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ASSESSMENT OF THE OPPORTUNITIES OF DEMOLITION WASTE USING AS A BUILDING MATERIAL OF THE FUTURE IN UKRAINE

The object of research is the potential of secondary use of waste from the destruction of buildings and structures, which were formed as a result of the military aggression of the Russian Federation on the territory of Ukraine. For Ukraine, the issue of demolition waste is critical at the level of environmental safety and ensuring the demand for building materials for the reclamation of Ukraine according to the principles of the circular economy. To date, there are no official methods that would allow to determine the exact amount of destruction and the quality of the material formed, which complicates the development of mechanisms for its utilization in production. The key industry considered during the research for disposal of demolition waste is the industry of construction materials production.

In the course of research, it was determined that most of the generated waste is waste from the destruction of buildings and structures made of precast concrete, however, considering that these wastes are generated by the action of explosions from shells. It is very difficult to ensure their compliance with the requirements of current standards due to the inclusion that such waste can contain. Therefore, the problem considered by this study is the determination of the nature of waste from the destruction of buildings and structures, their physical, mechanical and chemical characteristics, in the context of the final applications of products based on them.

The results of the study showed that when reproducing the concrete mix for tared concrete for civil purposes, which do not have high requirements for stability in aggressive operating conditions, when replacing natural aggregate crushed to a fraction of 5 to 20 mm, the requirements for concrete strength are achieved in the level of C40/50 strength class. But the rheological characteristics deteriorate due to the high absorption of water from the concrete mixture by the studied material. Research has shown that for further use in the production of ready-mixed concrete and precast concrete products, it is necessary to prepare demolition waste with a wide particle size distribution and low dust content. This can ensure a high level of recycling and meet the demand for concrete in the reconstruction of Ukraine. The fine aggregate from the demolition waste crushing process can be considered as secondary cementitious material for cement production.

Keywords: *construction and demolition waste, recycled concrete aggregates, ready mixed concrete, debris, building materials.*

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1. Introduction

Demolition waste in Ukraine after the Russian invasion becomes one the most discussible topics for local authorities, government, and business. There are not just about the circular economy and waste management, but about the habitat of people who had to live in the mountains of waste resulting from the destruction.

Every day this problem becomes more and more common: amount of the building waste increasing with every missile. The quantity of the materials is difficult to count and impossible to count in occupied regions of Ukraine. According to the latest Ministry of Communities, Territories, and Infrastructure Development data, more than 600,000 tons of demolition waste has accumulated in Ukraine. Representatives of the Ministry emphasized that the data cannot be considered accurate, sometimes these numbers vary by tens of thousands of times: from 600 thousand [1] to 15 billion tons.

Main document which regulates handling of waste from demolition is the Resolution No. 1073 of the Cabinet of Ministers of Ukraine [2]. According to the text of the Resolution, If within 90 calendar days after the termination or abolition of martial law on the territory of Ukraine, the owner of the waste has not carried out measures for environmentally safe collection, transportation, sorting, storage, processing (recycling), disposal, removal, neutralization and burial of waste from the destruction, the authorized

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body makes decisions on handling such waste taking into account the provisions of the Civil Code of Ukraine and other laws. Moreover, in the Resolution covered sorting and most common materials that demolition waste can contain, but there is no clear how these materials can be re-used.

Nowadays, building materials industry has the highest potential to utilize demolition waste as raw material, but is any technological process requires some preconditions that should be considered.

First – norms and regulations of building materials specification, performance, production, and conformity. State Standards of Ukraine (DSTU) do not cover such materials as raw materials. European Norms (EN) contain the meanings «recycled aggregate» [3] and «recycled concrete fines» [4], but from the documents clear if debris isn't sorted and isn't compliance with the chemical composition requirements it cannot counted as raw material for concrete or cement production.

Moreover, the standard, which counted as the main standard for concrete EN 206-1 [5], covers secondary aggregates in the meaning of coarse aggregate and limits its usage as natural aggregates substitutor. Recycled concrete aggregates could have maximum 50 % mass in all coarse aggregate content.

The next significant limitation in EN 206-1 is exposure classes. In general, as more secondary aggregates added fewer exposure classes can be covered. The same principle is in CEN EN 197-6:2023, for cement where some parts of secondary cementitious materials are replaced by recycled concrete fines. As more recycled concrete fines added as less applications of this cement type in concrete.

Second – technological aspects. Concrete and cement production is a part of chemical technology, where consistency of the chemical composition is a pre-condition for reaching the quality regalement. In case of demolition waste in Ukraine, this material cannot be treated as material from any country that already has an experience with recycling of debris.

In Ukraine, demolition waste was created by explosures of missiles, which mix concrete, bricks, glass, plastic, wood and everything that was inside of the building, and sometimes even treated with fire.

Construction and demolition waste, have been classified as Priority Waste Stearns by the Commission of European Communities (CEC) [6], and European countries already have an experience how to re-use debris.

For Ukraine, the European experience can be a good fundament, but any European country has no experience in how to use such demolition waste, generated by war, unsorted, with unclear chemical composition and it's stability, unclear amount of hazardous elements like parts of missiles, heavy metals, asbestos, etc.

So, before defining the applicable technological conditions for recycling these materials in Ukraine, it is necessary to define challenges across the demolition waste value chain (Fig. 1).

These challenges should encourage to approach the problem of demolition waste more strategically and to create a mechanism that would combine all the best practices for managing such waste in Ukraine that confirms the relevance of the study.

The aim of research is to find the most feasible applications to reuse of construction and demolition waste (CDW).

2. Materials and Methods

Before introducing investigation of the possible demolition waste applications, the material itself should be defined. It is known that every building or infrastructure consists some scope of the building materials. Thus, currently it is not possible to calculate the number of debris, but it is possible to review The Housing Fund of Ukraine and define the dominative components of demolishing waste.

As of 1 January 2013, Ukraine's housing stock consisted of 10.2 million residential buildings with a total surface area of 1,094.2 million m^2. Of this, 64 % were located in urban areas. The total surface area of the housing stock during the last five years increased at an average rate of 7.3 million m^2 annually. The average sizes of urban and rural housing units are 52.2 m^2 and 60 m^2, respectively [7].

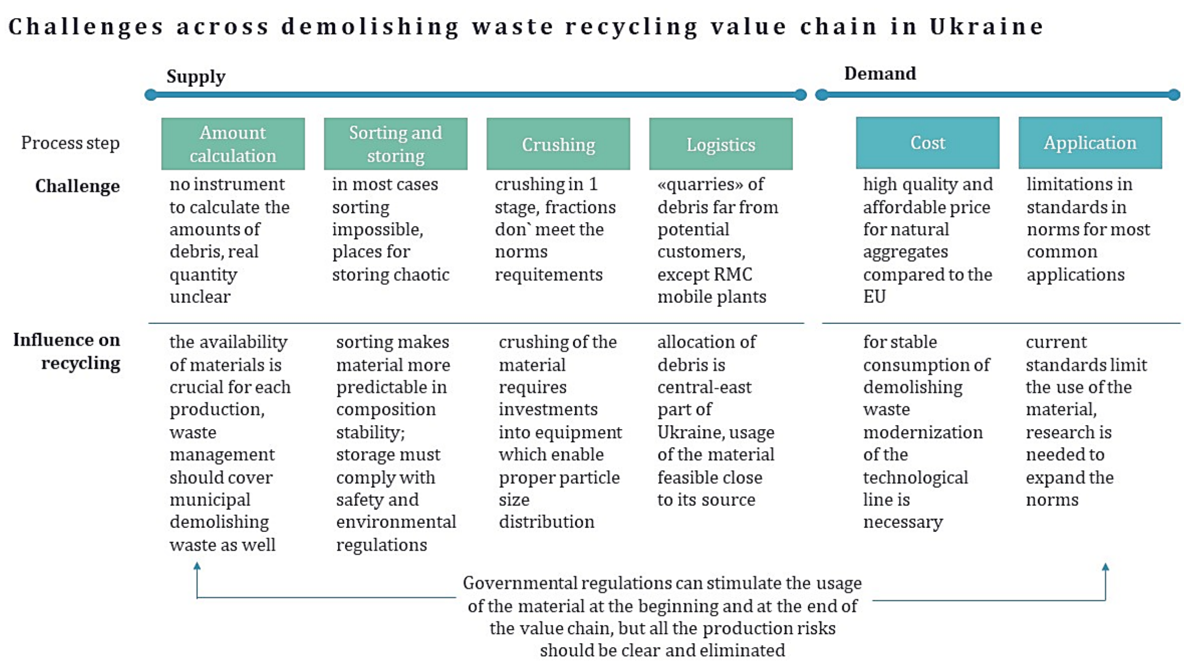

Fig. 1. Challenges across demolishing waste recycling value chain in Ukraine

Housing in the USSR has been based on industrial construction, i. e. the building of districts of 5- and 9-storey prefabricated panel houses, since the early 1960s. Therefore, it is reasonable to assume that the majority of demolition waste is concrete residue from prefabricated buildings which was constructed in 1960s, 1970s and 1980s [8]. They are known to the people as: «Stalinka», «Khrushchevka», «Brezhnevka» (Fig. 2).

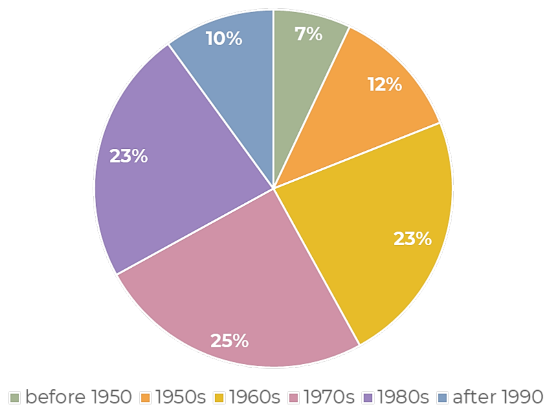

Fig. 2. The Housing Fund of Ukraine by construction period [8]

The destruction of buildings and structures by missile strikes occurs throughout Ukraine. It should also be noted that most of the prefabricated concrete buildings (60s and 70s) require reconstruction without the influence of military operations. The overall assessment of direct losses by region as of the beginning of 2024 shows that the Donetsk, Kharkiv, Luhansk, Zaporizhzhia, and Kherson regions experienced the greatest destruction and damage from missile strikes, according to the Kyiv School of Economics calculations [9].

Based on assumptions, possible applications of the demolishing waste re-use in Ukraine can be into cement in concrete production and road construction, depending on the composition of the material and recycled product (Fig. 3).

To test the CDW conformity for possible applications that have been highlighted in the analysis in Fig. 3, samples of the material were taken in the Kyiv region.

The sampled material was analyzed as aggregates according to EN 12620:2002 [10], as it had already been crushed and fractionated. The aggregate size was defined by the sieve test according to EN 933-1:2021 [11], using the basic set of sieves plus 2 mm coarse aggregate, a fraction distribution from 4 mm to 20 mm. This is also confirmed by the sieve test according to DSTU B V.2.7-75-98 [12].

EN method and DSTU method have differences in the shape of sieve cells and diameters of cells, but results can be considered identical for this study.

However, it should be noted, that the composition of the aggregates by visual assessment contains parts of wood, aerated concrete and gypsum-based plaster, but the dominant particles are crushed heavy concrete. Therefore, the further test approaches were related to the treatment of this material as recycled concrete aggregates.

According to EN 206-1 it is allowed to use up to 50 % of artificial aggregates in the concrete mix if they are made of pure crushed concrete. It is possible to understand that in conditions as these aggregates have been produced, it is not possible to obtain pure crushed concrete in terms of technological process and economic feasibility. Therefore, in this research, let's ignore the inclusions and saturate the concrete mix to the maximum with CDW aggregates.

To define the concrete mix to be tested, the application approach was applied. Ready-mixed concrete, which can be used for both general construction and infrastructure, dominates the Ukrainian market. This application for concrete with CDW should be studied in a separate study, analyzing the requirements for concrete for infrastructure, where the exposure classes should be achieved. Currently, to cover concrete for ordinary structural units – foundations, slabs, walls, columns, and floors for residential and commercial buildings with low exposure classes created the recipe which corresponds to C25/30 strength class and S4 plasticity.

For concrete mix, were used: Portland composite cement EN 197-1 CEM II/A-M (S-LL) 42,5 R type, in the quantity of 330 kg/m^3, sand from Dnipro River, and 3 types of aggregates: coarse natural aggregates, in particle size from 5 to 20 mm, from Zhytomyr region; coarse CDW aggregates in particle size from 5 to 20 mm, from Kyiv region and fine CDW aggregates in particle size from 0 to 5 mm, from Kyiv region.

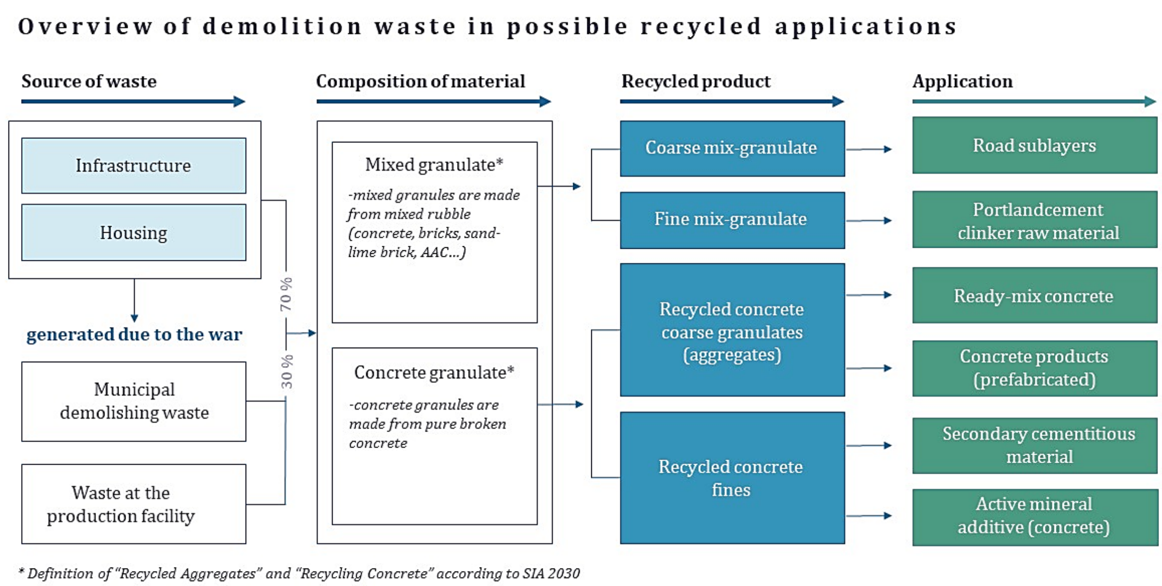

Fig. 3. Demolition waste in possible recycled applications

The recipe has been adapted to the introduction of demolition waste with a 10 % substitution step, i. e. the first sample is a sample with natural aggregates, and the second is a sample with 10 % substitution of natural aggregates with recycled aggregates, and so on up to 50 % substitution.

During the preparation of the concrete mix, the fine CDW aggregate was also investigated due to its influence on the rheology of the concrete mix. Sieve analysis was performed according to the method described in EN 933-1:2021. 16.27 % of the material passed through a sieve with a cell size of 0.063 mm. This means that the water absorption of the concrete mix could be high, so for the tests, the superplasticizer based on polycarboxylates with a highwater reduction coefficient was used to achieve the desired plasticity of the concrete mix.

Methods described in European standards were used to estimate the physical and mechanical properties of the concrete mix and hardened concrete, in particular:

– the density of the concrete mix was determined according to EN 12350-6 [13];
– the slump loss according to EN 12350-2 [14];
– the compressive strength of hardened cubes according to EN 12390-3:2019 [15].

3. Results and Discussion

The results of concrete mix tests show that when construction waste is used as an aggregate to make ready-mixed concrete, the design compressive strength of the concrete is achieved, which is shown in Table 1.

Table 1

Physical and mechanical test results

Parameters	0 %	10 %	20 %	30 %	40 %	50 %
Density, g/l	2451	2411	2414	2393	2378	2383
Slump 5 min, cm	24	20.5	18	16.5	7	4
Slump 60 min, cm	20	14	6	7	–	–
Slump 120 min, cm	13	7	3	2.5	–	–
Strength 1D, MPa	19.6	19.2	20.5	21.7	21	19
Strength 7D, MPa	38.7	37.6	40.2	42.8	32.5	42.4
Strength 28D, MPa	46.5	46.6	45.7	46.5	51.2	47.7

Physical and mechanical test results from Table 1 shows that C 40/50 strength class can be reached with maximum saturation of recycled concrete aggregates. From the rheology point of view, with increasing of the CDW amount in the concrete mix, the slump loss in its retention is decreasing over time. This is one of the most important parameters for the application of ready-mix concrete.

The effect of increasing strength with increasing CDW dosage is most probably related to the water-cement ratio in the concrete mix. This means that the water that should go to hydration reaction was absorbed by aggregates and less water was used for the hydration reaction. As a result, with the increase of CDW in the concrete mix, it is possible to observe an increase in strength due to the decrease in the general water-cement ratio.

The results also show that usage of demolition waste can be extended to precast concrete products, as low-workability concrete can be used for this application. However, the environment of exploitation should also be considered to ensure the durability of such products.

This phase of the study has made it possible to understand the physical and mechanical properties of demolition waste and its impact on the physical and mechanical properties of concrete, but these results are quite general and allow to determine the market for the use of concrete based on demolition waste to a greater extent.

Aggregates are the skeleton of the concrete, the strength and density of which must first be achieved. At the stage of primary processing of construction waste, it is necessary to ensure sorting and crushing in such a way that needle and pinch particles are avoided. These particles negatively affect the density of the concrete structure.

To increase the usage of demolition waste, further research should be carried out on the crushing, namely its stages, to be able to separate cement-sand mortar and natural aggregate from the secondary concrete.

Heidelberg Materials already made steps toward recycling demolished concrete by crushing it and separating it into its components: sand, aggregates, and recycled concrete paste (RCP) [16]. This technology can have a positive impact to the aggregate quality and separate concrete paste, which can be treated as recycled concrete fines according to EN 197-6.

It is important to continue research on the use of fine aggregates in the cement production and to reduce the impact on the rheology of concrete when this material is used as a fine aggregate in concrete while ensuring the maximum use of the material in production.

Today it is not possible to estimate the scale of Ukraine's reconstruction, but it is known that Ukraine will need innovative solutions for the production of building materials and the construction industry as a whole. This also means that the demand for building materials should be covered as well.

Hundreds of thousands of destroyed lives and millions of tons of waste from the destruction of buildings and structures, which in turn can be used as raw materials for the reconstruction of Ukraine, are the consequences of the military aggression of the Russian Federation.

4. Conclusions

According to the research results, construction and demolition waste is a valuable raw material. If properly processed, it can be used as a raw material for building materials production.

The key stage in demolition waste processing is sorting. Sorting is not always possible. However, the better the waste is sorted, the more applications it can have, as the material will be more stable in terms of composition and chemistry. The same principle is valid for the crushing process. From a raw material processing point of view, it is not enough to simply process the waste into a smaller fraction. It is necessary to technologically ensure the formation of uniform distribution of the fractions. Wide particle size distribution increases the possibility of using this material as a coarse aggregate for concrete influencing the packing density of the skeleton of aggregates – as better aggregates compacted, as fewer voids in concrete structure, which can positively affect the strength and rheological characteristics.

Many screenings, or fine aggregate, is produced during the crushing of construction waste. According to the test results, when this fine aggregate is formed during concrete crushing, it is a cement-sand mortar by nature. It can be used as a secondary cementitious material for cement production according to EN 197-6.

Conflict of interest

The author declares that she has no conflict of interest in relation to this research, whether financial, personal, authorship or otherwise, that could affect the research and its results presented in this paper.

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Data availability

The manuscript has no associated data.

Use of artificial intelligence

The author confirms she did not use artificial intelligence technologies when creating the presented work.

References

1. *Oleksandr Krasnolutskyi: V Ukraini utvorylosia ponad 600 tysiach tonn vidkhodiv ruinuvan: maiemo planuvaty de i yak efektyvno yikh vykorystovuvaty* (2024). Ministry of Environmental Protection and Natural Resources of Ukraine 16.03.2024. Available at: https://www.kmu.gov.ua/news/oleksandr-krasnolutskyi-v-ukraini-utvorylosia-ponad-600-tysiach-tonn-vidkhodiv-ruinuvan-maiemo-planuvaty-de-i-iak-efektyvno-ikh-vykorystovuvaty
2. *Pro zatverdzhennia Poriadku povodzhennia z vidkhodamy, shcho utvorylys u zviazku z poshkodzhenniam (ruinuvanniam) budivel ta sporud vnaslidok boiovykh dii, terorystychnykh aktiv, dyversii abo provedenniam robit z likvidatsii yikh naslidkiv ta vnesennia zmin do deiakykh postanov Kabinetu Ministriv Ukrainy* (2022). Postanova Kabinetu Ministriv Ukrainy No. 1073. 27.09.2022. Available at: https://zakon.rada.gov.ua/laws/show/1073-2022-%D0%BF#Text
3. *DSTU EN 206:2022. Concrete. Specification, performance, production and conformity (EN 206:2013+A2:2021, IDT)* (2022). Available at: https://online.budstandart.com/ua/catalog/doc-page.html?id_doc=106719
4. *CEN EN 197-6:2023. Cement – Part 6: Cement with recycled building materials* (2023). Available at: https://standards.iteh.ai/catalog/standards/cen/96772c60-54f9-4226-b230-8f5c39d-bd57d/en-197-6-2023
5. *EN 206:2013+A2:2021. Concrete – Specification, performance, production and conformity* (2021). Available at: https://standards.iteh.ai/catalog/standards/cen/4f3d2008-978a-47ec-bc12-5660aa40e04d/en-206-2013a2-2021
6. *Construction and Demolition Waste. Environment – European Commission*. Available at: https://environment.ec.europa.eu/topics/waste-and-recycling/construction-and-demolition-waste_en
7. Zhytlovyi fond Ukrainy v 2012 (2013). *Derzhavna sluzhba statystyky Ukrayiny*. Available at: https://ukrstat.gov.ua/operativ/operativ2007/zf/zf_u/2006_u.htm
8. Social and Demographic Characteristics of Households of Ukraine in 2013 (2014). *Derzhavna sluzhba statystyky Ukrayiny*. Available at: https://ukrstat.gov.ua/druk/publicat/Arhiv_u/17/Arch_cd-hd_zb.htm
9. *Zvit pro priami zbytky infrastruktury vid ruinuvan vnaslidok viiskovoi ahresii Rosii proty Ukrainy stanom na pochatok 2024 roku* (2024). Damages report. Available at: https://kse.ua/wp-content/uploads/2024/04/01.01.24_Damages_Report.pdf
10. *EN 12620:2002+A1:2008. Aggregates for concrete*. Available at: https://online.budstandart.com/ua/catalog/doc-page?id_doc=58786
11. DSTU EN 933-1:2021. Test methods for determining the geometric characteristics of aggregates. Part 1: Determination of grain size distribution. Sieving method (EN 933-1:2012, IDT) (2021). Available at: https://online.budstandart.com/ua/catalog/doc-page.html?id_doc=95570
12. *DSTU B V.2.7-75-98. Construction materials. Crushed stone and gravel dense natural for building materials, products, structures and works. Technical conditions* (1998). Available at: https://online.budstandart.com/ua/catalog/doc-page.html?id_doc=4674
13. *DSTU EN 12350-6:2022. Testing of concrete mixtures*. Part 6. Density (EN 12350-6:2019, IDT)
14. *DSTU EN 12350-2:2022. Testing of concrete mixtures. Part 2. Determination of the workability of concrete mixtures (cone slump)* (EN 12350-2:2019, IDT)
15. *EN 12390-3:2019. Testing hardened concrete – Part 3: Compressive strength of test specimens.*
16. Heidelberg Materials embarks on concrete recycling project in France (2023). *Global Cement*. Available at: https://www.globalcement.com/news/item/15995-heidelberg-materials-embarks-on-concrete-recycling-project-in-france Last accessed: 03.06.2024

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