IOP Conference Series: Materials Science and Engineering

PAPER • **OPEN ACCESS**

New point of view on materials development

To cite this article: M Y Elistratkin *et al* 2018 *IOP Conf. Ser.: Mater. Sci. Eng.* **327** 032020

IOP Conf. Series: Materials Science and Engineering **327** (2018) 032020 doi:10.1088/1757-899X/327/3/032020

New point of view on materials development

M Y Elistratkin, V S Lesovik, L H Zagorodnjuk, E A Pospelova, S V Shatalova

Belgorod State Technological University named after V.G. Shukhov, 46 Kostukov St., Belgorod, 308012, Russia

E-mail: mr.elistratkin@yandex.ru

Abstract. The paper considers the issue of improving the existing materials and developing new ones from the standpoint of their health and psycho-emotional impact. And not only from the point of view of their safety; the focus should be shifted to their active beneficial effect. The materials properties forming features in accordance with the proposed concept are considered. The targeted formation of material pore space at various scale levels is considered as effective implementation tools using specially created composite binders, in particular, in the production of non-autoclaved aerated concrete.

1. Introduction

Relative convenience and comfort of the so-called "civilized" world are leveled by a number of entirely new risks forming side effects of one and the same progress. Thus, the development of medicine is hardly able to keep up with new diseases and various negative impacts caused by "safe" modern equipment and technologies [1].

Perhaps, certain impacts are not dangerous for humans, but their joint effect throughout the entire life is hidden, implicit, and destructive to health, mood, work performance, and reproducibility. On average, the probability that the current generation will live until 60 years old is unlikely higher than their ancestors had 100-150 years ago. This is caused by social problems arising against the background of technological advancements: a decline in employment due to automation and robotization, transfer of production sites to low-paid regions, etc.

Since the times of large-scale construction in the latter half of the 20th century, the progress in the area of construction materials, except in rare circumstances, is focused on the reduction of production and construction costs. However, taking into account real estate prices, only producers, but not the consumers will likely to benefit from this. A certain reduction of energy to an output ratio with regard to production of construction materials and, undoubtedly essential fight for energy saving are firstly caused by the growth of energy cost, and secondly, by the desire to improve the ecological situation [2, 3].

In fact, the majority of construction materials applied these days, except for slightly higher strength and thermal properties, have almost no difference from century-old analogues. The reason for this lies in a stable approach to their production with the emphasis put on engineering and technical requirements.

Despite the aforesaid, the technical progress cannot be stopped. However, there is an urgent need to adjust its objectives with the focus on alignment between humans, artificial habitat and nature. The critical role in this case is given to construction that further forms the above-mentioned human environment. It is noteworthy that there is some positive progress in smart architectural design of buildings and settlements in general alongside with the need to reconsider the existing paradigm in terms of applied construction materials [4].

2. Results and discussion

The improvement of existing materials and the development of new ones shall be accompanied by thorough consideration of their impact on human health and psycho-emotional state. Moreover, not only their harmlessness but active favorable effect shall be taken into account. The intensity of positive impacts shall not be too high and shall mainly be long-lasting and ensure continuity of artificial habitat, especially for residents of large cities. At the same time, current standard requirements shall not be neglected.

Based on the above-mentioned facts, the requirements to properties of construction materials can be divided into three categories:

1. Standard requirements (strength, thermal parameters, radiological properties, etc.).

2. Comfortable human habitat, i.e. favorable temperature and humidity conditions, acoustic and olfactory background, coloristics, etc.

3. Protection of humans against negative environmental impacts: background (noise, electromagnetic, etc.) and active (psychotropic, acoustic, electromagnetic, etc. up to the application of different types of non-lethal weapons).

The majority of modern studies are devoted to the improvement of the first-category properties. This is fostered by enoumous reserves and knowledge base accumulated throughout the 20th century. Nevertheless, the progress in this field is still far from being ideal. This is clearly seen from such scientific area as Geonics [5]. Parameters of many artificial construction materials, for example a strength-density ratio, are several times, and sometimes even by far underperform their natural counterparts. The development of technologies that fully or partically reproduce geological processes is one of the key solutions of a considerable increase in properties [6, 7].

The second category of requirements and many properties necessary to satisfy them are not new at first sight. However, at present the microclimate of manned rooms (as an accepted characteristic of comfortable habitat) is formed mainly due to special systems (heating, ventilation, conditioning), which operating parameters are set depending on actual indicators of protective construction materials. In other words, the degree of material efficiency (for example, heat conductivity) impacts quantitative parameters, such as power consumption to maintain the required indoor temperature; however the role of material itself in the formation of favorable microclimate is passive and secondary. It can be replaced by another material with similar properties, but the main issue is to ensure comfortable living or staying conditions.

According to the proposed concept, new construction materials shall have properties that would foster favorable microclimate in premises and comfortable artificial human habitat.

Wall materials having certain nature of interaction with infrared radiation can illustrate achievements in this field. This gives an opportunity to use protective structures for optimal distribution of thermal flows, to control temperature of certain surfaces, to solve problems of humidity control of external walls, etc. This will result in the decrease in energy consumption for the required microclimate and essential increase in comfortable living conditions in such rooms.

This can also be exemplified through the implementation of regulations of Architectural Geonics, stipulating to consider geological features of construction region as much as possible when choosing materials, developing form, texture, coloring of structures and objects, and in certain cases to neglect them in order to create the required psycho-emotional conditions (concentration of attention, increase in work performance, reduction of stress and aggression levels) [5].

The proposed aromatization of construction materials at the level of their impact on subconsciousness has similar effect on humans. For instance, it is possible to make a dream of a person in his bedroom deeper, to improve perception of information in study rooms, to reduce stress and to increase work perfromance in offices, to calm patients in hospitals, to form the desire to leave a dangerous area or other areas where mass gathering is unacceptable.

The principles of attributing third-category properties to materials are mainly developed due to studies in the field of military construction and nuclear energy. However, these are the materials which were initially created to counteract certain affecting factors or strong negative impacts where other properties are formed residually. Another peculiar feature of such materials is their high cost, which leaves no chances to success when applied in mass civil engineering.

In this regard, in the framework of the proposed concept, it is necessary to create materials with the required properties to propect humans against the above-mentioned impacts.

In order to select countermeasures, first of all, it is necessary to identify the existing and potential types of negative impacts, the range of variation of their parameters. There are certain difficulties in this respect due to lack of available technical information or even its complete secrecy, especially when it concerns non-lethal weapons. Establishment of general physical principles of influences and elaboration of corresponding countermeasures can become a solution to this problem. On the one hand, such approach may reduce properties that ensure protection against certain impacts, and on the other hand, there is a need to make protection more universal, including protection against new devices operating under similar principles.

3. Materials and methods

The immediate task of construction materials science is to define rational principles that would foster the achievement of designated objectives. Due to non-obvious nature of problems, the search for solutions is only possible through the application of the transdisciplinary approach: integration of knowledge in the field of construction physics and materials science, chemistry, geology and some other disciplines.

It is possible to manage materials properties via various factors of influence. Targeted formation of their pore space presents a great interest for the implementation of the proposed concept as an effective managing mechanism.

This is caused by the following factors:

- inherence of pores as elements of the hydration hardening composite structure;
- variety of accumulated knowledge on their influence on various properties for further analysis and generalization;
- role of porosity in the formation of some properties influencing the microclimate and comfort (heat conductivity, vapor permeability, sound absorption and insulation, etc.);
- availability of industrial technologies to obtain porous materials.

Another important fact is that porosity is one of the most efficient ways to decrease material and power consumption at the production stage and to increase energy efficiency and safety during operation, which is extremely valuable from the point of view of the Green Construction concept.

Table 1. Influence of material porosity at various dimensional levels on the formation of its properties

Dimension level	Pore size	Achieved effects	Method of formation
Macro	>100 μm	Reduction of thermal conductivity, sound conductivity, heat capacity	Foam, gassing
Meso	20…100 μm	Increase in frost resistance, technological properties of mixtures	Additives, technological methods

Micro (capillary)	1…20 μm	Control of sorption properties of the material, influence on strength, permeability, etc.	Regulation of the amount of water, the grain composition of the solid phase
Micro (contraction)	0.01…1 μm	Shrinkage control, cracking	Regulation of mineralogical composition and morphology of neoplasms
Nano (pores of the gel)	<0.01 μm	Affect the strength of the crystalline splice	Use of nanostructuring modifiers

Tab. 1 shows that the porosity of various dimensional levels affects almost all significant properties of materials. The combination of multidimentional pores and matrix characteristics, i.e. targeted formation of the heteroporous structure, makes it possible to create composites with required properties, including properties of the second and third categories of the above-mentioned classification.

One of the most perspective materials from the point of view of the proposed concept is cell concrete due to the following:

– initial existence of pores with various dimensional levels in its structure;
– high efficiency for construction of protective structures confirmed and recognized by consumers;
– low material and power consumption, affordable cost.

Non-autoclaved aerated concrete is very attractive due to flexibility of technology, the achieved level of standard properties, chemical system life, and capital requirements of production. The use of composite binders as its basis, which are well-established to tackle special tasks [8-10], opens manifold opportunities for variation of matrix properties, including properties related to the second and third categories of the above-mentioned classification.

Since there is a need to develop properties initially not attributable to materials, the primary task is to select a method of their creation. The traditional approach to strengthen any property due to application of additives is not advisable since it may cause unfavourable side-effects that will require further adjustment. The reason for this is the need to maintain stability of materials, Portland cement in particular, to ensure influence through indirect factors. Consideration of properties within the area not typical for a material leads to a sharp decrease in efficiency of its application (Fig. 1).

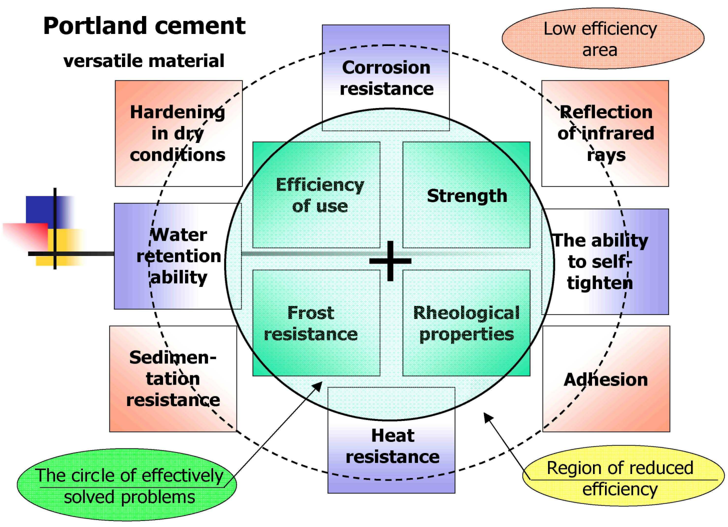

Figure 1. Example of rational tasks using Portland cement

In these cases, it is necessary to ensure targeted synthesis of a material to solve a specific task. The set properties are formed due to the use of various additives in combination with deep modification of main components. At the same time, the efficiency of additives increases alongside with anticipation of undesirable factors.

A consumer receives the ready-to-use product with a set of necessary properties to solve a certain task or a number of related tasks. The maximum efficiency of applied resources is thus provided. Despite additional costs for the preparation of composite binders, the total power consumption decreases.

The example of this can be cell concrete, where Portland cement, without introduction of finely-dispersed mineral or special chemical additives, cannot provide the required technological properties.

The standard manufacturing technology of non-autoclaved aerated concrete is not very complicated. However, in practice, the attempts to produce non-autoclaved aerated concrete with high properties are often unsuccessful from the technical or economic viewpoint. It is believed that a key point defining the success of technology is the transition from the system: “binder – mineral additives – functional additives – fine aggregate” to the simplified system: “composite binder – fine aggregate”.

Composite binder can be obtained through combined or separate grinding of its main components. At the same time the greatest possible number of ingredients (taking into account their compatibility factor) shall be introduced at the stage of binder preparation. This approach ensures the following:

– solves the task of grain structure heterogeneity of molding compound, which is especially critical when using various local natural and technogenic raw materials (for example, rock crushing and sawing dust, ash, slags, etc.) as mineral aggregates;

– provides uniformity of distribution and immediate beginning of works related to introduction of relatively small amounts of organic and inorganic additives (limes, plaster, etc.);

– simplifies the preparation of molding sand, reduces the risk of quality variations due to potential dosing errors;

– increases the activity of introduced components, Portland cement in particular, due to mutual mechanochemical activation. This causes the increase in strength characteristics or less consumption of active components, reduces energy consumption for thermal treatment. Over time, this will justify costs for grinding.

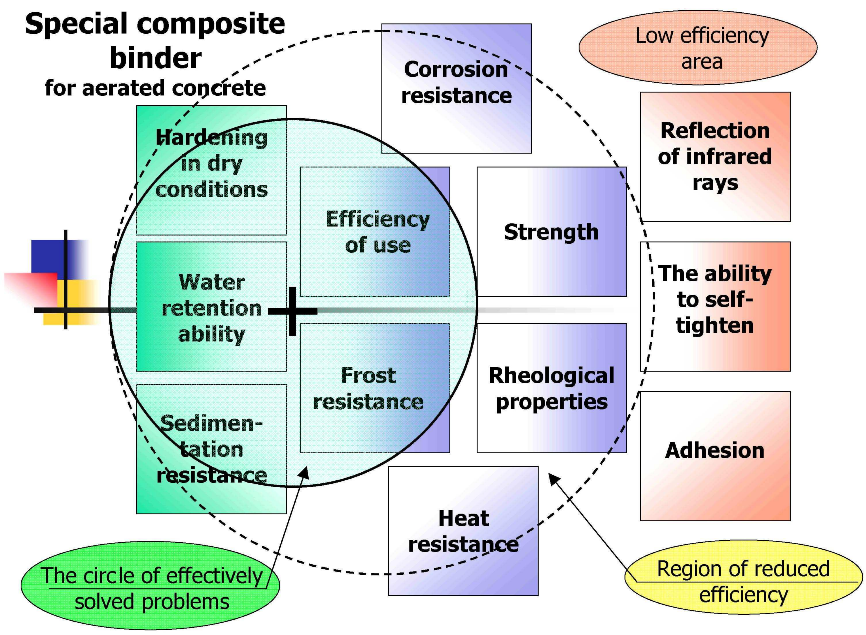

Figure 2. Example of rational tasks using composite binders

The above-mentioned facts resulted in the transition to composite binders containing all necessary functional components: brick basis, mineral additive, water reducing additive, pH and temperature controller and stabilizer of molding sand viscosity during porization. The properties of composite binders are completely optimized to produce cell concrete that ensures maximum efficiency of its application (Fig. 2). In fact, the production of aerated concrete requires mixing with water, insulation of a gas-forming agent and a room. Indicators of the obtained material are 30 … 40% better than those obtained via traditional methods (Fig. 3).

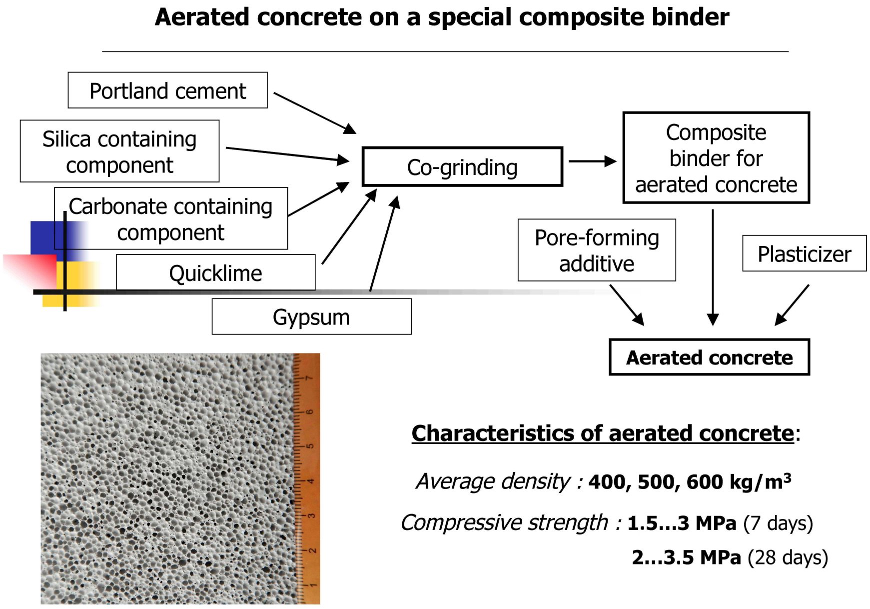

Figure 3. Example of rational tasks using composite binders

The proposed approach to intensification of composite structurization due to targeted creation of pores with various large-scale levels, ensured by the application of composite binders optimized to solve a certain task, allows developing the required materials properties, increasing safety and comfort of human habitat.

4. Conclusions

Summarizing the aforesaid, it is necessary to emphasize the need to reconsider the existing technology of forming the artificial habitat, which includes passive harmlessness and neutrality. New artificial environment has to exert positive impact on psycho-emotional and physical conditions, provide protection against different negative impacts thus ensuring harmony of a triple system: Person – Artificial Habitat – Nature.

The highest value in the formation of a new artificial habitat is placed on architecture and construction, as well as on the applied materials.

In order to implement the proposed concept, it is suggested to use non-autoclaved aerated concrete as the platform of further study, and targeted formation of the heteroporous structure and management of matrix properties due to application of special composite binders as its major tools.

5. Acknowledgments

The paper is prepared in the framework of the Flagship University Development Program at Belgorod State Technological University named after V.G. Shukhov using facilities of High Technology Center of BSTU named after V.G. Shukhov.

References

[1] Van Loon J 2002 *Risk and technological culture: Towards a sociology of virulence*. (Psychology Press)
[2] Pacheco-Torgal F, Jalali S 2012 *Earth construction: Lessons from the past for future eco-efficient construction*. *Construction and building materials* **29** 512-519
[3] Bribián I Z, Capilla A V and Usón A A 2011 *Life cycle assessment of building materials: Comparative analysis of energy and environmental impacts and evaluation of the eco-efficiency improvement potential. Building and Environment* **46(5)** 1133-1140
[4] Bazhenov Y, Murtazaev S A, Salamanova M and Saidumov M 2016 *High-performance scc-concrete at earthquake resistant construction. International Journal of Environmental and Science Education* **11(18)** 12779-12786
[5] Lessowik W S 2015 *Geonik. Geomimetik als grundlage für die synthese von intelligent bauverbundwerkstoffen. Internationale baustofftagung Ibausil* **19** 183-189
[6] Baumgartner B, Bojdys M J and Unterlass M M 2014 *Geomimetics for green polymer synthesis: highly ordered polyimides via hydrothermal techniques. Polymer Chemistry* **5(12)** 3771-3776
[7] Kuprina A A, Lesovik V S, Zagorodnyk L H and Elistratkin M Y 2014 *Research journal of applied sciences* **9(11)** 816-819
[8] Alfimova N I, Sheychenko M S, Karatsupa S V, Yakovlev E A, Kolomatskiy A S and Shapovalov N N 2014 *Journal of Pharmaceutical, Biological and Chemical Sciences* **5(5)** 1586-1592
[9] Alfimova N I, Trunov P V 2012 *Dry construction mixtures* **1** 37-40
[10] Alfimova N I, Shadskiy E E, Lesovik R V and Ageeva M S 2015 *International Journal of Applied Engineering Research (IJAER)* **10(24)** 45131-45136