ABSTRACT

on the theme «Heat-storing material based on petroleum products for building envelopes» for the degree of Doctor of Philosophy (PhD) by the specialty 6D073000 – «Production of building materials, products and structures»

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The research goal is the development of heat-storing phase transition materials based on petroleum commercial paraffins and justification of the effectiveness of their use in building envelopes.

The idea of the dissertation research is to develop heat-storing materials for building envelopes with specified thermal and operational properties based on commercial paraffins and n-alkanes, to show the effectiveness of their use using the example of energy-active outer shell structures and solar chamber structures for heat treatment of concrete and reinforced concrete products.

In accordance with the idea of the dissertation research, the following tasks were posed and solved:

- a literature review was conducted on the use of heat-storing materials in construction, phase-transition heat-storing materials and their thermophysical properties, the effectiveness of using commercial paraffins as heat-storing materials for building envelopes was substantiated;
- heat-storing materials were developed for building envelopes with a melting point of up to 25°C and a total enthalpy of melting and phase transition above 200 J/g based on commercial paraffins, methods for their production were described;
- methods and techniques for studying heat-storing materials were developed, on their basis the physico-chemical, thermophysical and operational properties of the developed heat-storing materials based on paraffins and their components were studied;
- the effectiveness of using the developed paraffin-based heat-storing materials in building envelopes was substantiated;
- an organization standard was developed for the developed heat-storing materials for building envelopes with a melting point of +25°C and a total enthalpy of melting and phase transition above 200 J/g.

The research object is the termal storage materials of phase transition based on commercial paraffins for external building envelopes.

The research subject is the thermal and operational properties of heat-storing materials based on commercial paraffins for multi-layer building envelopes and the effectiveness of their use in building envelopes.

Methods for achieving the goals. The methodology has been developed for studying the composition, physicochemical, thermophysical and operational properties of heat-storing materials based on paraffins was compiled on the basis of the objectives and tasks of this research.

The two methods were used to obtain heat-storing materials of a given thermophysical property in this work: 1) by mixing liquid and solid commercial paraffins in various ratios; 2) by mixing several individual n-alkanes with the required melting temperatures, high enthalpies of melting and phase transition.

To isolate the required paraffin fractions from the composition of commercial paraffin, a method based on sequential extraction of fractions with solvents according to solubility parameters was used.

Melting and phase transition temperatures, thermal properties of the developed heat-storing materials were determined by standard methods in accordance with the relevant GOSTs.

Scientific novelty of the dissertation:

- a heat-storing material was developed for building envelopes with a melting point of up to 25°C and with a high melting enthalpy (above 200 J/g) based on commercial paraffins and two main methods for their production were presented;

- the mechanism for obtaining stable heat-storing materials with specified thermal characteristics was studied by changing preparation modes, fractional compositions, crystallization conditions and phase transition of commercial paraffins and individual n-alkanes;

- the dependences of the enthalpy of melting and phase transition in the crystalline state and the total enthalpy of the heat-storing materials on the component composition of the initial paraffins were determined, which make it possible to control the composition of the heat-storing materials of the phase transition with the required thermal properties;

- based on the developed heat-storing materials, an energy-active fencing structure and a heliochamber for heat treatment of reinforced concrete products and structures were created, the efficiency of which was studied depending on the time of day and seasons, heat treatment modes of products and structures.

Scientific results (scientific provisions) submitted for the defense:

- methods for producing heat-storing materials of a given thermophysical property by mixing liquid and solid commercial paraffins in various ratios and mixing several individual n-alkanes with the required melting temperatures, high enthalpies of melting and phase transition;

- methods and techniques for studying the physicochemical, thermophysical and operational properties of the developed heat-storing materials based on paraffins;

- heat-storing materials for building envelopes with a melting temperature of up to 25°C and an enthalpy of melting and phase transition above 200 J/g based on commercial paraffins and their physicochemical, thermophysical and operational properties;

- results of calculation substantiation of the effectiveness of using the developed heat-storing materials based on paraffins in building envelopes;

- organization standard for the developed heat-storing materials for building envelopes with a melting point of +25°C and a total enthalpy of melting and phase transition above 200 J/g.

Relevance of the work. The areas of application of heat-storing materials in construction and their types are quite wide today. In this regard, there is a need to develop new effective heat-storing materials adapted to the operating conditions of buildings, study their thermophysical properties, as well as intensify research and use of multi-component heat-storage materials with high heat storage values.

A promising and economically feasible direction in the production of heat-storing materials is the development of new energy-saving materials with a hidden form of energy storage, which include phase-transition heat-storing materials. In phase-transition heat-storing materials, the transfer of thermal energy occurs during a phase transition, when the material changes from a solid state to a liquid state. When transitioning from solid to liquid, heat-storing materials behave like traditional storage materials, their temperature rising as they absorb heat. Unlike known heat-storing materials, in phase-transition heat-storing materials, heat transfer occurs due to the creation of a crystalline structure, accumulation occurs due to the destruction of the structure during melting.

At the same time, there is a need, based on an analysis of the thermophysical properties of various heat-storing materials, to investigate the possibility of their use as a phase-transition heat-storing material, mainly from industrial waste, which has optimal specific heat capacity, high operational reliability and economic feasibility.

In this regard, the research and development of heat-storing materials based on commercial paraffins, as well as justification of the effectiveness of their use in building envelopes to increase their heat-storing capacity is an urgent task.

Connection with the plan of scientific research work. The work was carried out in accordance with the state budget theme included in the thematic plan of the research work of M. Auezov SKU GB NIR-21-02-06 «Increasing the operational efficiency of building materials, products and structures based on raw materials of Turkestan region» for 2021-2026.

The practical significance of the dissertation lies in the developed heat-storing materials with the specified thermal and operational properties, which can be effectively used for heat accumulation in energy-active building envelopes, as well as in the proposed methods for their production.

The developed heat-storing materials, as well as methods for their production, can be used by engineering and technical workers in the construction industry, research and design institutes when designing new energy-active heat-storing and energy-saving building envelopes, as well as during reconstruction of existing buildings.

The practical significance of the results obtained in the work is justified by 3 patents for utility models: dated 06.08.2018 under No 3951 «Multilayer thermally efficient building envelope»; dated 02.07.2019 under No 4426 «Fencing design with an energy-active panel»; dated 17.08.2021 under No 6631 «Installation for heat treatment of concrete and reinforced concrete products using solar energy» and an innovative patent dated 10.12.2019 under No 34970 «Heat-storing material», as well as the author’s certificate «Methodology for determining thermal efficiency and assessing the heat storage capacity of energy-active structures of

external fencing» issued by Institute of Intellectual Property of the Republic of Kazakhstan, as well as the standard «Heat-storing material based on commercial paraffins of TAM-25 brand», TS (Organization Standard) ST 2425-1958-01-GP-007-2023, Shymkent-2023, acts of introducing the results of dissertation work into production.

The substantiation and reliability of scientific provisions, conclusions and recommendations is determined by the following:

- correctness of formulation and solution of problems, comparison of the final results with data known in the literature, evidence of physical and chemical studies of individual experimental results of the researcher;
- application of standard and proven methods and techniques for studying the component composition, determining the physico-chemical, thermophysical and operational properties of heat-storing materials;
- sufficient degree of testing of the results of the work and their consistency with the fundamental provisions of the theory of heat-storing materials of phase transition.

Personal contribution of the author. The author conducted an extensive literature review, set the objectives and tasks of the research, conducted theoretical studies and experiments to study the thermal properties of the developed materials, developed research methods and techniques, developed an energy-active fencing design with a heat-storing layer, developed a solar chamber design for heat treatment of concrete products using solar radiation. He obtained reliable and substantiated scientific results, on the basis of which a conclusion was formulated and the research results were tested.

Approbation of works. The main results of the dissertation work were published in 18 works: four articles were published in journals from the list of publications recommended by the Committee for Quality Assurance in the Field of Higher Education and Science of the Ministry of Higher Education and Science of the Republic of Kazakhstan. Three articles were published in international peer-reviewed journals indexed in the Scopus database (40th percentile) and Web of Science (Q1). One monograph was published and one patent for an invention was received, issued by Institute of Intellectual Property of the Republic of Kazakhstan. Three articles were published in international journals and conferences.

Publications:

- Modeling the Thermal Regime of a Room in a Building with a Thermal Energy Storage. Mathematical Modelling of Engineering Problems Vol. 9, №2, April 2022, pp. 351-358 Journal homepage: https://doi.org/10.18280/mmep.090208. Engineering (miscellaneous). Scopus percentile according to Cite Score is 47;
- Construction of a model for an enclosing structure with a heat-accumulating material with phase transition taking into account the process of solar energy accumulation. Eastern-European Journal of Enterprise Technologies ISSN 1729-3774. 6/8 (120) 2022. DOI:10.15587/1729-4061.2022.268618; Engineering Industrial and Manufacturing. Scopus percentile according to Cite Score is 45;

- Study of the model of the phase transition envelope taking into account the process of thermal storage under natural draft and by air injection. Case Studies in Construction Materials. Volume 18, July 2023, https://doi.org/10.1016/j.cscm.2023.e02050. Case Studies in Construction Materials, 2023, 18, e02050. Materials Science (miscellaneous). Scopus percentile according to Cite Score is 71;

- The influence of the component composition of heat-storing materials based on commercial paraffins on their physical, chemical and thermophysical properties. KazGASA Bulletin. Section “Building structures and materials”. – Almaty, 2020. – No. 1 (75). – P. 212-222. 1608188675_kRs7Y4.pdf (kazgasa.kz);

- Construction of an energy-active heliochamber for heat treatment of reinforced concrete products and structures. KazGASA Bulletin. – Almaty, 2020. – No. 2 (76). – P. 126-130. Вестник 2-2020 Готовый.indd (kazgasa.kz);

- Mathematical model of heat exchange during phase transition of heat-storing material. Bulletin of L.N. Gumilyov ENU. Series of Technical science and technology. – Nur-Sultan, 2022. – No 2 (139). – P. 102-110. DOI: https://doi.org/10.32523/2616-7263-2022-139-2-102-110;

- Methodology for determining the expected pressure in an unexpansive accumulative structure. KazGASA Bulletin. Series of Construction structures and materials. – Almaty, 2023. – No 2 (88). – P. 219-225. https://doi.org/10.51488/1680-080X/2023.2-22;

- Preparation of compositions of heat-insulating materials based on liquid paraffins and n-alkanes. Path of Science. International scientific journal. Volgograd, 2019. – No 9 (67). – P. 20-24. http://scienceway.ru/f/the_way_of_science_no_9_67_september.pdf;

- Preparation of heat-storing materials by displacement of individual n-alkanes and their thermophysical properties. Scientific publication «Scientific aspect». – Samara: Publishing house «Aspect». – 2019. – No 3. – P. 333-240. https://na-journal.ru/arhiv/1919-zhurnal-nauchnyj-aspekt-3-2019-tom3;

- Shrinkage of heat storage material obtained by mixing commercial liquid and solid paraffin’s. European journal of natural history. Technical sciences. – 2020. – No 3. – P. 46-50. https://world-science.ru/en/article/view?id=34084;

- New energy-saving materials based on heat-storing materials. International scientific journal «Global science and innovations 2019: CENTRAL ASIA» NUR-SULTAN, Kazakhstan, SEP-OCT 2019;

- Optimal methods for obtaining heat-storing materials based on commercial paraffins. M.Kh. Dulati Taraz State University. «Mechanics and technologies» scientific journal, Building materials section, - Taraz, 2020. – No 2. – P. 210-219. meh-teh-2020-2.pdf (dulaty.kz);

- Patent for the utility model of the Republic of Kazakhstan No 3951 dated 06.08.2018 «Multilayer thermally efficient building envelope»;

- Patent for the invention of the Republic of Kazakhstan No 34970 dated 10.12.2019 «Heat-storing material»;

- Patent for the utility model of the Republic of Kazakhstan No 4426 dated 02.07.2019 «Fencing design with an energy-active panel»;

- Patent for the utility model of the Republic of Kazakhstan No 6631 dated 17.08.2021 «Installation for heat treatment of concrete and reinforced concrete products using solar energy»;

- Certificate of entry of information into the state register of rights to objects protected by copyright No 12868 dated 28 October 2020 «Methodology for determining thermal efficiency and assessing the heat storage capacity of energy-active structures of external fencing» Свидетельство.pdf (kazpatent.kz);

- Heat-storing material based on commercial paraffins of TAM-25 brand. TECHNICAL SPECIFICATIONS (Organization standard). ST 2425-1958-01-GP-007-2023, Shymkent-2023.

Structure and volume of the dissertation. The dissertation work, in accordance with the content and tasks of the research, consists of Introduction, four sections, conclusion, list of 216 references, appendices. The volume of the work is 129 pages of text typed on a computer, including 39 figures and 29 tables.