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# Research and development of wood-cement composites as sustainable building materials based on secondary resources

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**ABSTRACT**
Conversion of waste into innovative materials that contribute to the sustainable development of infrastructure and the construction industry is an important task in today's society. Wood-cement composites which are building materials that combine wood components and a cement matrix are studied herein. These composites have a number of such advantages as high strength, excellent thermal insulation properties, durability and environmental friendliness. The manufactured composite material is a lightweight concrete based on secondary resources, binders and mineral components. Standardized measuring equipment and methods intended to analyze the chemical composition and physical and chemical properties of wood-cement composites (arbolite) were used in laboratory experimental tests. All samples studied were 40 mm × 40 mm × 160 mm lightweight concrete. Four options to obtain a wood-cement composite in various combinations of binders, minerals and other additives were proposed in the research work. All samples were tested to determine the physical and mechanical characteristics and the optimal composition with improved properties. Secondary resources in the form of wood waste and ash from combined heat and power plants (CHPP) were obtained from industrial structures of the Republic of Kazakhstan. An X-ray diffraction analysis of the CHPP ash was performed to determine the chemical mineral composition that showed a high content of silicon. According to the test results, the CH-4 sample demonstrated high physical and mechanical characteristics. The compression strength of the wood-cement composite sample reached 37.1 MPa, and the bending strength was 7.4 MPa on the 28th day, which proves the high performance properties of this composite.

***Keywords:*** wood waste, CHP ashes, wood-cement composites, building materials, secondary resources, arbolite.

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## Introduction

The United Nations (UN) Sustainable Development Goals (SDGs), established on September 15, 2015, under the title "Transforming our world: The 2030 Agenda for Sustainable Development" are crucial in context. Some of these UN Sustainable Development Goals, such as building resilient infrastructure, promoting inclusive and sustainable industrialization and innovation (Goal 11), sustainable cities and human settlements (Goal 11) and ensuring sustainable consumption and production patterns (Goal 12), are closely linked in improving the preparation of composite materials with the use of industrial waste for infrastructure development and construction in cities and communities' points of the world [1].

Global environmental challenges and the need for sustainable development of infrastructure and the construction industry have prompted scientists and engineers to look for innovative solutions to create efficient materials using secondary resources in recent decades. One of the promising areas is the development of wood-cement composites (DCC) with the use of wood waste. Wood-cement composites combine the properties of organic and inorganic materials, which provides them with high mechanical characteristics, durability, environmental friendliness and resistance to adverse environmental influences. Researchers have found that it is possible to improve the characteristics of arbolite concrete composites by purposefully changing their properties and structure with the use of various additives from industrial and vegetable waste [2].

Wood waste is a significant economic and environmental problem. Recent studies found that more than fifty million cubic meters of wood waste are generated annually in the European Union [3]. Given the current technological capabilities, the potential for recycling wood waste is still relatively low. It is due to the lack of sustainable methods and technologies for the reuse and recycling of secondary resources [4]. To date, the possibility to recycle wood waste can be either production of energy in the form of a renewable energy source, or use as an additive for building materials [5]. A study demonstrated that a structural arbolite with a strength of 1.5 to 6.0 MPa and a density in the range of 600–950 kg/m³ can be produced using organic cellulose aggregates in the form of wood waste [6]. These materials not only improve the mechanical properties of arbolite but also contribute to its environmental sustainability and energy efficiency. Arbolite has strength, biostability, fire resistance, frost resistance and other characteristics due to the mineral binder in the composition that not only make it more durable but also increases its performance in various conditions [7].

Research on wood sawdust and cement composites has been conducted by many scientists. In the works of Chowdhury S. and others [8], it was found that replacing part of the cement with wood ash leads to an increase in the flexural strength of the composite. The use of wood ash can improve the material's resistance to moisture and aggressive chemicals, as well as reduce its cost and environmental impact due to waste recycling. Furtos and colleagues investigated the properties of geopolymer composites reinforced with wood fiber and found that the inclusion of wood fiber helps to reduce the density and thermal conductivity of these new materials [9]. Coatanlem P. and colleagues conducted a study of lightweight concrete to which wood chips were added and confirmed that such concrete can be produced using wood chips as an additive [10]. They also found that the adhesion between wood chips and cement matrix could be improved by pre-soaking the chips in a liquid glass solution. Xiao Song and co-workers [11] demonstrated that cement-based wood composites made by the hydrostatic method with the addition of wood chips exhibited maximum flexural strength at a wood content of 30% and a particle size of 5.0–10.0 mm, while modification of wood with NaOH and silane binder improved their performance. Kasai et al. [12] used wood particles from construction waste to produce wood chip concrete, which had a density of 0.92 to 1.25 g/cm³ and demonstrated flexural strength in the range of 4–7 MPa and compressive strength from 5 to 8 MPa; The ratio between flexural strength and compressive strength was 0.5-0.9, which was higher than that of ordinary concrete, indicating the reinforcing effect of wood particles, and the addition of synthetic lightweight aggregates reduced the density to about 0.78 g/cm³ and resulted in lower flexural and compressive strength values, which were 2.05 and 2.2 MPa, respectively. In a study by Alireza Ashori et al. [13], the feasibility of using waste wooden railway sleepers as a filler for wood cement composites was investigated and the effects of pressing temperature (25 and 60 °C) and calcium chloride content (3%, 5% and 7% by weight of cement) on the physical and mechanical properties of the boards were assessed, finding that the addition of calcium chloride improved the properties of the boards and the maximum strength properties were achieved at pressing temperature of 25 °C and calcium chloride content of 7%, making WTRS suitable for use in lightweight concrete structures such as paneling, ceilings and partitions. A. Quiroga and colleagues investigated the effects of different wood treatment methods such as water extraction, alkaline hydrolysis and inhibitor retention on the mechanical properties of wood fibre and wood-cement composites, finding that alkaline hydrolysis was the most effective method to suppress inhibitors and improve the properties of the composites, and presented empirical relationships describing the effects of treatment on the compressive modulus and compressive strength [14]. Insulation materials with outstanding thermal insulation properties can be produced using corn cob particles. Shao and colleagues investigated the addition of these particles to solutions by varying their concentration (2.25%, 4.5% and 6.75%) and size (200 μm and 500 μm) [15]. Their work showed that this approach was effective in preventing self-shrinkage cracking. At the same time, Owczarek studied the effect of 1 mm corn cob particles on the mechanical properties of materials [16], finding that the addition of these particles reduced thermal conductivity and increased flexural strength. Kun Zhang and colleagues investigated eco-concrete with corn cob granules [17], shavings and wood chips, assessing the effect of replacing corn cob particles on the physical and mechanical properties of concrete. Using NMR and MRI, they found that the addition of biomass increased the content of harmful pores, which reduced the compressive strength. However, with the addition of wood chips up to 50%, the uniaxial compressive strength increased by 18.9% to 2.565 MPa, meeting the requirements for self-supporting wall blocks.

The purpose of this study is to develop an effective technology for the production of wood-cement composites with improved performance characteristics, such as mechanical, thermophysical properties, as well as to reduce the cost of building material due to the use of secondary natural and industrial resources.

## Experimental part

2.1 Materials

This study used wood waste in the form of poplar sawdust from a wood processing plant in Karaganda, the Republic of Kazakhstan. The sawdust was crushed and sieved to produce a homogeneous fraction that is about 5mm in size for use in wood-cement composite. Ash from the Ekibastuz CHPP, Ekibastuz town, the Republic of Kazakhstan, and Portland cement of the M 400 brand were also used as a binder. Talcchlorite, calcium chloride, aluminum sulfate, hydrated lime and liquid glass of grade A were used in different combinations and ratios as an additive. Some samples of wood-cement composites were reinforced with polypropylene fibers of the Polyfiber PM54 brand with a fiber length of 18 mm.

2.2 Preparation of wood-cement composites

Wood-cement composites were manufactured in various combinations and ratios of mineral binder, reinforcing substances and additives with the use of wood sawdust. The preliminary test of composites was performed for four combinations (Table 1).

The sequence of introduction of components into the mixer was as follows. 50% of the consumed water was added to the mass of wood sawdust during the preparation process. It was stirred during 5 minutes to ensure its even distribution in the cement matrix. Then mineral and other additives, a reinforcing substance and a binder in the form of Portland cement and the CHPP ash according to the formulation and the rest of the water were introduced into the mass. The mixture was stirred for 1.5-2 hours. The finished cement paste was transferred into pre-prepared molds and formwork.

The formwork was a collapsible hollow cylinder with blind ends with a steel working pipe placed inside. The blocks were formed on a vibrating table, and the mixture was laid in layers.

**Table 1** – Data on the quantitative contents of the preliminary test for wood-cement composite samples.

| Name | | CH-1 | CH-2 | CH-3 | CH-4 |
|---|---|---|---|---|---|
| | | m, kg | m, kg | m, kg | m, kg |
| Organic filler | Wood sawdust | 3.65 | 3.65 | 3.50 | 3.50 |
| Binder | Portland cement M400 | 3.17 | 3.17 | 3.00 | 3.00 |
| | CHPP ash | – | – | 0.12 | 0.05 |
| Supplements | Hydrated lime | 0.16 | 0.16 | 0.45 | 0.45 |
| | Grade A liquid glass | 0.43 | 0.43 | 0.45 | 0.45 |
| | Aluminum sulfate | 0.20 | 0.20 | 0.15 | – |
| | Calcium chloride | – | – | – | 0.15 |
| | Talcchlorite | 0.45 | 0.45 | 0.45 | 0.45 |
| Reinforcement | Polyfiber PM54 Polypropylene Fiber | 0.01 | – | 0.01 | – |
| Moistening | Water | 2.5 | 2.5 | 3.3 | 3.3 |

The formwork was a collapsible hollow cylinder with blind ends with a steel working pipe placed inside. The blocks were formed on a vibrating table, and the mixture was laid in layers. The specimens were 40 mm × 40 mm × 160 mm as specified in JTG 3420–2020 (Test Methods for Cement and Concrete for Road Construction) [18]. In 24 hours after demolding, the samples were placed in a curing chamber with a temperature of 20 ± 2 °C and a relative humidity of more than 95%. Bending and compression strength tests were performed in 5 and 28 days, respectively. These conditions provided optimal parameters for the assessment of the mechanical properties of the composite material. The finished wood-cement composites were stacked and stored for further tests (Figure 1).

**Figure 1** – Ready-made wood-cement composite blocks

2.3 Methods of analysis and testing.

2.3.1 Determination of the chemical composition of the CHPP ash.

Phase identification of the fly ash sample was performed with the powder X-ray diffraction method using the Rigaku Mini Flex II Desktop X-ray diffractometer manufactured by Rigaku Corporation (Tokyo, Japan) [19].

2.3.2 Compression and bending tests

The compression and bending tests of wood-cement composites were performed under the requirements of the JTG3420-2020 (ISO) specifications. For this purpose, three samples of 40 mm × 40 mm × 160 mm were prepared and kept under standard curing conditions for 5 and 28 days. After that, the samples were subjected to bending and compression tests [20]. Bending and compression strength tests were performed on the AGS-X series universal testing machine (Shimadzu, Japan).

The bending strength was determined by the equation (1). The average of the test results of three specimens was chosen as a representative bending strength. If the difference between the mean values was greater than ±10%, the test data were considered heterogeneous and the average of the remained data was taken as the final bending test results.

$$R_f = \frac{1.5 F_f L}{b^3} \quad (1)$$

Where $R_f$ is the ultimate bending strength; $F_f$ is the breaking load, N; L – a span of supports (100), mm; b is the cross-section width of the specimen (40), mm.

The compression strength was determined by equation (2), and the results were rounded to the nearest maximum and minimum values obtained during the tests. The average of the remained data was then calculated and taken as the final compression strength of the specimen.

$$R_c = \frac{F_c}{A} \quad (2)$$

Where $R_c$ is the ultimate compressive on strength; $F_c$ is the breaking load, N; A is the compressed area of the specimen, 40 mm × 40 mm.

## Discussion of the results

3.1 X-ray diffraction analysis (XRD)

X-ray diffraction analysis was performed to determine the mineral composition of the CHPP ash. An X-ray of the sample is shown in Figure 2. X-ray diffraction analysis confirmed the presence of the minerals specified in Table 2.

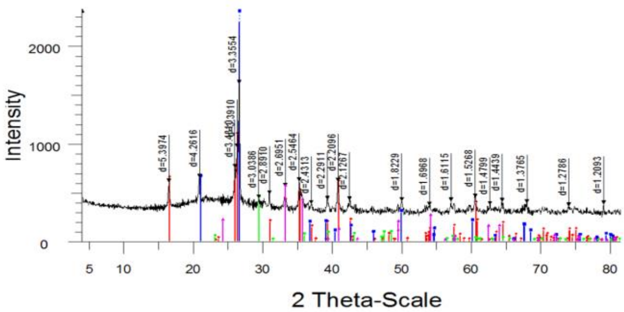


**Figure 2** - X-ray diffraction pattern of the CHPP ash

**Table 2** – X-ray diffraction analysis of the composition of the CHPP ash

| Name | Formula | Content, % |
|---|---|---|
| Sillimanite | $Al_2SiO_5$ | 32.5 |
| Mullite, syn A | $Al(Al_{0.83}Si_{1.08}O_{4.85})$ | 27.2 |
| Hedenbergite | $CaFe+2Si_2O_6$ | 12.4 |
| Quartz low, syn | $SiO_2$ | 8.7 |
| Hematite, syn | $Fe_2O_3$ | 6.7 |

XRD analysis confirmed the presence of the minerals - Sillimanite (Al2SiO5), Mullite, syn A (Al(Al0.83 Si1.08 O4.85), Hedenbergite (CaFe+2Si2O6), Quartz low, syn (SiO2) and Hematite, syn (Fe2O3) in the CHPP ash sample. The XRD result showed that the silicon mineral content in the sample was higher than other existing minerals in the CHPP ash sample.

3.2 Compression and bending strength

Samples of the wood-cement composite were prepared in different combinations of components (Table 1) and tested for compression and bending strength on a universal testing machine AGS-X series (Shimadzu, Japan) to determine the optimal formulation. The test parameters were calculated according to equations (1) and (2). The following samples were tested: CH-1, CH-2, CH-3 and CH-4. The results obtained at the end of the tests are shown in Figure 3-4.

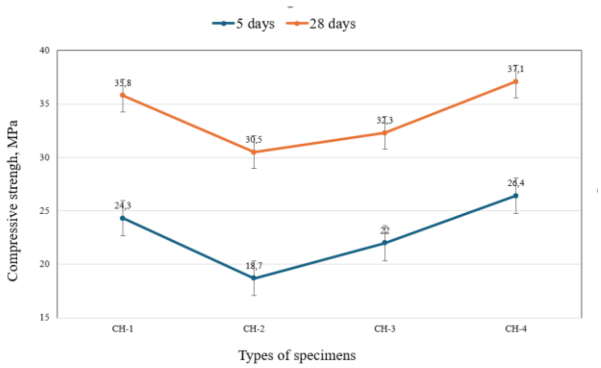


**Figure 3** – Compression strength

Figure 3 shows that the wood-cement composite samples showed the same trend in compression strength on Day 5 and Day 28. The CH-4 sample had the highest compression strength, and the CH-2 sample had the least one of the prepared samples. The other two wood-cement composite samples showed relatively similar compression strength.

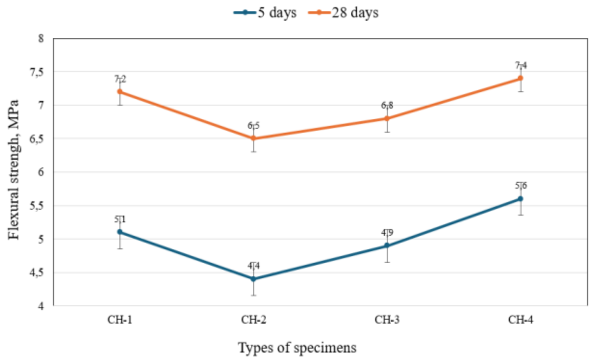


**Figure 4** – Bending strength

As shown in Figure 4, the bending strength had a similar change tendency for the bending strength on Day 5 and Day 28 of the physical-mechanical measurement when it was tested with the testing machine. On the 28th day, the CH-4 sample showed the highest bending strength. Thus, the addition of CHPP ash and the use of calcium chloride as a mineral additive, as specified in Table 1, significantly improved the compression and bending strength of the CH-4 sample. So, we prove that the use of secondary resources such as CHPP ash and sawdust, in combination with mineral additives, can be an effective way to improve the performance of wood-cement composites, contributing to the creation of more sustainable and durable building materials.

## Conclusions

A scientific study on the development of wood-cement composite blocks for use as building materials was carried out herein. Various mineral additives and secondary resources, such as wood sawdust and ash from the thermal power plant, were combined to achieve this goal, and several options for arbolite blocks were proposed. These components have shown high potential for the creation of wood-cement composites with improved physical and mechanical properties. Secondary resources in the form of wood waste and ash from combined heat and power plants (CHPP) were obtained from industrial structures of the Republic of Kazakhstan. An X-ray diffraction analysis of the CHPP ash was performed to determine the chemical mineral composition that showed a high content of silicon.

The CH-4 sample stood out among the proposed samples after the tests demonstrating high strength characteristics. The compression strength of the CH-4 sample reached up to 37.1 MPa, and the bending strength increased up to 7.4 MPa on Day 20. It proves the efficiency of use of secondary resources in the development and production of wood-cement composites for construction purposes. Recycling secondary resources into new materials that contribute to the sustainable development of infrastructure and the construction industry is an urgent task in the modern world.

This article can serve as an important reference and theoretical resource for the integration of wood waste into the composition of cement composites. It is planned in the future to continue research aimed at optimization of the proportion of wood chips in composites to improve their mechanical properties. Besides, future research will focus on the durability of these composites, their resistance to various external influences and operating conditions, as well as on identification of additional advantages and possible limitations on the use of wood waste in building materials.

***Conflict of interest.*** The authors state that they have no known competing financial interests or personal relationships that could affect the work presented in this article.

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# Қайта өңделген ресурстарға негізделген тұрақты құрылыс материалдары ретінде ағаш цемент композиттік материалдарын зерттеу және дамыту

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**ТҮЙІНДЕМЕ**
Қалдықтарды инфрақұрылым мен құрылыс индустриясының тұрақты дамуына ықпал ететін инновациялық материалдарға айналдыру қазіргі қоғамдағы маңызды мәселе болып табылады. Бұл жұмыста ағаш компоненттері мен цемент матрицасын біріктіретін құрылыс материалдары болып табылатын ағаш-цемент композиттері зерттеледі. Бұл композиттердің жоғары беріктігі, тамаша жылу оқшаулағыш қасиеттері, беріктігі және қоршаған ортаға зиянсыздығы сияқты бірқатар артықшылықтары бар. Өндірілетін композиттік материал қайта өңделген ресурстарға, байланыстырғыштарға және минералды компоненттерге негізделген жеңіл бетон болып табылады. Зертханалық тәжірибелік сынақтар кезінде стандарттталған өлшеу құралдары мен ағаш-цемент композиттерінің (арболит) химиялық құрамы мен физика-химиялық қасиеттерін талдау әдістері қолданылды. Барлық сыналған үлгілердің өлшемдері 40 мм × 40 мм × 160 мм болатын жеңіл бетон болды. Зерттеу жұмысында байланыстырғыштардың, минералдардың және басқа да қоспалардың әртүрлі комбинацияларында ағаш-цемент композициясын алудың төрт нұсқасы ұсынылды. Барлық үлгілер физикалық-механикалық сипаттамаларын және жақсартылған қасиеттері бар оңтайлы құрамды анықтау үшін сынақтан өтті. Ағаш қалдықтары мен жылу электр станцияларының күлі түріндегі қайталама ресурстар Қазақстан Республикасының өнеркәсіптік құрылымдарынан алынды. Химиялық минералдық құрамын анықтау үшін ЖЭС күліне рентгендік дифракциялық талдау жүргізілді, оның нәтижесінде кремнийдің жоғары мөлшері анықталды. Сынақ нәтижелері бойынша CH-4 үлгісі жоғары физикалық және механикалық сипаттамаларды көрсетті. Ағаш-цементті композициялық үлгінің қысуға беріктігі 37,1 МПа-ға жетті, ал иілу беріктігі 28-ші күні 7,4 МПа болды, бұл осы композиттің жоғары өнімділік қасиеттерін дәлелдейді.

***Түйін сөздер:*** ағаш ағаш қалдықтары, ЖЭС күлі, ағаш-цемент композиттері, құрылыс материалдары, қайталама ресурстар, арболит (ағаш ұнтағы қосылып жасалатын жеңіл бетон түрі).

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# Исследование и разработка древесно-цементных композитных материалов как устойчивых строительных материалов на основе вторичных ресурсов


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**АННОТАЦИЯ**

Преобразование отходов в инновационные материалы, способствующие устойчивому развитию инфраструктуры и строительной отрасли, представляет собой важную задачу в современном обществе. В данной работе исследованы древесно-цементные композиты, которые представляют собой строительные материалы, объединяющие древесные компоненты и цементную матрицу. Эти композиты обладают рядом преимуществ, таких как высокая прочность, отличные теплоизоляционные свойства, долговечность и экологичность. Изготовленный композиционный материал представляет собой легкий бетон на основе вторичных ресурсов, связующих веществ и минеральных компонентов. При лабораторных экспериментальных испытаниях использовались стандартизированные измерительные оборудования и методики анализа химического состава и физико-химических свойств древесно-цементных композитов (арболита). Все исследуемые образцы были легким бетоном размером 40 мм × 40 мм × 160 мм. В исследовательской работе было предложено четыре варианта получения древесно-цементного композита в различных комбинациях связующих веществ, минеральных и других добавок. Все образцы подвергались испытаниям для определения физико-механических характеристик и оптимального состава с улучшенными свойствами. Вторичные ресурсы в виде древесных отходов и золы ТЭЦ были получены из промышленных структур Республики Казахстан. Проведен рентгеноструктурный анализ золы ТЭЦ для определения химического минерального состава, который выявил высокое содержание кремния. По результатам испытаний образец СН-4 продемонстрировал высокие физико-механические характеристики. Прочность на сжатие образца древесно-цементного композита достигла 37,1 МПа, а прочность на изгиб составила 7,4 МПа на 28-й день, что доказывает высокие эксплуатационные свойства данного композита.



***Ключевые слова:*** древесные отходы, золы ТЭЦ, древесно-цементные композиты, строительные материалы, вторичные ресурсы, арболит.



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## References


[1] United Nations. General Assembly Resolution A/RES/70/1. Transforming Our World: The 2030 Agenda for Sustainable Development. New York. 2015.

[2] Isakulov B, Abdullaev H, Mukasheva A, Akishev U, & Ordabayeva G. Investigation of the formation of microstructure and strength characteristics of slag-alkaline arbolite. EUREKA: Physics and Engineering. 2023; 2:209-221. https://doi.org/10.21303/2461-4262.2023.002814

[3] Bergeron FC. Energy and climate impact assessment of waste wood recovery in Switzerland. Biomass and Bioenergy. 2016; 94:245-257.

[4] Ramage M H, Burridge H, Busse-Wicher M, Fereday G, Reynolds T, Shah D U, Scherman O. The wood from the trees: The use of timber in construction. Renewable and sustainable energy reviews. 2017; 68:333-359. https://doi.org/10.1016/j.rser.2016.09.107

[5] Faraca G, Tonini, D, & Astrup T F. Dynamic accounting of greenhouse gas emissions from cascading utilisation of wood waste. Science of the Total Environment. 2019; 651:2689-2700. https://doi.org/10.1016/j.scitotenv.2018.10.136

[6] Bazhirov N S, Dauletiyarov M S, Bazhirov T S, Serikbayev B E, & Bazhirova K N. Research of waste of aluminum production as the raw components in technology of composite cementing materials. News of the national academy of sciences of the Republic of Kazakhstan. Series of geology and technical sciences. 2018; 1(427):93-98. https://doi.org/10.32014/2021.2518-1491.31

[7] Gonov M E. Mechanical properties of fiber-reinforced concrete under dynamic compression. Probl. Strength Plast. 2022; 84:130-148.

[8] Chowdhury S, Mishra M, & Suganya O M. The incorporation of wood waste ash as a partial cement replacement material for making structural grade concrete: An overview. Ain Shams Engineering Journal. 2015; 6(2):429-437. https://doi.org/10.1016/j.asej.2014.11.005

[9] Furtos G, Molnar L, Silaghi-Dumitrescu L, Pascuta P, Korniejenko K. Mechanical and thermal properties of wood fiber reinforced geopolymer composites. Journal of Natural Fibers. 2022; 19(13):6676-6691. https://doi.org/10.1080/15440478.2021.1929655

[10] Coatanlem P, Jauberthie R, & Rendell F. Lightweight wood chipping concrete durability. Construction and building Materials. 2006; 20(9):776-781.

[11] Song X, Zhou H, Liu Z, Li X, & Han C. Fabrication and mechanical properties of waste wood chips/cements composites for paving materials. Journal of Wood Chemistry and Technology. 2023; 43(3):164-175. https://doi.org/10.1080/02773813.2023.2202191

[12] Kasai Y, Kawamura M, & Zhou J D. Study on wood chip concrete with used timber. Special Publication, 1998; 179:905-928.

[13] Ashori A, Tabarsa T, & Amosi F. Evaluation of using waste timber railway sleepers in wood–cement composite materials. Construction and Building Materials. 2012; 27(1):126-129.

[14] Quiroga A, Marzocchi V, & Rintoul I. Influence of wood treatments on mechanical properties of wood–cement composites and of Populus Euroamericana wood fibers. Composites Part B: Engineering. 2016; 84:25-32. https://doi.org/10.1016/j.compositesb.2015.08.069

[15] Shao K, Du Y, & Zhou F. Effect of bio-based internal curing agent on the performance of high-performance mortar. Journal of Building Engineering. 2022; 49:104092. https://doi.org/10.1016/j.jobe.2022.104092

[16] Owczarek M. Study of the workability and mechanical properties of concrete with added ground corncobs. Materiali in tehnologije. 2022; 54(4):479-483. https://doi.org/10.17222/mit.2019.182

[17] Zhang K, Wang C, Zhao Y, Bi J, Shen M, & Deng X. Study on the effect of wood admixture on the physical and mechanical properties of corn cob ecological recycled concrete. Journal of Building Engineering. 2024; 88:109116. https://doi.org/10.1016/j.jobe.2024.109116

[18] JTG 3420-2020. Testing Methods of Cement and Concrete for Highway Engineering. Ministry of Transport of the People's Public of China: Beijing, China. 2020.

[19] McCarthy G J, Johansen D M, Steinwand S J, & Thedchanamoorthy A. X-ray diffraction analysis of fly ash. Advances in X-ray Analysis. 1987; 31:331-342. https://doi.org/10.1154/S037603080002214X

[20] Liu Z, Han C, Li Q, Li X, Zhou H, Song X, & Zu F. (2022). Study on wood chips modification and its application in wood-cement composites. Case Studies in Construction Materials. 2022; 17:e01350. https://doi.org/10.1016/j.cscm.2022.e01350