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PHYSICAL AND TECHNOLOGICAL BASICS AND NEW GENERATION TECHNOLOGY OF RADIATION-MODIFIED POLYMER CONCRETE

In this paper we present the research results of physical and technical problems of new RMPC types, the development of methodology of the irradiation with electrons and the creation of the necessary research radiation technique for this purpose which is suitable for irradiation of concretes and their components on the stages of the optimization of recipes and structure of new composites.
Keywords: radiation technology, polymer concrete, hidrofobization, radiation technique.

Introduction

Concrete is the most distributed modern construction material. Its production technologies are being constantly improved; new composite cement systems are created. Involving unique possibilities of radiation technologies is one of the perspective approaches of solving actual problems of concrete production progress.

Porosity is the major drawback of this material. Moisture easily penetrates into the thickness of the material and promotes its corrosion. This problem was studied by many researchers and various measures for the elimination of the porosity were developed. Chemists suggested to saturate the pores of concrete with different polymers. This method significantly improved the situation for a certain period of time. But it turned out that during exploitation at different temperatures, the effect of the difference of coefficients of thermal volume expansion of mineral base concrete and polymer appears, and this causes gradual destruction of polymer and of its repellent (water resistant) properties. Under such circumstances, covering the surface of concrete with thin polymer repellentpellicles is inefficient. The pellicle is destroyed under the influence of ultraviolet sun irradiation, temperature difference and climat change periods. Re-introduction and application of polymers is not efficient. But the idea of the creation of organic-mineral composite concrete is perspective and stimulates the search of new types of polymers, which would have more suitable physical and chemical properties. It is advisable to involve modern scientific radiation technologies to promote the process of the creation of higher quality concrete.

Radiation technologies use the ability of irradiation of piko-waves range of electromagnetic oscillations (ionizing) to influence on orbital structures of atoms of the materials. This is particularly effective for the polymerization of monomers. With optimal choice of energy of ionizing irradiation, the effect can be focused on the outer orbits of electrons in atoms that define their covalent bonds [1]. Such irradiation can be used as an instrument for the initiation of chemical reactions among different elements and compounds which are traditionally not suitable for chemical combination into a single system with certain physical properties. Analysis of the experience of such works in related branches shows that the initiation with ionizing irradiation of chemical activity of the surface of mineral components (concretions) and organics for their reliable chemical cross-linking is the most effective way of promoting

the creation of new organo-mineral compositions. If such reactions are stimulated in the pores of concrete, then the formation of monolithic material with certain physical and mechanical properties takes place. Thus, physical properties of monomer, its ability to penetrate into deep layers of concrete (minimum viscosity) and to stay elastic after polymerization in the wide range of temperatures are the main condition of the reliability of such material. And the lack of toxicity is the condition of its effective implementation.

Ways of solving technological problems.

Problem on the progress of concrete radiation technologies can be solved only with two simultaneous directions – the development of new, non-toxic monomers or oligomers with minimal viscosity and low cost, and the development of electro-physical technique for the study of technological process of concrete radiation modification. The development of effective ways of irradiation of monomers even in inner layers of this dense material is the condition of technological realization of the production.

Physical basics of the new RMPC technologies.

Most intensively the activation process takes place under the influence of high energy electrons. During the absorption of the electrons' energy, processes in the material that promote and intensify numerous chemical reactions, including those which can't take place under other conditions. The scheme of these processes is shown in the fig. 1.

The basis of the processes is the formation of flow of free electrons with sufficient energy to initiate (or tear off) electrons of the outer orbits of neighboring atoms and thus - promoting the formation of covalent bonds.

Passing near atom, primary high energy electron e_W interacts with orbital electrons and ionizes the atom, or interacts with nucleus and emits photon hν, which is also able to ionize nearby atoms. During the interaction with orbital electrons, primary electron gives them some energy and secondary electrons shift to the orbits with larger radius, or even break away from the atom.

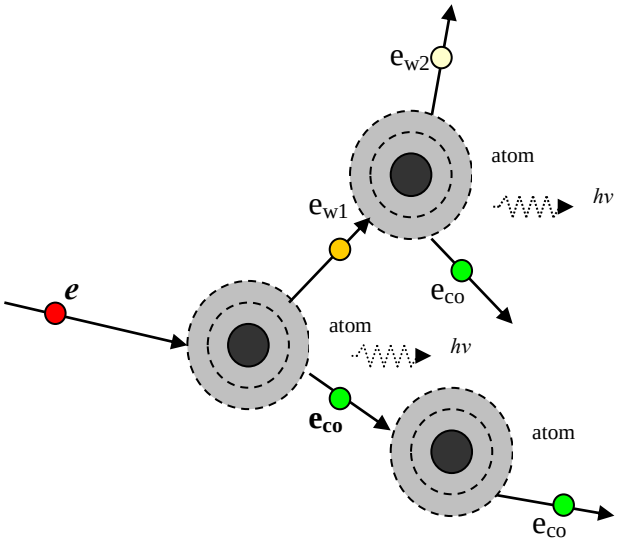

Fig.1. Scheme of modification processes of shell structures of atoms under the action of megavoltelectrons.

Primary electron is deflected from its original direction and continues to move in the matter, gradually giving its energy to the atoms which are on its way. During every next interaction act, the same products of the interaction are formed; and the excess of free secondary electrons with a lot of energy is formed in the material. In its turn, such secondary electron is able to initiate two or three molecules. Every ionizing act is actually disturbance of one chemical bond. The flow of such primary high-energy electrons leads to the formation of the large amount of activated molecules and ionized atoms. Charged and uncharged fragments of molecules, formed as a result of the rupture of bonds, have high chemical activity and quickly interact with each other and with other nearby molecules. Herewith, new molecular structures emerge in the irradiated material, and substances with new propertiesare formed. Thus, it is possible chemically the combine substances, which are incompatible with other technologies and to form solid multilayer composite materials with unique properties without any chemical catalysts or initiators.

Radiation chemistry of polymers is the theoretical basis of such model for organics; and radiation physicsis for mineral materials. The subject of our study is concrete – a

mixture of indicated materials. The combination of two disciplines mentioned above provides the ability of the analysis and design of the new methods of production of radiation-modified polymer concrete.

Using such models, new type of composite organic-mineral cementing systems was created by theunited team of executants of the STCU 4599 project. Chemists have developed new recipes of monomers, which meet certain specific requirements, and physicists have developed the technologies of radiation processing of monomers in deep layers of the composite. Chemical and technological problemswhich were solved in this project were described in several publications [2-4].

In this paper we present the results of the research of physical and technical problems of new RMPC types, the development of the methodology for processing with electrons and the creation of necessary research radiation technique which is adapted for the irradiation of concretes and their components on the stages of the optimization of recipes and the structure of new composites.

The creation of the appropriate experimental radiation technical base for standardized researches, which are obligatory for concretes appeared to be the biggest challenge of the project implementation. Special production line was created in KINR with the purpose of the irradiation of concrete products which have significant size and weight. Technological dosimetry of these processes was developed.

The researches of large volumes of samples of various compositions of monomers with the purpose of identifying and selecting a monomerwhich is the most sensitive to radiation and satisfies other technological requirements of RMPC production were made on the base of this radiation technique. The methodology of radiation tests was developed taking into account all concomitant physical effects, which can take around irradiation of the monomers;for example, temperature increase. To obtain reliable results, the influence of this physical factor was excluded through theoretical modeling of temperature dynamics, the development of the methodology of experimental verification of models and the development of the ways of technical support of the irradiation of samples' mass with appropriate control means.

Practical implementation of the technology

It is necessary to solve set of technical tasks for practical implementation of radiation tests of monomers'components. In their list the means for radiation processing of experimental samples of monomers and control of physical parameters of these processes are of utmost attention (fig. 2).

Fig. 2. Samples of monomers on the operation conveyer of radiation installation.

Technical and technological problem of these processes is the requirement of mass irradiation of different samples in the same and stable radiation conditions with the exception of other concomitant effects (heat, expansion, etc.). Fig. 2. shows the working moment of testing large group of monomers concerning the sensitivity to electron irradiation.

Their irradiation was carried out with simultaneous checkout of temperature of control samples located near working samples (fig. 3).

Measurements helped obtain the data about real temperature of the samples in

different modes of irradiation. This provided the possibility to define the limits of temperature range when thermo-chemical effects insignificantlyinfluence radiation-chemical ones. And thus, the mechanisms of the choice of optimal processing modes of electronic processing of monomers were established with the purpose of accurate determinationof their radiation sensitivity and suitability for usage in the RMPC production.

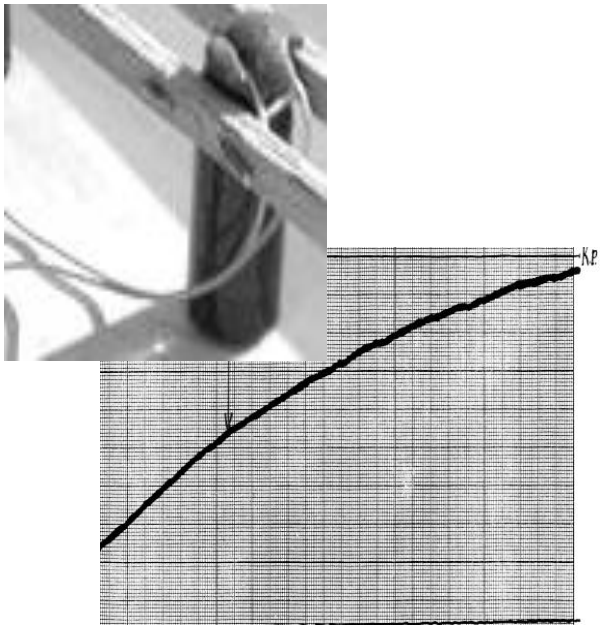

Fig. 3. Control of temperature of samples during irradiation. Photo shows control sample with irradiated monomer. Chart shows temperature dynamics of monomer solution during irradiation

Metrology

Problems of the metrology of radiation process require primary methodological work for the processes of electronic processing of concrete mixtures – the determination of actual distribution of the absorbed dose of irradiation energy in deep layers of this solid and dense material with large size. Taking into account the analysis of perspective directions, the method of phantoms of the same material as experimental samples appeared to be the most suitable. During the development of this methodology, the peculiarities of beams of electrons were taken into account, which are generated with electro-physical sources (accelerators). The model of absorption processes of electrons'energy along the trajectory of their movement in the concrete was developed and analyzed. As a result, the simplest scheme of technological dosimetry of these processes was created (fig.4) and is based on the application of full-scale samples-phantoms.

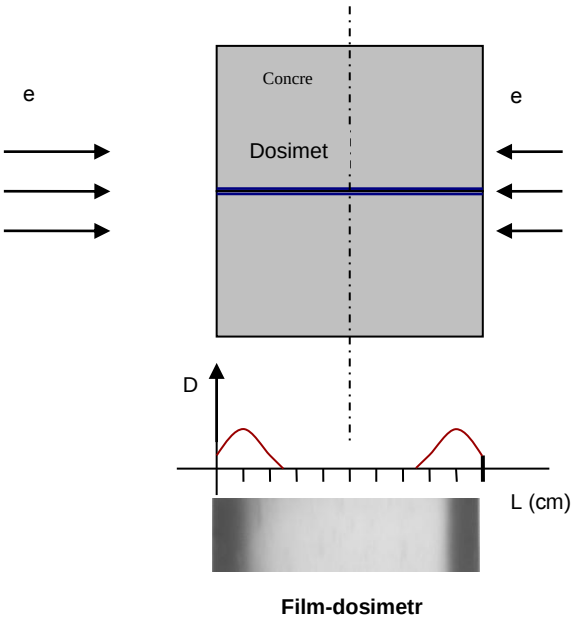

Fig. 4. Phantom methodology of technological dosimetry of the processes of receiving RMPB.

Practice confirmed the effectiveness of such methodology of dosimetry and the ability to determine in this way actual distribution of absorbed doses in different layers of concrete products.

Physical and technological methods of enhancing the RMPC solidity.

Previous generations of the materials of this type were made using deep penetrating gamma rays. This led to the substantial rise of RMPC cost and its extremely limited usage. In this project it was decided to use more available and ecologically safe electro-physical installationson on the basis of electron accelerators. Such sources provide extremely high radiation power. The process of radiation processingon such installations completely meets typical norms of technological expenses for conventional industrial equipment. Limited course in the material, which decreases proportionally to the density of the processed material, is the only drawback of electron irradiation technologies. The penetration of electrons of typical technological energies (3-10 MeV) for concrete does not exceed 20-25 mm, which is definitely insufficient for the reconstitution of the previous radiation technologies of RMPC.

In practice it shows that with the help of electrons it is possible to realize radiation induced polymerization of monomers only in limited layer of concrete. And this was confirmed with measurements of the distribution of absorbed dose, mentioned above and shown in fig. 4. Darkening of membranousdosimeter reflects the thickness of concrete layer where theabsorption of the energy of electrons and polymerization of monomer took place. This effect is used to improve the index of the solidity of polymer concretes.

Physical principles of improving the solidity lie in the formation of a two-layer (or multi-layer) frame structure of products (fig. 5).

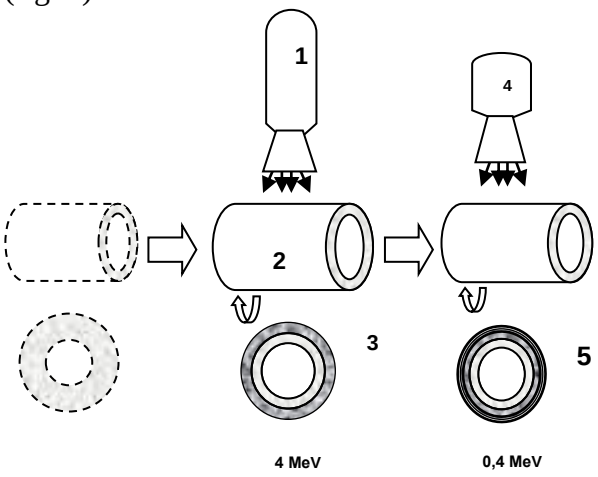

Fig. 5. Enhancing the solidity of a concrete product with the formation of a two-layer and three-layer structure in the body of the product.

Scheme of the technology consists of 3 stages. During the first stage product of polymer concrete (for example, the tubular support structure) is formed and passed under irradiation with high-energy electrons of 4 MeV. As a result, a layer of dense, hydrophobic and solid RMPC is formed in the body of the construction (it is shaded on the figure). If the characteristics of concrete satisfy the consumer, the product is transferred into operation. If there is a need in having the increased indexes of concretehydrophobicity, its surface layers are additionally saturated (or covered) with another composition of monomers and irradiated. As a result, another protective layer of high water-resistance and corrosion resistance is formed. On this stage the irradiation can be done with electrons of less energy and with higher dose power. The sources of electrons of such energy belong to the group of the simplest and cheapest radiation installations with high technological efficiency.

Choosing the thickness and the number of radiation-modified layersof polymer-concrete, it is possible to create composite constructional concretes and products with enhanced indexes of solidity, which considerably prevail over typical concretes.

Conclusions

Technologyof the new generation of RMPC is developed with the usage of new types of non-toxic monomers with minimum viscosity, and megavoltage electrons for the irradiation of monomers in deep layers of concrete. To work out the stages of the technological process of RMPC production a specialized research radiation technique is createdwhich has no domestic analogues so far. The methodologies and means of control in irradiation process are developed. Basic physical and technical peculiarities of the implementation of new technologies are researched and formulated.

Group of concrete products is let out, and the properties of new material according to actual standards of this branch are tested. The research of their indexes shows that the technology and technique, which provide the production of RMPC with characteristicsthat are substantially higher than those of typical concrete are developed (table 1).

Table 1

Test results of radiation-modified concrete

Researched concrete samples	Water absorption of concrete, %	Solidity during the compression of concrete samples, MPa
RMPC mix1	0,28	30
RMPC mix2	0,33	31
RMPC mix3	0,05	23
Control non-modified samples of typical concrete	1,60	23

Advantages of the new generation of RMPC in comparison with traditional concrete are obvious.

Microphotographs (fig. 6) illustrate the enhanced density of the created material (right

photo). This indicates that the expected process of electron-ray initiation of chemical cross-linking of all components of the concrete mix took place.

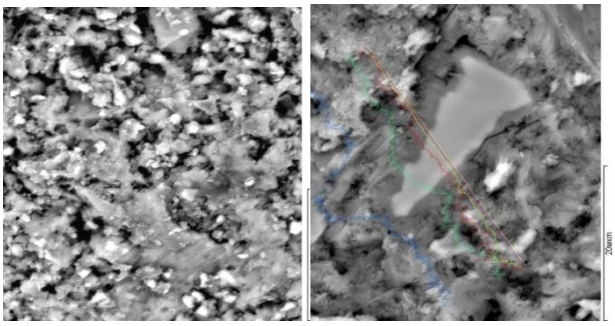

Fig. 6. Microphotographs of the concrete structure.

To the left we see a typical granular micro-capillary structure of the conventional non-modified concrete; to the right – RMPC using new technologies, the capillaries are not observed, the material has dense structure.

The research according to standardized methodologies indicated the possibility of using the research results of physical and chemical and radiation-chemical processes and developments of radiation technique in the production technology of monolithic organic-mineral composite material for concrete products, including those which will be exploited in the extreme conditions.

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ФІЗИКО-ТЕХНІЧНІ ОСНОВИ І ТЕХНОЛОГІЯ НОВОГО ПОКОЛІННЯ РАДІАЦІЙНО-МОДИФІКОВАНОГО ПОЛІМЕРБЕТОНУ

В даній роботі відображено результати дослідження фізико-технічних проблем нових типів РМПБ, розробку методики обробки електронами та створення необхідної для цього дослідницької радіаційної техніки, пристосованої для опромінення бетонів і їх компонентів на етапах оптимізації рецептур та структури нових композитів.
Ключові слова: радіаційна технологія, полімербетон, гідрофобізація, радіаційна техніка.

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В работе отображены результаты исследований физико-технических проблем новых типов РМПБ, разработка методики обработки электронами и создание необходимой для этого исследовательской радиационной техники, приспособленной к облучению бетонов и их компонентов на этапах оптимизации рецептур и структур новых композитов.
Ключевые слова: радиационная технология, полимербетон, гидрофобизация, радиационная техника.