PRODUCTION OF AN INSULATION MATERIAL FROM CARPET AND BORON WASTES

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ABSTRACT

Buildings are large consumers of energy in all countries. In regions with harsh climatic conditions, a substantial share of energy goes to heat and cool buildings. This paper reports an investigation of the insulation materials made from mixing carpet wastes with a solution with added crude colemanite ore, one of boron minerals, and a solution with added colemanite wastes from a barrage. A new building insulation material was produced which is name, Halibur. Optimum mixing ratios were determined for mass production and the physical properties of the product were established. In addition, the material produced was compared with similar products used in buildings in terms of physical properties. As a result of the investigations, it was established that the product provides high heat and sound insulation and can be used easily in building and construction industry.

1. Introduction

Of the total energy produced in the world, 25% is consumed during industrial production, 25% during use of motor vehicles, and 50% in buildings. A very large proportion of the energy consumed in buildings is used for heating or cooling buildings. The efficient use of energy makes a significant contribution to preventing negative environmental impacts. The emission of greenhouse gases, primarily CO₂, causes global warming and along with it, climate change. Thermal insulation enables heating or cooling of buildings with less fuel so greenhouse gases, such as carbon dioxide (CO₂), sulfur dioxide (SO₂), will also be reduced, thus contributing to mitigation of greenhouse effect in the atmosphere, global warming and climate change (Demir and Orhan 2006; Enek, 2012, Erdoğan and Yaşar, 2005).

According to building census of 2000, there are 7.8 million buildings in Turkey. This number is increasing every day in proportion to the rate of population growth and urbanization. According to the census, the area occupied by residential and commercial buildings is 913 million m², 400 million m² of which is heated. In terms of resource consumption and environmental damage, buildings are responsible for 13.6% of water use, 70% of electricity consumption, 60% of solid waste generation, and 33-39% of greenhouse gas emissions. From the perspective of building life cycle, it is seen that 83% of the total energy is consumed during use of the building. 80% of the energy consumed in households is spent on heating. The efficiency of use of a building and environmental damage caused by it vary depending on its design, the materials used during its construction and efficiency in its operation. Therefore, it is possible to lower energy consumption values and support sustainability by insulation to be implemented in buildings as well as increasing efficiency of building energy systems (Keskin, 2010).

In other words, thermal insulation appears to be an important factor. Reducing building energy demand, thus reducing energy consumption by applying insulation material with high thermal resistance means reducing fossil fuels used for heating as well as fossil fuel-based carbon emissions. In this way, energy-related air pollution can be reduced ( Yaşar et al., 2004). In addition, urbanization, industrialization, technological development and population growth
in our developing world requires an increasingly noisy way of life. Today, noise is expressed as an environmental problem as well as a health issue. To get rid of this problem, people are seeking a quiet and peaceful life as much as possible. In order to reduce noise pollution, living areas with high sound insulation and less noise should be developed. For this reason, the product developed in this study has heat conduction as well as sound insulation properties, providing great advantages in terms of marketing the product (Erdoğan and Yaşar, 2012; Erdoğan, 2007).


In this study has been reported on the development of insulation materials from carpet waste fibers with comparable properties as that of conventional materials. Two different insulating materials were produced by mixing carpet wastes with a solution with added crude colemanite ore, a boron derivative, and a solution with added colemanite wastes from a barrage. The name, HaliBor, was chosen as the designation for the resultant insulation material for use in patent applications. The product (HaliBor) is a low-cost material with high heat and sound insulation values, whose physical and mechanical properties comply with standards in building and construction industry. Moreover, mineralogical advantages of boron and use of idle raw materials enabled the product to be both a fire-resistant and an environmentally friendly material.

2. Materials and methods

2.1. Material

Carpets are complex composite material structures often made from a number of natural or synthetic materials. A typical carpet has four main layers or components. The top layer, or face fiber, represents the main component in the carpet waste and is usually made of wool, nylon or polypropylene (Olivares-Marín and Maroto-Valer, 2011). Weft yarn, warp yarn and pile yarn are used to manufacture carpets. In the province of Gaziantep, where almost half of Turkey’s carpet production takes place, it was determined that total wastage and loss of yarns per year amounts to 6-16% for weft yarn, 10-15% for warp yarn and 15-20% for pile yarn. According to information obtained from carpet factories and studies in the literature, annual total amount of carpet waste is approximately 600,000 tonnes. For the national economy, such high amount of carpet waste is a significant loss. Furthermore, carpet edges, threads ripped away from rug underlay and jute yarn generated in carpet factories or plants for cutting carpets are important wastes which are sustainable wastes waiting to be utilized. Main theme of this study was to utilize constantly increasing carpet wastes and use boron, a valuable resource of Turkey, in this sector (Kozak, 2010). During preliminary studies, the state of the carpet wastes of a company operating in carpet making in the province of Gaziantep, was examined and these wastes were found to be generated consistently (Figure 1).
Boron is a chemical element shown with symbol B in the periodic table and its atomic number is 5. Other properties of boron are as follows: atomic weight: 10.81, density: 2.84 gr/cm³, melting point: 2300°C and boiling point: 2550°C. It is a metalloid with semiconductor properties. It is found in the form of compounds with other elements and is not found naturally on Earth. There are about 230 varieties of boron in nature. Since it is susceptible to bonding with oxygen, there is a wide variety of boron-oxygen compounds. Boron-oxygen compounds are generally called borate. Turkey has 72.2% of the world’s boron deposits, and mining and processing of high grade boron ores is very easy and cost-effective.

In the study, carpet wastes were mixed with two individual solutions with different concentrations. The first solution contains concentrated colemanite ore with 36.19% of B₂O₃, and the other contains concentrated colemanite waste with 25.77% of B₂O₃. Colemanite ore and concentrated wastes were supplied by Emet Boron Works attached to Directorate-General of Eti Mining, and their chemical composition is given in table 1. Concentrated colemanite wastes are stored in barrage pools inside the facility and are not used. Efforts were made to also use these idle concentrated wastes, which pose an environmental problem, to produce the resultant HaliBor material. After completion of all these procedures, the mixture was pressed and the insulation material was dried (Batar et al., 2009; Yılmaz, 2004).

Table 1 - Espey concentrate colemanite ore and chemical analysis of colemanite waste.

<table>
<thead>
<tr>
<th>Chemical Composition</th>
<th>Concentrate Ore (%)</th>
<th>Espey Colemanite Waste (waste of old dam) (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>B₂O₃</td>
<td>36,19</td>
<td>25,77</td>
</tr>
<tr>
<td>SiO₂</td>
<td>14,6</td>
<td>22,46</td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>1,04</td>
<td>1,51</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>3,84</td>
<td>5,83</td>
</tr>
<tr>
<td>CaO</td>
<td>19,83</td>
<td>15,9</td>
</tr>
<tr>
<td>MgO</td>
<td>2,46</td>
<td>5,02</td>
</tr>
<tr>
<td>TiO₂</td>
<td>3,54</td>
<td>4,84</td>
</tr>
<tr>
<td>As(ppm)</td>
<td>205</td>
<td>400</td>
</tr>
<tr>
<td>SO₂</td>
<td>0,13</td>
<td>0,18</td>
</tr>
</tbody>
</table>

2.2. Method

Flow diagram for the production of insulation material with added boron from carpet wastes is given in figure 2. As seen in figure 2, first, carpet wastes were cut and torn into pieces. Then, pre-determined amounts of water, colemanite, and CMC and carpet wastes were placed inside a mixer and mixed, after which the resultant product was placed inside a mold, pressed and shaped. Following the pressing procedure, the product was oven-dried at 35°C for 4 hours and became ready for use.

3. Results and Discussion

As a result, two different products which gave optimal values were obtained. The product with added crude colemanite ore was designated as HaliBor-1, and the other with added colemanite barrage waste was designated as HaliBor-2. The resultant materials were designed in dimensions of 40 x 40 x 10 cm (width x length x height).

Physical and mechanical properties of the product (density, thermal conductivity, flame retardency properties and sound insulation values) were determined. In addition, HaliBor-1 and HaliBor-2 were compared with other insulation and construction materials used in building and construction industry. A classification of materials by flame retardency values was made according to the DIN 4112 standard and the results are given in table 2 (DIN 4112, 1960, http://www.termo1numara.com). In view of table-2, it is clear that HaliBor insulation materials gave considerably good results when compared with other materials used in the industry. A density value ranging between 185 and 200 kg/m³ was obtained.

The insulation material with values comparable to those of HaliBor-1 in the industry is glass wool. HaliBor-1 with added crude ore turned out to be a new insulation material with the lowest density value used in the industry (Figure 3).

Thermal conductivity tests were performed according to TS 825. The results showed that HaliBor-1 and HaliBor-2 gave values of 0.035 \( \lambda \)W/ (mK) and 0.04 \( \lambda \)W/(mK), respectively. When HaliBor with added boron and carpet waste was compared with other materials, it was seen that HaliBor-1 with added crude ore also gave the highest heat insulation value (Figure 4).
Production of an Insulation Material From Carpet and Boron Wastes

Figure 2- HaliBor production plan.

Figure 3- Density values of the sealing materials.

Table 2- Comparison Table of Various Structural Elements (http://www.termo1numara.com).

<table>
<thead>
<tr>
<th>Insulation Material</th>
<th>Density (kg/m³)</th>
<th>Thermal Conductivity λW/(mK)</th>
<th>Flammability (DIN 4112)</th>
<th>Sound Insulation (dB) (10cm/500hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HaliBor-1</td>
<td>185</td>
<td>0,035</td>
<td>B1- Difficult Flaming</td>
<td>38</td>
</tr>
<tr>
<td>HaliBor-2</td>
<td>200</td>
<td>0,04</td>
<td>B1- Difficult Flaming</td>
<td>38</td>
</tr>
<tr>
<td>Aerated concrete blocks</td>
<td>500</td>
<td>0,14</td>
<td>B1- Difficult Flaming</td>
<td>38</td>
</tr>
<tr>
<td>Black cement plaster</td>
<td>1800</td>
<td>0,87</td>
<td>A- Fireproof</td>
<td>35</td>
</tr>
<tr>
<td>Air brick</td>
<td>700</td>
<td>0,24</td>
<td>A- Fireproof</td>
<td>37</td>
</tr>
<tr>
<td>Glass wool</td>
<td>205</td>
<td>0,04</td>
<td>B1- Difficult Flaming</td>
<td>36</td>
</tr>
</tbody>
</table>
Sound insulation is given by the amount of sound absorbed by the materials to provide insulation in a room with sound insulation where sound is emitted by an amplifier at a certain distance (TS EN ISO 10140-3, 2011). Considering the results obtained, it is clear that HaliBor-1 and 2 were the materials offering the highest insulation along with aerated concrete (Figure 5).

4. Conclusions

In this study, it was understood that carpet wastes with limited use in the industry and concentrated colemanite ore and wastes can be used to generate insulation materials. The insulation material with added crude colemanite ore was designated as HaliBor-1, and the other with added concentrated colemanite wastes was designated as HaliBor-2.

Physical properties of HaliBors were determined and comparisons were made with other insulation materials used in the industry. As a result of such comparisons, it was seen that HaliBors can be used quite easily in building and construction industry. Importance and value of the work was further increased by the fact that waste materials were recycled to obtain a different product.
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1. Aims

The main aims of the journal are

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- To announce and share the researches in all fields of geoscience studies in Turkey with geoscientists worldwide.
- To announce the scientific researches and practices on geoscience surveys carried out by the General Directorate of Mineral Research and Exploration (MTA) to the public.
- To use the journal as an effective media for international publication exchange by keeping the journal in high quality, scope and format.
- To contribute to the development of Turkish language as a scientific language

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Manuscripts should be written in word format in A4 (29.7 x 21 cm) size and double-spaced with font size Times New Roman 10-point, margins of 25 mm at the sides, top and bottom of each page. Authors should study carefully a recent issue of the Bulletin of Mineral Research and Exploration to ensure that their manuscript correspond in format and style.

- The formulas requiring the use of special characters and symbols must be submitted on computer.

- Initial letters of the words in sub-titles must be capital. The first degree titles in the manuscript must be numbered and left-aligned, 10 point bold Times New Roman must be used. The second degree titles must be numbered and left-aligned, they must be written with 10 point normal Times New Roman. The third degree titles must be
numbered and left-aligned, they must be written with 10 point italic Times New Roman. The fourth degree titles must be left-aligned without having any number; 10 point italic Times New Roman must be used. The text must continue placing a colon after the title without paragraph returns (See:Sample article: http://bulletin.mta.gov.tr).

- Line spacing must be left after paragraphs within text.
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- The manuscript must include the below sections respectively;
  - Title Page
  - Abstract
  - Key Words
  - Introduction
  - Body
  - Discussion
  - Conclusion
  - Acknowledgements
  - References

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- While processing subject, care must be taken not to go beyond the objective highlighted in “Introduction” section. The knowledge which do not contribute to the realization of the purpose of the article or are useless for conclusion must not be included.

- All the data used and opinions put forward in this section must prove the findings obtained from the studies or they must be based on a reference by citation.

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- This section should explore the significance of the results of the work, not repeat them. This must be written as a separate section from the results.

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- The main conclusion of the study provided by data and findings of the research should be stated concisely and concretely in this section.

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Acknowledgement of people, grants, funds, etc should be placed in a separate section before the reference list. While specifying contributions, the attitude diverted the original purpose of this section away is not recommended. Acknowledgments must be made according to the following examples.

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- The figures published in the Bulletin of Mineral Research and Exploration must be prepared in computing environment considering the dimensions of single-column width 7.4 cm or double-column width 15.8 cm. Figure area together with the writing at the bottom should not exceed a maximum 15.8x21.

- Figures must not be prepared in unnecessary details or care must be taken not to use a lot of space for information transfer.

- Figures must be arranged to be printed in black-and-white or colored. The figure explanations being justified in two margins must be as follows:

  Figure 1 - Sandikli Town (Afyon); a) Geological map of the south-west, b) general columnar section of the study area (Seymen 1981), c) major neotectonic structures in Turkey (modified from Koçyiğit 1994).

- Drawings must be drawn by well-known computer programs painstakingly, neatly and cleanly.

- Using fine lines which can disappear when figures shrinks must be avoided. Symbols or letters used in all drawings must be Times New Roman and not be less than 2 mm in size when shrink.

- All the standardized icons used in the drawings must be explained preferably in the drawing or with figure caption if they are very long.

- Linear scale must be used for all drawings. Author’s name, figure description, figure number must not be included into the drawing.

- Photos must have the quality and quantity that will reflect the objectives of the subject.

6.2. Plates

- Plates must be used when needed a combination of more than one photo and the publication on a special quality paper.

- Plate sizes must be equal to the size of available magazine pagespace.

- Figure numbers and linear scale must be written under each of the shapes located on the Plate.

- The original plates must be added to the final copy which will be submitted if the article is accepted.

- Figures and plates must be independently numbered. Figures must be numbered with Latin numerals and plates with Roman numerals (e.g., Figure 1, Plate 1).

- There must be no description text on Figures.
6.3. Tables

- Tables must be numbered consecutively in accordance with their appearance in the text.
- All tables must be prepared preferably in word format in Times New Roman fonts.
- Tables together with table top writing must not exceed 15x8 cm size.
- The table explanations being justified in two margins must be as follows:

Table 1- Hydrogeochemical analysis results of geothermal waters in the study area.

7. Nomenclature and Abbreviations

- Non-standard and uncommon nomenclature abbreviations should be avoided in the text. But if essential, they must be described as below: In cases where unusual nomenclatures and unstandardized abbreviations are considered to be compulsory, the followed way and method must be described.
- Full stop must not be placed between the initials of words for standardized abbreviations (MER, SHW, etc.).
- Geographical directions must be abbreviated in English language as follows: N, S, E, W, NE … etc.
- The first time used abbreviations in the text are presented in parenthesis, the parenthesis is not used for subsequent uses.
- The metric system must be used as units of measure.

- Figure, plate, and table names in the article must not be abbreviated. For example, “as shown in generalized stratigraphic cross-section of the region (Figure 1…………..”

7.1. Stratigraphic Terminology

Stratigraphic classifications and nomenclatures must be appropriate with the rules of International Commission on Stratigraphy and/or Turkey Stratigraphy Committee. The formation names which has been accepted by International Commission on Stratigraphy and/or Turkey Stratigraphy Committee should be used in the manuscript.

7.2. Paleontologic Terminology

Fossil names in phrases must be stated according to the following examples:

- For the use authentic fossil names:
  - e.g. Calcareous sandstone with *Nummulites*
- When the authentic fossil name is not used.
  - e.g. nummulitic Limestone
- Other examples of use;
  - e.g. The type and species of Alveolina/Alveolina type and species

- Taxonomic ranks must be made according to following examples:

| Super family: Alveolina Ehrenberg, 1939 | Not reference, Not stated in the Reference section |
| Family: Borelidae Schmarda, 1871 | Schweighauser, 1951 not reference |
| Type genus: *Borelis* de Montfort, 1808 | Cited Schweighauser (1951), stated in the Reference section. |
| Type species: *Borelis melonoides de Montfort, 1808; Nautilus melo* Fitchel and Moll, 1789 | Cited Hottinger (1974), stated in the Reference section. |
| *Borelis vonderschmitti* (Schweighauser, 1951) (Plate, Figure, Figure in Body Text) | |
| 1951 *Neoalveolina vonderschmitti* Schweighauser, page 468, figure 1-4 | |
| 1974 *Borelis vonderschmitti* (Schweighauser), Hottinger, page, 67, plate 98, figure 1.7 | |
The names of the fossils should be stated according to the rules mentioned below:

- For the first use of the fossil names, the type, species and the author names must be fully indicated

*Alveolina aragoensis* Hottinger

*Alveolina cf. Aragoensis* Hottinger

- When a species is mentioned for the second time in the text:

A.aragoensis

A.cf.aragoensis

A.aff.aragoensis

- It is accepted as citation if stated as *Alveolina aragoensis* Hottinger (1966)

The statement of plates and figures (especially for articles of paleontology):

- For statement of the species mentioned in the body text

Borelis vonderschmitti (Schweighauser, 1951).

(plate, figure, figure in the body text).

- When citing from other articles

1951 Neoalveolina vonderschmitti Schweighauser, page 468, figure 1-4, figure in body text

1974 *Borelis vonderschmitti* (Schweighauser), Hottinger, page 67, plate 98, figure 1-7

- For the citation in the text

- (Schweighauser, 1951, page, plate, figure, figure in the body text) (Hottinger, 1974, page, plate, figure 67, plate 98, figure 1-7, figure in the bodytext.)

8. Citations

All the citations in the body text must be indicated by the last name of the author(s) and the year of publication, respectively. The citations in the text must be given in following formats.

- For publications written by single author:

- Altınlı (1972, 1976) defined the general characteristics of Bilecik sandstone

- For publications written by two authors:


- For publications written by three or more authors:

According to Caner et al. (1975) Alici formation reflects the fluvial conditions.

The unit disappears wedging out in the East direction (Tokay et al., 1984).

- If reference is not directly obtained but can be found in another reference, cross-reference should be given as follows:

- It is known that Lebling has mentioned the existance of Lias around Çakraz (Lebling, 1932: from Charles, 1933).

9. Reprints

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