Lightweight materials based on wood waste

A S Yespayeva¹*, Z N Altayeva¹, B K Sarsenbayev², G O Karshyga³ and G R Sauganova²

¹ T. Basenov Institute of Architecture and Construction, Satbayev University, 22a Satpayev Str., Almaty, 050013, Kazakhstan
² M. Auezov South Kazakhstan State University, 5 Tauke Khan Avenue, Shymkent, 160012, Kazakhstan,
³Korkyt Ata Kyzylorda University, 29a Ayteke bi Str., Kyzylorda, 12001, Kazakhstan

E-mail: stroitelstvo_ukgu@mail.ru

Abstract. This paper discusses ways of recycling woodworking waste into light aggregate, optimal compositions of modified binders, as well as the mechanism of cement hydration in the presence of dispersion polymer powders. The methods of obtaining light aggregate based on woodworking waste by granulating in a disc granulator, which is a plate with a tilt angle of 45° and a number of turnovers of 17-19 rpm, are considered. Methods for obtaining granulated aggregate using sawdust of various fractions by the roasting free method are presented, optimal granulation modes are determined, and the main characteristics of the resulting aggregate and concrete based on them are studied. The optimal composition of granulated aggregate on modified cement provides 40 ... 60 % of wood processing waste, 60 ... 40 % of cement, 25 ... 32 % of water and granulation time - 7 ... 9 minutes. With this composition, the bulk density of the resulting aggregate corresponds to 850...750 kg/m³, the maximum strength of the granules when compressed in the cylinder is 3.5...4.1 MPa. The optimal content of the polymer additive in the binder is in the range of: movilith - 0.4...0.7 % and tylose - 0.21...0.13 %. Granulated aggregate on modified cement has a frost resistance in the range of F35... F50. The choice of granulated aggregate on modified cement showed the effectiveness of the aggregate for light concretes. The strength characteristics of modified concrete of 25-75 brands were studied. The mechanical properties of modified concrete depending on the average density were studied. Concrete with an average density of 1000 kg/m³ has M25 brand, at 1200 kg/m³ - M35, at 1300 kg/m³ - M50, at 1500 kg/m³ - M75.

1. Introduction

The problem of low waste production of building materials in many aspects coincides with the problem of rational use of mineral resources [1-5].

Among the main directions for implementing the principles of waste-free technology in the production of building materials is the processing of waste from various industries in order to save natural resources.

The technologies for producing light aggregates, mainly by firing are known. Due to the increase in the cost of energy resources, there is an urgent need to develop a technology for obtaining light aggregates using the roasting free method [6-9].
A simple technology for obtaining filler – roasting free one is known [10-12]. Production of aggregate using this technology is based on granulation of a mixture consisting of ash and its activators, which can be used as lime, cement, cement dust, gypsum. Granule hardening occurs in natural conditions and during hydrothermal treatment, which reduces fuel and electricity consumption, and does not require large investments in comparison with traditional technology.

The roasting free light aggregate based on ash, lime and slag-Portland cement was obtained [13-15]. Pulverized ash mixed with clinker binder or lime is crushed on a vibrating mill and granulated with water on a disc granulator, and then the resulting granules are steamed at 85°C in the mode 4+10+2H. The strength of the granules is 50-70 kgf/cm² with a bulk density of 700-730 kg/m³, water absorption in the range of 30-34%.

Kazakhstan has accumulated a huge amount of various wastes, including woodworking waste, which is increasing every year. However, the use of wood waste in the production of building materials is very low, which requires the development of cost-effective technological methods for their processing.

However, the use of woodworking waste to produce light concrete and its use in the construction industry is not widespread.

Recycling of woodworking waste for the production of construction materials contributes to the creation of low- and waste-free technologies, reducing the cost of production, reducing the area of land for dumps [16-18].

Thus, the solution of the problem of using woodworking waste for the production of light materials, the analysis of the main physical and mechanical properties and the nature of the hardening process by developing new effective technologies for processing these wastes is relevant.

2. Materials and methods

2.1. Materials
As raw materials for obtaining light aggregates we used: Portland cement (table 1), dispersion polymer powders mowilith DM 2072 and tylose MV 5009 P2, wood waste – sawdust fraction of 1.25 mm or less, sand with a size modulus of 2.05.

| Table 1. Physical and mechanical properties of cement. |
|---------------------------------|-----------------|------------------|
| Cement properties               | Measure unit    | Values           |
| normal density                  | %               | 25.1             |
| gripping time:                  |                 |                  |
| beginning                       | hour-min        | 2-45             |
| ending                          |                 | 3-15             |
| specific surface                | cm²/g           | 3100             |
| strength after steaming at:     |                 |                  |
| compression                     | MPa             | 33.9             |
| bending                         | MPa             | 6.0              |
| strength at 28 day age of hardening at: |     |                  |
| compression                     | MPa             | 40.85            |
| bending                         | MPa             | 6.5              |
| uniformity of volume change     |                 | resist           |
| brand                           |                 | M 400            |

Mineralogical composition of cement, mass. %: C₃S – 50; C₂S – 20…30; C₃A=8, C₄AF – 10…13, the rest is glass phase.

*Mowilith DM 2072* is a water-redispersible synthetic polymer based on homo -, co - and triple polymers of vinyl acetate (CH₃COOCH=CH₂). The composition of mowilith – “know-how”, has a high adhesive ability. Firm “Clariant” (Germany) produces mowilith of different brands.
**MV 5009 P2 tylose** is also produced by the firm “Clariant” (Germany). In the composition of tylose, presumably the main component is ethylcellulose \([\text{C}_6\text{H}_7\text{O}_2(\text{OH})_3,\text{(OC}_2\text{H}_5)_n]\). Physical and chemical studies (ICS) revealed the presence of absorption bands of C-H, O-H and C-O – bonds. But unlike the latter, in the IR spectrum of tylose, the frequency of the absorption band of deformation vibrations of \(\text{CH}_2\) groups corresponds to the influence of a double bond (=CH\(_2\)), and the splitting of the absorption band of the methyl group is characteristic of the isopropyl group (\(\text{CH}_3\)) \(\text{CH}\) \[19\]. Changes in the structure, as well as the “know – how” of the company characterize tylose as a water-retaining additive. Figure 1 shows the structure of the tylose.

![Figure 1. Structure of the dispersion polymer additive—tylose at the nanoscale.](image1)

The additive was introduced into the cement paste and concrete mix in a dry state.
To obtain a granular light aggregate, we used woodworking waste - sawdust of a fraction of 1.25 mm or less.
Sawdust of 1.25 mm fraction was previously crushed into smaller particles to obtain granulated aggregate. Waste fractions of 0.63 mm were also used for granulation.
Sand with a size modulus of 2.05 is used as filler.

2.2. Methods
The chemical and mineralogical composition of raw materials, as well as the influence of additives and aggregates on the processes of hydration and hardening of cement were studied using physical and chemical analysis methods.

The morphology, phase composition, contact zones and phase relationships, and the distribution of elements over the area were studied using analytical scanning electron microscopy (ASEM).

We used the DRON-3M x-ray unit, the MOM-1500 derivative graphic unit, the Specord m-80 infrared spectrophotometer, and the MIN-8 microscope.

Light roasting free granulated aggregate based on woodworking waste is obtained by granulation in a disc granulator, which is a plate with a tilt angle of 45\(^\circ\) and a number of turnovers of 17-19 rpm (figure 2).

![Figure 2. Disc laboratory granulator](image2)

Methods for obtaining granulated aggregate by granulation in a disc granulator.

**First method.** The crushed waste of the 1.25 fraction was pre-soaked in water to reduce extractives for 0.5-1 hour. After the pre-soaking time, the waste was dried at a temperature of 100\(^\circ\)C to a humidity of 8 %. Then in the mixer, the waste was thoroughly mixed with 2...3 parts of cement,
gradually adding water to the mixture humidity of 25 ... 35 %. The prepared mixture in the amount of 4 ... 5 kg was given to a disc laboratory granulator. During the pelletizing process, the resulting granules were powdered with the remains of cement.

Second method. To obtain granulated aggregate, waste fractions of 0.63 mm were used. The mixer was loaded with woodworking waste and 3 parts of cement, thoroughly mixed with the subsequent addition of water to the mixture humidity of 35 ... 40 %. The resulting mixture was given in an amount of 4 ... 5 kg to a disc laboratory granulator followed by powdering the pellets with the remains of cement.

Third method. In this way the mixer was charged with 50 % of crushed waste fraction of 1.25 mm and 50 % fractions 0.63 mm, after thorough mixing they add 2...3 parts of cement, 0.5 % polymer additive of the quantity of dry mix and re-produce thorough mixing. Water is added to the mixture with constant stirring until the humidity reaches 30 ... 35 %. The prepared raw material mixture in the amount of 4 ... 5 kg is given to a disc laboratory granulator to produce pellets, followed by powdering them with cement. Mowilith and tylose were used as polymer additives. Granulation depends on the following factors: the humidity of the mixture, the tilt angle of the granulator, the degree of filling of the plate and the granulation time. Therefore, along with the change in the granulometry of the mixture, the granulation time varied within 7 ... 9 min.

The compositions of mixtures and their densities are shown in table 2.

| № of composition | Amount of components, mass. % | cement | water | polymer additives | sawdust fractions, mm | dry |
|----------------|-------------------------------|--------|-------|--------------------|-----------------------|-----|
| 1 *            |                               | 65     | 29    | -                  | 55                    | -   |
| 2 **           |                               | 55     | 26    | 0.4                | -                     | -   | 45 |
| 3 *            |                               | 50     | 30    | -                  | -                     | 55  |
| 4 ***          |                               | 40     | 35    | 0.9                | 60                    | -   |
| 5 **           |                               | 45     | 30    | 0.75               | -                     | 20  | 35 |
| 6 **           |                               | 50     | 35    | 0.24               | -                     | 50  |
| 7 **           |                               | 55     | 28    | 0.6                | 25                    | 20  | -  |
| 8 ***          |                               | 60     | 27    | 0.4                | 0.21                  | -   | 40 |
| 9 **           |                               | 50     | 32    | 0.5                | 0.18                  | 25  |
| 10 ***         |                               | 40     | 25    | 0.7                | 0.13                  | 20  | 20 |

Note: * - according to I method; ** - according to II method; *** - according to III method.

3. Results
At containing a small amount of cement, the strength of the granules in all cases was low, so when selecting the optimal composition, the cement consumption varied within 40 ... 70 %. The amount of wood processing and water waste, respectively, varied between 60 ... 30 % and 35...25 %. The content of polymer additives for the third composition varied in quantity: mowilith - 1.5...3 % of the dry weight; tylose - 0.5...1.0 % of the dry weight.

When 50% of the cement was added to the mix, the raw granule density was 650 g/ gran. With the introduction of 70% cement, the density of granules doubled. The optimal composition corresponds to the consumption of materials in the following amounts: 55 % of wood waste, 45 % of cement and 30 % of water. The presence of a polymer additive in the mixture increases the strength of the granules, which explains the increase in the strength of the granulated aggregate. Wood waste particles are wetted with an aqueous solution when wet, forming films. Water films under the influence of surface tension are connected, bringing together the particles of waste. Because of repeated impacts, the particles are compacted, and excess water appears on their surface, which attracts new particles.
and, at the same time, cement grains. When the crushed waste is constantly rolled in the granulator with cement grains, the granules increase in size and are compacted. At 35% humidity of the mixture, the raw density of the granules was 450 g/cm³, and at 30% humidity it was 580 g/cm³, which is quite acceptable. When 65...45% of cement is added to the mixture, the same pattern is observed. Increasing the amount of cement to a certain limit (70%) improves the granularity of the mixture by increasing the dispersion of the mass and the interaction of cement with the components of crushed waste.

As the granulation time increases, the granules decrease in size and their bulk density increases. High strength of granules is obtained at a granulation time of 7...9 min, and this time is accepted as optimal for all compositions. An increase in the time above the optimal one leads to the emergence of cracks.

Table 3 shows the dependence of the raw density of granules and the strength of the finished product on the granulation time. When granulating the cement-wood mixture for 3...5 minutes, the granules are obtained larger and less durable.

| Granulation time, min | Raw density, g/cm³ | Bulk density, kg/m³ | Tensile strength at compressing in the cylinder, MPa |
|-----------------------|-------------------|---------------------|-----------------------------------------------|
| 3                     | 500               | 800                 | 1.1                                           |
| 5                     | 450               | 630                 | 1.5                                           |
| 7                     | 700               | 880                 | 2.9                                           |
| 9                     | 650               | 800                 | 2.5                                           |
| 12                    | 750               | 810                 | 2.1                                           |

Compliance with the optimal technological parameters allowed obtaining granulated aggregate on modified cement of the following grain composition (table 4). The test results showed that the aggregate is mainly dominated by granules of the 5-10 mm fraction.

Table 4. Grain composition of granulated aggregate.

| № compound | Residues on the sieves, mass. %, fraction, mm | Pass through a sieve of 0.14, % |
|------------|---------------------------------------------|--------------------------------|
|            | 10  | 5.0 | 2.5 | 1.25 and less | part | full | part | full | part | full |
| 8          | 19.81 | 19.81 | 47.79 | 67.9 | 26.81 | 94.41 | 4.19 | 98.6 | 1.4 | 100 |
| 9          | 17.23 | 17.23 | 45.82 | 63.05 | 28.63 | 91.68 | 7.42 | 99.1 | 0.9 | 100 |
| 10         | 18.51 | 18.51 | 46.19 | 64.70 | 28.01 | 92.71 | 6.09 | 98.8 | 1.2 | 100 |

Table 5 shows the main physical and technical characteristics of granulated aggregate compositions 8...10. Granulated aggregate of composition 7 containing mowith in an amount of 2.25%, based on crushed waste from fractions 1.25 and 0.63 mm, has a higher bulk density of 1000 kg/m³ than composition 1 obtained on a cement binder. In this regard, the brand of granulated filler on modified cement (900...1100), respectively, higher than that of the cement (500, 600), the strength of the granules from the first ranges from 4.5...5.2 MPa, and the second two and a half times lower (1.7...2.0 MPa), the coefficient of the first resistance is 1.2...1.7. Low water resistance of the granulated filler compositions 8...10 due to the content in the binder dispersion of the polymer, which forms a kind of film on the surface of the grains of cement and waste wood.
Table 5. Physical and technical properties of the filler.

| Main indicators | Granulated fraction filler, mm, compositions (№) |
|-----------------|-----------------------------------------------|
|                 | 5          | 6          | 7          | 5-10 | 10-20 | 5-10 | 10-20 | 5-10 | 10-20 |
| Bulk density, kg/m³ | 950        | 900        | 1000      | 950  | 1100  | 1000 |
| Compressive strength of granules (MPa) in the state of: | | | | | | | | | |
| dry             | 4.8        | 4.5        | 5.1       | 4.6  | 5.2   | 4.9  |
| saturated with water | 3.9        | 3.6        | 4.5       | 3.9  | 4.3   | 4.0  |
| Water resistance coefficient | 1.2        | 1.3        | 1.6       | 1.7  | 1.4   | 1.5  |
| Water absorption, % | 18.0       | 19.5       | 13.7      | 14.9 | 16.1  | 16.0 |
| Intergranular voidness, % | 33.3       | 41.2       | 36.2      | 39.8 | 37.4  | 38.2 |
| Frost resistance, cycles | 40         | 35         | 45        | 50   | 50    | 45   |
| Thermal conductivity, W/m*deg | 0.11       | 0.10       | 0.09      | 0.091| 0.092 |

Granulated aggregate on modified aggregate has frost resistance in the range of F35... F50. All this generally determines the choice of granulated aggregate on modified cement as the most effective aggregate for light concrete.

The strength characteristics of modified concrete 25-75 brands were studied. The mechanical properties of modified concrete depend mainly on the average density. Concrete with an average density of 1000 kg/m³ has M25 brand, at 1200 kg/m³ - M35, at 1300 kg/m³ - M50, at 1500 kg/m³ - M75. The strength characteristics of the modified concrete meet the requirements of the standards for light concrete. The prismatic strength and bending tensile strength for the above brands fluctuates between 2.7 – 7.0 MPa and 0.79 - 1.8 MPa, respectively, and grows with increasing average density of modified concrete (table 6). However, the strength coefficients decrease with increasing compressive strength of concrete.

Table 6. Physical and mechanical properties of concrete containing mowilith.

| Brand | Average density, kg/m³ | Tensile strength, MPa, at: | | | |
|-------|------------------------|-----------------------------|----------------|-----------------|----------------|----------------|
|       |                        | compression, R_com           | prismatic, R_prism | bending, R_bend |
| M25   | 1000                   | 3.5                         | 2.7             | 0.79             |
| M35   | 1200                   | 5.0                         | 3.8             | 1.15             |
| M50   | 1300                   | 7.5                         | 5.5             | 1.65             |
| M75   | 1500                   | 10.0                        | 7.0             | 1.80             |

Table 7 shows experimental data on determining the degree of hydration of Portland cement of the Karaganda cement plant for a test of normal density with a polymer additive of tylose in comparison with non-additive cement. The samples were solidified in water at a temperature of 20°C.
Table 7. The degree of hydration of the modified cement.

| № of composition | Type and quantity of additives, tylose, % | W/C | Chemically bound water, %, at the age, days | The degree of hydration of cement, %, at the age, days |
|------------------|------------------------------------------|-----|----------------------------------------------|-----------------------------------------------|
|                  |                                          |     | 7   | 28 | 90 | 7   | 28 | 90 |
| 1                | -                                        | 0.26| 12.8| 15.5| 18.7| 0.53| 0.61| 0.72|
| 2                | 0.5                                      | 0.2 | 11.0| 12.5| 15.3| 0.45| 0.51| 0.62|

It should be noted that there is a slight decrease in the amount of chemically bound water and the degree of hydration of cement. The discrete distribution of dispersions of the polymer additive - tylose is additively realized with the active centers of the clinker phases of cement grains.

4. Discussion

The high physical and technical properties of a granular aggregate based on woodworking waste obtained on a binder containing dispersed polymer powders can be explained in such a way that the polymer phase in the cement stone forms an organic structure. In this case, the hydrate phases form a crystallization-coagulation structure, which is strengthened in defective places, such as pores, cracks, and the polymer component, which causes the formation of a more durable and elastic structure. With a higher ratio of polymer to cement (P/C), a continuous polymer mesh is formed.

The hydration kinetics of clinker minerals changes in the presence of polymer additives. The process of C₃S hydration in aqueous solutions of most organic additives slows down somewhat[19]. In this case, the phase composition of cement stone is represented by fibrous hydroxides and calcium hydroxide. Organic additives have almost no effect on the hydration of C₃S, as this mineral is characterized by low activity in the initial period, and the effect of the polymer component is reduced in the later period.

Polymer additives have the greatest influence on the interaction of C₃A with water, and not only the speed of the process changes, but also the phase composition of the cement stone. As a result of C₃A and C₃S hydration, part of the water binds to hydroxides and calcium hydroxides, and partial water evaporation occurs. Increasing the concentration of the solution leads to coagulation of the polymer phase and the formation of membranes between the hydrated and initial particles of cement and aggregate. In the subsequent period, two phases (inorganic and polymer) germinate: the polymer component fills the pore space and the resulting defective places, compacting and connecting additional elements of the cement stone structure.

The use of dispersion polymer powders increases the adhesion of cement stone to other materials. Water-soluble polymer additives, introduced in an amount of up to 3%, plasticize the concrete mixture, increase its uniformity and workability, and reduce water separation.

In some polymer systems, the coagulation is preceded by the formation of a framework of cement stone. In this case, the hardening process slows down, but there is a greater mutual penetration of the two phases, which provides high performance properties of the composition. The polymer phase in cement stone has a microheterogenic structure, as it contains inorganic inclusions of hydrated phases, non-hydrated cement particles or thin fractions of aggregates. Reinforcement of the polymer component improves the properties of the component itself and the system as a whole.

Cement concrete of the third millennium is a modified concrete. Features in the mechanism of hydration and hardening of cement are enhanced by the action of additives in concrete - a water-reducing effect, i.e. the effect of reducing the water demand of the concrete mixture. Modifiers of cement concretes - natural or artificial chemicals introduced into the composition of concrete during manufacture, significantly improve the technological properties of the concrete mix, physical and technical indicators of concrete, reducing its cost and increasing its durability [20, 21].

The effect of the modifying additive in the cement system is manifested by the following features: the ability to absorb at the interface of phases and participate in the formation of spatial coagulation structures, both in the volume and in the surface layers [22].
Exchange processes during cement hydration occur by the donor-acceptor mechanism. The strength and crack resistance of concrete increases significantly. The effect of the short-range selective action of the modifier of the cement matrix structure with the maximum technical and technological action is observed. This process is associated with the dissolution of the tylose additives with the mixing water, with the formation of a liquid phase with a low surface tension and the subsequent manifestation of Deryagin- Rehbinder disjoining effect at defective surface sites of cement grains. The adsorption-energy “capture” of the liquid phase should be attributed to the mechanism of cement activation during hydration [23-25].

5. Summary
The optimal composition of granulated aggregate on modified cement provides 40 ... 60 % of wood processing waste, 60 ... 40 % of cement, 25 ... 32 % of water and granulation time - 7 ... 9 minutes. With this composition, the bulk density of the aggregate corresponds to 850...750 kg/m³, the maximum strength of the granules when compressed in the cylinder is 3.5...4.1 MPa. The optimal content of the polymer additive in the binder is within the range of: mowilith - 0.4...0.7 % and tylose - 0.21...0.13 %.

The mechanism for forming a modified active layer on light aggregate granules from wood waste is as follows:
- the result of the mechanism provides the creation of a protective hydrophobic polymer film based on a complex additive of mowilith and tylose, each of which has a double effect, regulating the water-holding capacity and creating the surface section of phases;
- the formation of cement hydration products occurs on film surfaces in the form of nanoscale defect-free nanocrystals of hydrosilicates that provide the strength of the surface film;
- it was found that the water-holding capacity of the dispersion polymer additive tylose is regulated by the microstructure of the cellulose fiber that is part of it.

When forming the nanostructure of modified concrete, the effective role of the polymer additive should be noted. In order to distinguish elements of unity in the mechanism of active formation of such diverse structural initial phases of cement stone and concrete, a sharp change in the rheological properties of cement paste and concrete mix in our experiments was achieved by a significant change in the amount of distribution of dispersed particles in the volume of the dispersion medium.

6. References
[1] Shevchuk M O 2017 Problems and achievements of processing of vegetable raw materials Bulletin of Polotsk State University. Series B. Industry. Applied science. Chemical technology. Labour protection 11 95–102
[2] Grinshpan D, Savitskaya T, Tsygankova N, Makarevich S, Kimlenka I, Ivashkevich O 2017 Good real world example of wood-based sustainable chemistry Sustainable Chemistry and Pharmacy 5 1 – 13 doi.org/10.1016/j.scp.2016.11.001
[3] Dubovoy E V, Sviridov E B, Shcherbak N V, Dubovoy V K 2017 Energy-saving, environmentally safe technology of air cooling by evaporative type devices Saint-Petersburg: Publishing house of Polytechnic University 286
[4] Litvyak V V, Ospankulova G H, Shaymeredenova D A, Yurkshtovich N K, Butrim S M, Roslyakov Yu F 2016 Atlas: morphology of polysaccharides Astana: LLP “EDIGE” 335
[5] Medvedeva G A, Lifntyeva A F 2020 The research of multilayer outer fencing including materials using ash and slag waste of thermal power plants Construction Materials and Products 3 (2) 29 – 35 DOI: 10.34031/2618-7183-2020-3-2-29-35
[6] Barkhatov V I, Dobrovolsky I P, Kapkaev Yu Sh 2015 Rational use of natural resources of the Chelyabinsk region: monograph. I. Barkhatov, Chelyabinsk: Publishing House of Chelyabinsk State University 624
[7] Lesovik V S, Absimetov M V, Elistratkin M Yu, Pospelova M A, Shatalova S V 2019 For the study of peculiarities of structure formation of composite binders for non-autoclaved
3.4 Aerated concrete

Aerated concrete

Construction Materials and Products 2 (3) 41 – 47

[8] Klyuev S V, Khezhev T A, Pukhareno Yu V, Klyuev A V 2018 To the question of fiber reinforcement of cement Construction Materials Science Forum 945 25 – 29

[9] Orentlicher L P, Soboleva G N 2000 Roasting free composite porous aggregate from wet asbestos-cement waste and light concrete based on it Construction materials 7 18–20

[10] Bondarenko N I, Bondarenko D O, Kochurin D V, Bragina L L, Varfolomeeva S V 2018 Technology of phase metallization of the wood and fibrous board Construction Materials and Products 1(3) 4 – 10

[11] Bessmertny V S, Kochurin D V, Bondarenko D O, Bragina L L, Yalovenko T A 2018 Vitreous protective and decorative coverings on wood particle board Construction Materials and Products 1 (4) 4 – 12

[12] Klyuev S V, Khezhev T A, Pukhareno Yu V, Klyuev A V 2018 Experimental study of fiber-reinforced concrete structures Materials Science Forum 945 115 – 119

[13] Tolstoy A D 2020 Fine-grained high-strength concrete Construction Materials and Products 3 (1) 39 – 43 DOI: 10.34031/2618-7183-2020-3-1-39-43

[14] Ivanova V N 2017 Processing of high-yield fibrous semi-finished products IVUZ Forest journal 6 15-17

[15] Ivanova V N, Makhotina L G 2018 Prospects for the use of commercial types of cellulose for the production of products with high added value Chemical fibers 4 25-26

[16] Khviyuzov S S, Bogolitsyn K G, Gusakova M A , Zubov I N 2015 Estimation of lignin content in wood by IR spectroscopy Fundamental research 9 87-90

[17] Shapovalova I, Vurasko A, Petrov L, Kraus E, Leicht H, Heilig M, Stoyanov O 2018 Hybrid composites based on technical cellulose from rice husk Journal of Applied Polymer Science 135 (5) 45796

[18] Smolin A S, Komarov V I 2017 Role of lignin in the technology of materials for corrugated cardboard Problems of mechanics of pulp and paper materials: Proceedings of the IV International scientific and technical conference. - Arkhangelsk: Northern (Arctic) Federal University named after M.V. Lomonosov 29-34

[19] Klyuev S V, Klyuev A V, Shorstova E S 2019 The micro silicon additive effects on the fine-grass concrete properties for 3-d additive technologies Materials Science Forum 974 131–135 doi:10.4028/www.scientific.net/MSF.974.131

[20] Aymenov A Zh, Khudyakova T M, Sarsenbayev B K 2018 Studying the mineral additives effect on a composition and properties of a composite binding agent Oriental journal of chemistry 34(4) 1945-1955

[21] Taimassov B T, Sarsenbayev B K, Khudyakova T M, Kolesnikov A S, Zhanikulov NN Development and testing of low-energy-intensive technology of portlandcement //Eurasian chemico-technological journal -2017y. Volume 19 –Number 4. Pg.347-355.

[22] Aymenov A.Zh., Sarsenbayev N.B., Khudyakova T.M., Sarsenbayev B.K., Kopzhassarov B.T. 2016 Effect of additive of polycmetallic ores’ tailings on properties of composite cements Eurasian chemico-technological journal 153-160

[23] Klyuev S V, Klyuev A V, Shorstova E S 2019 Fiber concrete for 3-d additive technologies Materials Science Forum 974 367–372 DOI: 10.4028/www.scientific.net/MSF.974.367

[24] Klyuev S V, Khezhev T A, Pukhareno Yu V, Klyuev A V 2018 Fiber concrete for industrial and civil construction Materials Science Forum 945 120 – 124

[25] Elistratkin M Yu, Minakov S V, Shatalova S V 2019 Composite binding mineral additive influence on the plasticizer efficiency Construction Materials and Products 2 (2) 10 – 16