm$^{-1}$K$^{-1}$. But in the replacement of 10% coarse WSW, there is not a significant reduction of thermal conductivities of LWC-10 and LWM-10 samples as compared with control and LWF-10 samples. The reductions of thermal conductivity values of LWC-10 and LWM-10 are about 4.1 and 0.1% as compared with control sample, respectively (see Fig. 1).
The values of thermal conductivity in the all of samples with WSW are effectively decreased with an increase in the 20% replacement level of WSW as compared with control sample.

<table>
<thead>
<tr>
<th>Mix no.</th>
<th>Unit weight (g/cm³)</th>
<th>Thermal conduct (W m⁻¹ K⁻¹)</th>
<th>Porosity (%)</th>
<th>UPV (km/s)</th>
<th>E (GPa)</th>
<th>γ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>1.88</td>
<td>0.984</td>
<td>23.3</td>
<td>2.72</td>
<td>15</td>
<td>0.20</td>
</tr>
<tr>
<td>LWF-10</td>
<td>1.80</td>
<td>0.788</td>
<td>24.8</td>
<td>2.32</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>LWF-20</td>
<td>1.63</td>
<td>0.728</td>
<td>27.4</td>
<td>2.27</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>LWF-30</td>
<td>1.47</td>
<td>0.626</td>
<td>27.8</td>
<td>1.98</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>LWC-10</td>
<td>1.74</td>
<td>0.944</td>
<td>23.0</td>
<td>2.67</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>LWC-20</td>
<td>1.65</td>
<td>0.780</td>
<td>26.4</td>
<td>2.38</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>LWC-30</td>
<td>1.50</td>
<td>0.621</td>
<td>30.3</td>
<td>2.03</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>LWM-10</td>
<td>1.70</td>
<td>0.983</td>
<td>23.5</td>
<td>2.63</td>
<td>14</td>
<td>0.17</td>
</tr>
<tr>
<td>LWM-20</td>
<td>1.66</td>
<td>0.746</td>
<td>25.0</td>
<td>2.38</td>
<td>11</td>
<td>0.19</td>
</tr>
<tr>
<td>LWM-30</td>
<td>1.51</td>
<td>0.601</td>
<td>29.0</td>
<td>2.08</td>
<td>8</td>
<td>0.23</td>
</tr>
</tbody>
</table>

The reductions in the thermal conductivity values of LWF-20, LWC-20 and LWM-20 samples at the 20% fine, coarse and mixed WSW replacements are 26, 20.7 and 24.2% as compared with control sample, respectively (see Fig. 1).

The thermal conductivity values of samples with WSW are effectively decreased at 30% WSW replacement. The reductions in the thermal conductivity values at 30% WSW replacement in the LWF-30, LWC-30 and LWM-30 samples are about 36.4, 36.9 and 38.9% as compared with control sample, respectively (see Fig. 1). It is also established a correlation among the thermal conductivity, UPV and unit weight values of samples produced. In the 95% confidence level, there is also strong relationship among the thermal conductivity, UPV and unit weight of samples. The regression equation of thermal conductivity as a function of unit weight and UPV is found as,

\[ k = 0.5484UPV - 0.4829 \]

where, \( k \) and \( UPV \) are the thermal conductivity (W m⁻¹ K⁻¹) and ultrasonic pulse velocity (km/h), respectively.

The R² value for (2) is 0.95. This means that using the UPV and unit weight of samples the thermal conductivity is also calculated more accurately.

In this study, a correlation between the thermal conductivity and \( UPV \) values of samples is established. The relationship between the thermal conductivity and \( UPV \) values of samples is given in Fig. 2. It can be seen from Fig. 2 that there is a strong relationship between the thermal conductivity and \( UPV \) values of all samples and the \( UPV \) values are directly proportional to thermal conductivity values of samples. The relation of thermal conductivity against the \( UPV \) has the best correlation \( R^2 = 0.95 \). This value is nearest to unity. This means that the thermal conductivity of any samples studied in this work can readily be calculated from laboratory determined \( UPV \) value. The relationship between the thermal conductivity and \( UPV \) is found as,

\[ k = -0.459 + 0.530UPV + 0.020\rho \]

where, \( \rho \) is unit weight of sample (g/cm³)

The R² value for (2) is 0.95. This means that using the \( UPV \) and \( \rho \) the thermal conductivity is also calculated more accurately.
20×60×100mm³ plates, which takes longer time. In conductivity tests to reach steady-state conditions takes a longer time. However, the effectiveness in the other porous materials of this relationship should be investigated.

The effect of 10 to 30% WSW replacements in WSW-LPW matrix did not exhibit a sudden brittle fracture even beyond the failure loads and indicated high energy absorption capacity because of low modulus of elasticity of WSW samples.

The test results showed that the WSW-LPW combinations had a potential to be used in the production of a new lighter brick.

ACKNOWLEDGMENT

The authors would like to thank Miss Tanay Atasoy for her helpful comments on the preparation.

REFERENCES


