TO THE PROBLEM OF MAN - MATERIAL - HABITAT SYSTEM COMFORT INCREASE

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ABSTRACT
The development of building material science in the light of such flows as green building, architectural geonics, the concept of sustainable development poses new challenges for researchers, one of which is the human environment comfort improvement. Comfort is closely related to a premise microclimate, which is formed as the result of heating and ventilation system interaction with the building materials of wall structures. Traditionally, the role of building materials in this interaction is a passive one and is characterized by two properties: thermal conductivity and vapor permeability. A further increase in the efficiency of engineering systems is not possible without the inclusion of building materials in this process as an active component. It is known that the radiation heat exchange plays an important role in the distribution of energy indoors. This heat exchange takes place between the surfaces in the infrared range. Moreover, the work of radiant heating systems is based on this principle. It has significant advantages as compared with traditional ones and has great prospects concerning the energy consumption reduction for heating. In this regard, they studied the issues of composite development which have a particular interaction character with a particular spectrum of infrared light.

Keywords: human comfort, radiant heat exchange, radiant heating systems, composite materials.

INTRODUCTION

The post-industrial society, to which most economically developed countries referred (or are in the process of transformation) as is commonly believed, gave rise to new values, the most important of which is human capital [1]. The issues related to construction appeared in new light. In particular, a special attention is paid to comfort now [2].

The notion of "comfort" is interpreted by the dictionary in two main ways. First of all, comfort is a set of amenities. The other value implies a state of inner satisfaction which arises under the influence of any favorable conditions, circumstances, etc. With regard to the human habitat conditions, these interpretations should be considered only integrally.

According to the concepts of building thermal physics, the comfort of a premise thermal environment has an important value to maintain good health, efficiency and a man's health, since most people spend more than 85% of their lives in premises. In its turn, the temperature of walling structure inner surface plays an important role in the formation of the indoor environment [3, 4].
A significant drawback of the traditional approach is that when you choose some material for walls and ceilings, only two properties are taken into account which directly characterize its ability to participate in the heat exchange processes - thermal conductivity and heat capacity. The ability of building materials (except for transparent ones) to participate in the radiant heat transfer, applied to the targeted formation of indoor climate, is not considered as a rule. In standard calculation methods the accounting of this factor is performed by the use of averaged coefficients.

The convection and radiation processes are studied thoroughly by physics that enables a conscious approach to the development issue of building materials with necessary qualities. In its turn, this will allow to provide an additional tool of a man's environment comfort improvement and to reduce the energy consumption through their more efficient distribution. For this reason, and within the framework of the green building concept element implementation in practice the systems of premise radiant heating provide an increased interest [5, 6].

For a broad practical introduction of premise IR heating one should seek to minimize the flux density in the area of a man possible location without the reduction of its total power [7]. This is possible due to its redistribution by multiple reflection and an excess radiation by surfaces with a flow direction change. I.e. in order to create safe and comfortable environment IR rays should extend not only in the direction of an emitter - a man, but also in the planes perpendicular to this direction. At that, in order to preserve the aesthetic performances, the redistribution function of IR radiation should be provided by the building materials used indoors.

This method of control by the distribution of energy flows suggests new possibilities for microclimate development in a premise, in particular:

- The regulation of exterior wall humidity at the expense of the required temperature maintaining of their surface;
- The supply of additional quantities of energy to the coldest parts of premise surfaces;
- The microclimatic zoning of premises;
- The return of the heated air energy share of a premise top part to a man's habitation area.

The solution of these problems is possible at the expense of building material properties study concerning the cooperation with IR radiation, the principles of building composite development with the desired properties.

**METHODS**

A large amount of primary information on the interaction of various substances, rocks and minerals with monochromatic radiation of different wavelengths is provided by infrared spectroscopy which is a widely accepted method of material composition determination. Using the materials of U.S. Geological Survey (USGS) [8] the primary selection of minerals was performed, whose spectra were used for further analysis. The reflection spectrum of monochromatic radiation was overlaid by a primary radiator laboratory device (Figure 1 a), on the basis of which the curves of radiation reflection of different wavelengths were developed and the degree of blackness was calculated.

The study of radiative heat transfer process was carried out using a developed laboratory device the diagram of which is shown on Figure 1 b.
The device consists of a flat radiator, heated to a desired temperature and a measuring cell for the studied materials, equipped with the measuring thermocouples. In order to reduce the energy loss the measuring cell is equipped with an efficient thermal insulation, and the top is covered with a thin plastic film that is transparent to infrared radiation. The radiator surface temperature adopted in operation made 300 °C. The registration of heating and cooling process of the studied materials was carried out using a computer through the converter.

The assessment of blackness degree concerning studied powder materials was carried out by drawing the energy balance at the radiant heat transfer between them and a radiator. The amount of energy per unit of time absorbed, reflected and emitted by the material must comply with its quantity brought to the sample. The amount of energy flow supplied to the material was determined by analyzing the curve of water heating. Taking into account the blackness degree of water 0.95 (according to reference data), and the time for heating from 30 to 40 °C - the energy flow made 463.5 J/s per 1 m2 of surface.

**MAIN PART**

The ability of the materials to interact somehow with infrared radiation depends on several factors:

1. Radiation source features: the radiation spectrum for heat sources or a wavelength during monochromatic radiation.

2. The chemical and mineral composition.

3. The material temperature.

4. The features of a surface structure and material layer thickness.

5. The angle of absorbing surface inclination with respect to the main direction of infrared rays distribution.
6. The material humidity.

These factors influence on the development of such material characteristics as the reflection, absorption and transmission ratio, the blackness degree of a surface and a heat flux density.

One should keep in mind that most of these factors are interrelated and are formed by the interaction of internal and external aspects, therefore, the analysis of certain phenomena must take into account the test performance conditions. During the development of building composites the factors # 2, 4, 6 are of practical importance.

In order to predict the effect of mineral composition on the ability of building materials to interact with infrared radiation, on the reflection spectrum of a mineral the spectrum of the source radiation was applied. The value of blackness degree was calculated according to these data. Among the analyzed minerals that make up the majority of building materials, the lowest value of blackness degree was showed by calcite (0.77) and the largest value was showed by gypsum (selenite, 0.94). Quartz took an intermediate position (0.84) according to this indicator.

![Graphs showing the overlay of source spectrum on the reflection spectrum of essential minerals.](image)

**Figure 2** – The overlay of source spectrum on the reflection spectrum of essential minerals

Despite the close values of calcite and quartz blackness degree, the latter has a high degree of reflection in the wavelength range of 8 .. 10 microns. This area accounts for a maximum intensity of the secondary radiation, i.e. the radiation which is produced by all of the surfaces of a premise. Due to this, the materials containing large amounts of silica will be well-heated under the influence of IR emitters (during the cold season) and will be cooler during a warm season, when the heaters are not working.

The reflection region (4 .. 5.5 microns) of radiation by calcite almost coincides with the maximum intensity of the primary radiation source. Due to this reason the materials saturated with calcite will reflect its substantial part, and therefore they will be less heated during the heating operation period, redirecting the radiation to other surfaces. At that an intensive secondary heat exchange with the surrounding surfaces will take place.
Selenite has a very low degree of reflection throughout the considered range of wavelengths. This creates the prerequisites for its active interaction with primary and secondary sources of radiation.

In order to assess the influence of material surface structure on the nature of interaction with infrared radiation, using the developed device the process of radiative heat exchange with the original source was studied. Calcium containing bulk materials - chalk and limestone - were used for the analysis; quartz - quartz sand, crushed silicate and ceramic brick [9]. Gypsum was studied as the most suitable material for interior operations of decoration composite matrix. The indicators of radiative heat exchange of materials are presented in Table 1.

**Table 1. Parameters of material radiant heat exchange**

<table>
<thead>
<tr>
<th>№</th>
<th>Material</th>
<th>Main mineral (its share, % wt)</th>
<th>The amount of energy flows per 1 m² of surface, J/s</th>
<th>Blackness degree</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Emitted</td>
<td>Consumed (spent on heating)</td>
</tr>
<tr>
<td>1</td>
<td>Limestone</td>
<td>CaCO₃ (&gt;90%)</td>
<td>144</td>
<td>164</td>
</tr>
<tr>
<td>2</td>
<td>Chalk</td>
<td>CaCO₃ (&gt;97%)</td>
<td>78</td>
<td>63</td>
</tr>
<tr>
<td>3</td>
<td>Quartz sand</td>
<td>SiO₂ (&gt;96%)</td>
<td>197</td>
<td>222</td>
</tr>
<tr>
<td>4</td>
<td>WMS waste</td>
<td>SiO₂ (&gt;75%)</td>
<td>168</td>
<td>182</td>
</tr>
<tr>
<td>5</td>
<td>Crushed ceramic brick</td>
<td>SiO₂ (&gt;70%)</td>
<td>138</td>
<td>170</td>
</tr>
<tr>
<td>6</td>
<td>Crushed silicate brick</td>
<td>SiO₂ (&gt;85%)</td>
<td>153</td>
<td>255</td>
</tr>
<tr>
<td>7</td>
<td>Salt **</td>
<td>NaCl (&gt;97%)</td>
<td>106</td>
<td>125</td>
</tr>
<tr>
<td>8</td>
<td>Water**</td>
<td>-</td>
<td>312</td>
<td>128</td>
</tr>
</tbody>
</table>

**Bulk**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th>Emitted</th>
<th>Consumed (spent on heating)</th>
<th>Reflected</th>
<th>Estimated</th>
<th>Other data</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>V/G=0,35</td>
<td>CaSO₄×2H₂O</td>
<td>177</td>
<td>224,3</td>
<td>62,2</td>
<td>0,87</td>
<td>0,903…0,94*</td>
</tr>
<tr>
<td>10</td>
<td>V/G =0,5</td>
<td></td>
<td>177,5</td>
<td>206,3</td>
<td>79,7</td>
<td>0,83</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>V/G =0,65</td>
<td></td>
<td>157,1</td>
<td>216,5</td>
<td>89,8</td>
<td>0,81</td>
<td></td>
</tr>
</tbody>
</table>

*on the basis of literary data
**presented for comparison

In general, a clear link between the absorption of infrared radiation by the layer of a bulk material and the same indicator of a predominant mineral is not traced. A probable cause is a great influence on the interaction with the radiation of structural factors - a high emptiness of a system, an irregular shape of grains and the surface formed by a break.
Figure 3 - The microstructure of the particle surface with the increase of:

a) chalk (x20k); b) crushed silicate brick (x25k); c) crushed ceramic brick (x25k)

For example, crushed limestone has the blackness degree (0.67) close to calcite (0.77). At the same time this figure of chalk with a similar mineral content is significantly lower (0.3). The probable cause is a smooth surface of chalk particle structural elements representing their spatial units (Figure 3 a).

The materials based on quartz, the particles of which are coated with a build-up of other minerals consume the energy of source radiation spectrum best of all among the considered ones. For example, a crushed sand-lime brick is largely composed of quartz sand particles the surface of which has calcium hydrosilicates (Figure 3b). Crushed ceramic brick - quartz particles, the surface of which has fused clay minerals (Figure 3).

With the increase of V/G ratio of gypsum from 0.5 to 0.65 the radiated energy flow quantity decreases. This is probably due to the increase of a surface layer porosity and the size of its pores, reducing the radiating surface area. At that such a phenomenon is not observed during the transition from water-gypsum ratio of 0.35 / 0.5, which suggests the existence of a critical pore size at which the radiation of their walls can not get out of the material replacing by multiple internal repeated reflection.

The increase of gypsum matrix humidity to the level of 15% or higher leads to the material blackness degree increase.

On the basis of the studied filler and gypsum matrix and the samples of 1:1 composition were prepared by weight. The indicators of their heating by a primary radiation source are shown in Table 2.

<table>
<thead>
<tr>
<th>№</th>
<th>Composite</th>
<th>Average density, kg/m³</th>
<th>The amount of energy flows per 1 m² of surface, J/s</th>
<th>Estimated blackness degree</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Emitted</td>
<td>Consumed (spent on heating)</td>
</tr>
<tr>
<td>1</td>
<td>Gypsum – Limestone</td>
<td>1542</td>
<td>189,8</td>
<td>233</td>
</tr>
<tr>
<td>2</td>
<td>Gypsum – Chalk</td>
<td>1259</td>
<td>17,6</td>
<td>141,7</td>
</tr>
<tr>
<td>3</td>
<td>Gypsum – Quartz sand</td>
<td>1584</td>
<td>194,5</td>
<td>214</td>
</tr>
</tbody>
</table>
As can be seen from the presented data, the value of the filler blackness indicator is reflected in the corresponding index of composites with their application.

**SUMMARY**

According to the obtained data, the considered finishing composite materials can be divided into three types:

Type 1. Highly reflective ones concerning the energy of primary source of radiation - the composition with chalk as a filler. The finishing composite of this composition reflects more than 60% of incoming emitter energy. Such properties can be used to redistribute the infrared radiation of heaters particularly in the horizontal plane, while lowering the flux density to improve the comfort of their operation. The finishing of surfaces by such compounds will reduce the number of used heaters without loss for the uniformity of a premise radiation. At that, due to decreased density and heat capacity, a surface finished by these compositions will have a comfortable temperature. The own radiation will be a decreased one.

Type 2. This is the type with a high degree of spectrum energy absorption. They include the compounds with a filler made of splintered autoclave materials - gas silicate and silicate bricks. The blackness degree of a surface with respect to an emitter range exceeds 0.98. These materials almost do not reflect the primary source radiation, but they actively absorb and emit it in the spectrum corresponding to the temperature of their surface. Such composites may be used as original spectrum transformers which transform the shorter wavelength radiation into the long wave one with a lower intensity but radiated from a higher surface. Their effective use for such purposes requires their application on a substrate made of an effective insulation. Otherwise a considerable part of the energy received by them will be spent for structure heating used as their substrate.

On the other hand, the use of such compositions on the inner surface of outer walls without a separating insulation layer will allow to increase the wall temperature due to the use of heater infrared energy situation and will allow to control a dew point in an outer wall. A dew point offset to the outer surface will provide a structure moisture reduction and will improve its insulating performance [10]. Due to this, it is possible to justify the expenditure of energy for a wall heating.

Type 3. The compounds demonstrating the intermediate values of blackness degree at 0.85 ... 0.95. The most typical representatives of this group are the compounds with the use of limestone, crushed ceramic brick and quartz sand as the fillers. The use of such materials provides the redistribution of the primary transmitter energy and its efficient uptake with the repeated emission in a long wavelength spectrum.

**CONCLUSIONS**

According to the presented results, the following conclusions may be made:

1. Nowadays the world is in the formation of postindustrial society, the main accepted value of which are human resources. This requires the review of the requirements for building materials, the introduction of such an additional criterion as a comfort for a man. The practical realization of this thesis is possible due to the inclusion of building structures in the active creation of a favorable microclimate for a person.
2. One of the promising heating methods is the use of infrared systems. The key ensuring the effectiveness of their work is the account of not only the emitter parameters, but also the properties of materials, perceiving a radiation flux. Thus, the impact of building materials on the process of active microclimate control is almost carried out.

3. The development of surface properties concerning their interaction with infrared radiation is advisable to carry out due to the creation of finishing layers with a certain value of blackness degree in relation to the spectrum of applied heaters, since the interaction with radiation is mostly superficial one, and has a superficial character (to the depth of a few millimeters).

4. The material properties for the cooperation with IR radiation, are based on mineralogical composition, but are greatly influenced by the structure of particles and their surface during the transition to bulk materials, and are largely inherited by the composites on their basis, combining with the properties of the used matrix.

5. Depending on the structure of particles the blackness degree of materials with the same mineralogical composition can vary widely, as can be seen according to the example of chalk-limestone pair.

6. Granular materials have the best ability to absorb infrared radiation, the particles of which have a build-up on their surface from other entities: microcrystalline product of binder hydration or glass crystalline formations of baked clay. The new formations of autoclave materials, probably because of their introduction of quartz particles into a surface layer, are the best modifiers in performed experiments.

REFERENCES