Methods of organizing work on construction and demolition waste recycling

Olga Saimanova*, *Svetlana* Teplykh, and *Vadim* Alpatov

Samara State Technical University, 443001, 194, Molodogvardeyskaya str., Russian Federation

Abstract. The research is aimed at finding new ways that contribute to environmental improvement. It is evident that there is a great need at the moment to find optimal methods of construction and demolition waste recycling while renovating urban areas. The researchers examine the recycling method which is characterized as one of the most effective ways to solve the problem of construction waste disposal. In this paper the authors resort to the method of comparison as well as to graphical, tabular, and abstract-logical methods. They analyze two main methods used to carry out recycling operations: the first method involves recycling waste at the site of construction using mobile crushing plants and the second involves recycling at stationary crushing and grading complexes. Then the authors point out advantages and disadvantages of these methods and examine the efficiency of a stationary complex. The researchers also calculate the prime cost of construction waste processing at a stationary crushing and grading complex and its payback period. It is concluded that the use of a stationary complex for construction and demolition waste recycling is technically and economically feasible.

1 Introduction

A global problem at present is a significant increase in the volume of industrial waste accumulation, including the growth of construction waste that outstrips its processing and disposal. For example, in Russia over the past 5 years, the annual growth in the production of industrial waste amounts to 20-30%, which is a threat to the ecological balance and the environment, since most waste is not recycled, but is stored at landfill sites [1].

Construction waste is usually described as waste from reconstruction, major repairs, renovation of residential buildings and former industrial zones, disassembly and demolition of buildings and structures. It is also generated during the construction of new buildings and structures, highways and engineering networks [2, 3]. Construction waste includes concrete and reinforced concrete scrap, scrap brick, scrap metal, asphalt concrete chipping, linoleum waste, glass fight, wood waste and other types of construction waste.

Renovation programs set up at the moment in many Russian cities only complicate the situation. Thus, the fact remains that the search for new ways of construction waste disposal and the management of this process has become an urgent global problem. Such scientists as P.P. Oleinik, V.O. Chulkov, S.F. Korenkova, V.I. Brodsky, A.S. Bannikova and others have repeatedly addressed this topic, pointing out in their research the need for recycling

*Corresponding author: olga.sayma@mail.ru

and reuse of construction and demolition waste. They note that in the process of large cities urbanization in different countries, similar problems inevitably arise in the reconstruction of territories vacated during their reorganization and associated with the demolition of dilapidated housing and former industrial enterprises buildings [1, 4]. The scientific community of other countries is also very interested in this problem [5]. However, only part of the works is devoted to the problem of recycling and there are little-studied issues that require further investigation.

The study aims to examine methods of construction and demolition waste recycling and to work out solutions for streamlining the process of construction and demolition waste pretreatment before crushing.

The object of this study is the process of construction and demolition waste recycling during reconstruction, major repairs of buildings and structures, as well as renovation of urban areas.

The subject of the study is methods of organizing work on construction waste recycling.

2 Methods

The comparison method serves as a methodological basis of this study that makes it possible to correlate this study with former research on the matter and determine their common features and differences in order to make an optimal management decision. The researchers resort to such methods as analysis and synthesis, graphical, tabular and abstract-logical methods.

The use of the comparison method made it possible to determine the advantages of construction waste recycling at stationary complexes on condition that reconstruction works are carried out on a large scale. The combination and synthesizing method helped recognize the necessity of waste pretreatment before crushing.

3 Results

The research demonstrated techno-economic expediency of using a stationary crushing and sorting complex in conditions of large-scale urban renovation works. It also introduced measures that can be used to streamline the process of pre-treatment of construction and demolition waste before crushing.

The authors considered methods of organizing work on construction and demolition waste recycling, paying special attention at its recycling at a stationary crushing and sorting complex with a capacity of 40 t/h. The results obtained are as follows:

1. The technical and economic assessment of the use of a stationary crushing and screening complex has shown its feasibility in the conditions of large-scale work on the renovation of urban development.
2. Approximate cost of the crushing and sorting complex for one shift of work while recycling construction and demolition waste is 37.916 thousand rubles.
3. The prime cost of secondary crushed stone output is 118.49 rubles/ton.
4. Energy savings during pre-treatment of construction and dismantling waste is 26.4 kW per shift.
5. The payback period of the equipment is from 4 months.

4 Discussion

Recycling is one of the most effective methods of solving the problem of construction waste. It consists in construction waste reuse (or secondary use) which means that some materials contained in construction waste (that is metal, wood, brick, concrete, reinforced concrete, etc) are returned to construction production and used again [6] (see Figure 1).

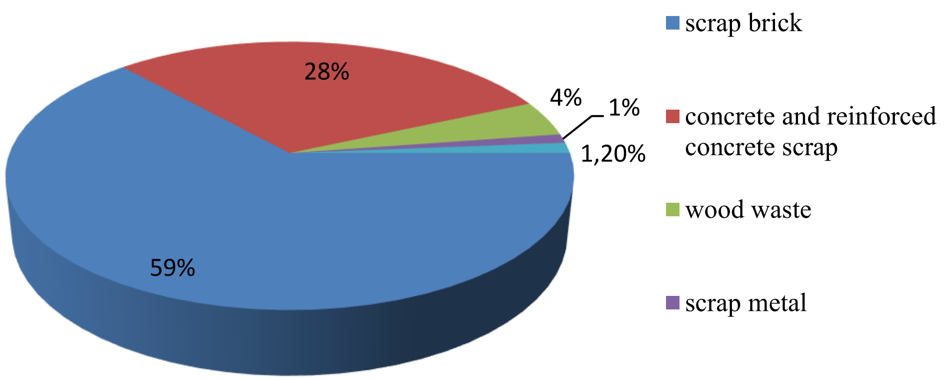

Fig. 1. Construction and demolition waste types.

The sphere of handling construction and demolition waste is quite profitable, since the scope of processing products application is wide. E.g., secondary crushed stone can be used in the construction of highways, in making access roads to public buildings, in constructing drainage of trenches and ditches. It also can be used as foundation beds and in landscape architecture for creating "alpine slides", "rain ponds", "dry streams", etc. [7].

Construction waste can also be used as reclamation materials in domestic solid waste landfills. To be used as an intermediate layer, though, construction and demolition waste should be sorted out in accordance with a number of criteria, depending on the type of waste and the possibility of its further use.

It should be noted that industrial areas with large population are in greater need of construction and demolition waste recycling [8-13].

There are two main methods used to carry out recycling operations: the first method involves recycling waste at the site of construction using mobile crushing plants and the second involves recycling at stationary crushing and grading complexes. Both methods have their advantages and disadvantages (see Table 1).

Table 1. Advantages and disadvantages of methods used in recycling of construction and demolition waste.

Recycling method	Advantages	Drawbacks
Recycling waste at the site of construction using mobile crushing plants	- no costs for transportation of construction waste to the place of recycling - possible to move the crushing plant at any time and start production in a new place - immediate installation and dismantling of production equipment with a minimum of financial costs - requires less operation personnel and territory for accommodation - small size of the occupied space	- preparation for primary and two-stage crushing is necessary, which causes difficulties - sorting by fractions is difficult - no possibility to use high-tech equipment - requires creating environmental protection measures due to nearby residential buildings - no possibility of continuous operation of the crushing plant - low productivity - small amount of waste recycling
Recycling at	- high productivity and volume of	- not possible to quickly move the

stationary crushing and grading complexes	construction waste recycling - deeper processing with separation into fractions - sorting by fractions is less costly - possibility of organizing permanent logistics and marketing - preparation for primary and two-stage crushing causes no difficulties - continuous operation of the crushing plant is possible - simpler solution to environmental problems - possibility to carry out the process of construction waste pretreatment before recycling.	installation to the new place of buildings or structures demolition - additional costs for transportation of construction waste to the place of recycling - higher costs for installation and adjustment of equipment compared to mobile installations - requires a large enough area - more staff

Mobile crushing plants have the advantage of minimizing the costs of transporting recycled construction waste and can start production as quickly as possible at the place where the reorganization of the territory is carried out.

The advantage of using stationary crushing and screening complexes is their high productivity and reliability. At the same time, there are significant costs for the delivery of construction waste to the place of its processing as it is impossible to quickly relocate the crushing plant. Stationary complexes are more efficient than mobile ones in the case of processing large volumes of demolition waste during reconstruction or renovation of large territories that are being vacated from buildings. Such criteria as the range of urban areas renovation work, the recycling volume and the cost of equipment placement give grounds for choosing a stationary installation.

The final choice of the type and method of work organization is carried out by the management of the construction company after conducting a feasibility study. The choice depends on the amount of work on construction waste recycling, on the location of the future object relative to residential quarters, on availability of engineering infrastructure, availability of power sources and other factors.

For the organization of private business in the field of recycling, which involves large-scale demolition of five-story large-panel buildings erected in the 60s of the last century, it is recommended to use stationary crushing and sorting complexes. Such complexes make it possible to process concrete and reinforced concrete scrap, which makes up the most part in the composition of construction waste, into widely demanded secondary crushed stone [8]. Technological scheme of stationary crushing and sorting complex DSK-48-13, which implements an integrated method of processing construction waste, is shown in the figure (see Figure 2). DSK-48-13 is a stationary crushing and sorting complex, which implements an integrated approach to construction waste recycling.

The productivity of stationary complexes ranges from 20 to 600 tons of waste per hour. The output of secondary crushed stone is from 100 to 500 m^3 per shift. The grain size at the output is 15-25 mm. The number of service personnel is 5-6 people.

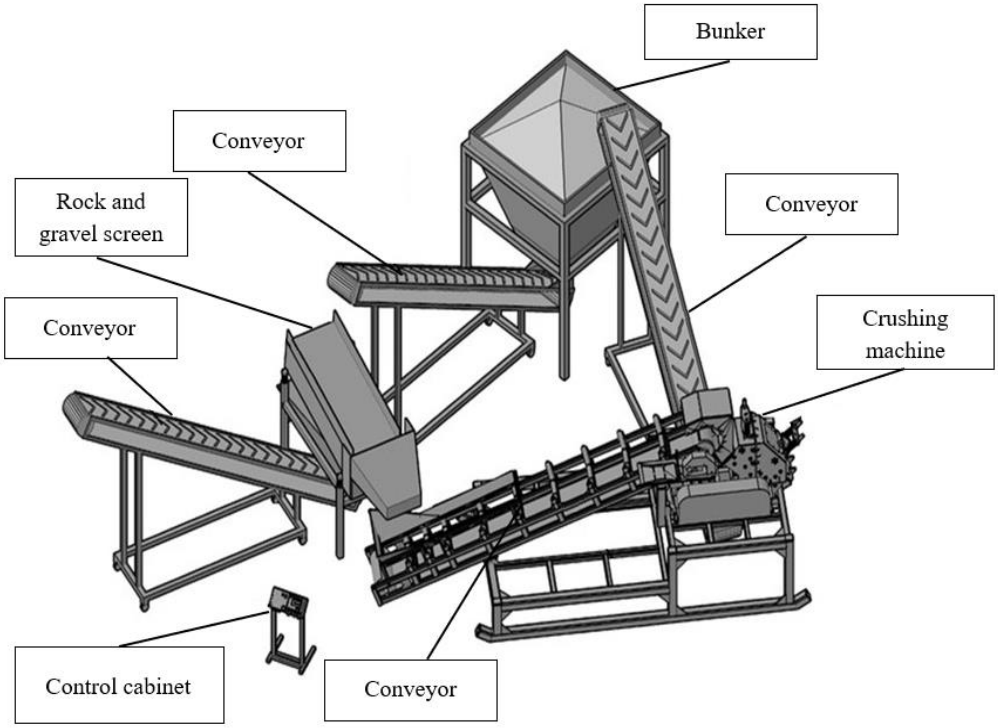

Fig. 2. Technological scheme of stationary crushing and sorting complex DSK-48-13.

The cost of the crushing and sorting complex DSK-48-13 for one shift of its operation with the processing of 40 tons of construction and demolition waste per hour is 37.916 thousand rubles (see Table 2).

Table 2. Calculation of the costs of a stationary crushing and screening complex DSK-48-13 for one shift of work.

№	Indicator	Calculation
1	Electric power consumption of a crushing and sorting complex per hour, kW/hour	110
2	Working shift duration, h	8
3	Electricity consumed per shift, rub.	880
4	Electricity costs, rubles/kWh	4.45
5	Electricity costs per shift, rub.	3 916
6	Number of service personnel, people.	5
7	Salary of one employee per shift	2000
8	The salary of the service personnel per shift, rub.	10000
9	The cost of renting equipment, rub.: - mechanical loader; - truck crane.	 1500 1500
10	Equipment rental costs per shift, rub.	24000
11	Total costs, rub.	37916
12	Volume of secondary crushed stone output per shift, t	320
13	Secondary crushed stone output prime cost, rub/t.	118.49
14	Secondary crushed stone cost, rub/t	1062
15	Income from the sale of secondary crushed stone, RUB.	339.840

Provided that the volume of crushed stone output is 320 tons per shift (with metal further separated from it and sold separately), the cost of secondary crushed stone will be 1 062.5 rubles, and the income from the sale of secondary crushed stone is 320 x 1.062 = 340 thousand rubles. The payback period of the equipment is from 4 months.

In order to reduce the crushing and sorting complex costs and increase the recycling process efficiency, it is recommended to improve the process of pretreatment of construction and demolition waste, which will bring about additional effect. Rationalization of waste preliminary preparation can be carried out both in the direction of changing their physical and mechanical properties before the grinding process, and while increasing the resource of wear-out parts of equipment responsible for crushing which is the most expensive process (see Table 3).

Table 3. Procedures used to rationalize the process of pre-treatment of construction and demolition waste.

№	Procedures	Result
1	Pre-soaking of construction and demolition waste	- Reducing physical wear of crushing machines without loss of productivity - Increasing crushing machines service life by 3%
2	Preheating/freezing of construction and demolition waste before crushing	- Increasing brittleness and, accordingly, reducing energy consumption to ensure the process of waste crushing
3	Replacement of parts and components of crushing machines with wear-resistant steels	- Increasing the service life of crushing machine parts without replacement. - Increasing durability of crushing machine service life without loss of productivity - Improving equipment reliability - Increasing crushing machine parts service life by 50%

Preheating or freezing of construction and demolition waste before crushing will provide a 3% reduction in electricity, which amounts to 26.4 kW or 117.48 rubles per shift of the crushing and sorting complex DSK-48-13 work.

Replacement of metal assemblies and parts of crushing equipment (augers, teeth, stators, rotors, hammers, beaters) operating under conditions of abrasion with wear-resistant steels also seems potentially productive as it will increase equipment reliability. The use of wear-resistant steels increases crushing and screening complexes service life, significantly reduces operating costs (maintenance and repair costs), unproductive losses of working time, equipment downtime, and, in addition, the wear of the equipment itself as well as the wear of its parts.

The wear of the crusher parts results in a change in their surface. The surface of the crushing equipment parts is mainly subject to abrasive and fatigue wear, which accumulates as a result of constant shock loads and repeated indentation of the processed material by moving and stationary parts of the crusher.

Existing manufacturers advise to manufacture wear-out parts of crushing equipment from austenitic high-manganese steel with additives of various alloying elements, which has the property of mechanical hardening under strong shock or compressive load. The manganese content in the proposed alloys ranges from 11 to 24%. It is also possible to use alloys with the addition of chromium, molybdenum and other alloying elements. Manufacturers also propose to use 110G13L steel for the manufacture of crusher parts with additional alloying with titanium up to 0.05%, vanadium up to 0.3% and molybdenum up to 0.2% They also recommend modifying carbide-forming elements with high wear resistance under the simultaneous impact of shock loads and high pressure (see Table 4). The research underlines the fact that industrial tests have shown an increase in the service life of crushing equipment parts without replacement and loss of productivity by 50%.

Table 4. Alloys recommended for manufacturing wearing parts of crushing equipment.

№	Steel grades	Proposed alloys
1	XT510	Ordinary manganese steel
2	XT520	Manganese steel with the addition of molybdenum.
3	XT610	Manganese steel with the addition of chromium
4	XT710	High-manganese steel with the addition of chromium
5	XT720	High-manganese steel with the addition of chromium
6	XT750	Special high-manganese steel
7	XT770	Special high-manganese steel with the addition of molybdenum
8	XT810	Special high-manganese steel with the addition of chromium and subject to heat treatment
9	110G13L	High-manganese austenitic steel (Gadfield steel) with additional alloying and modification of carbide-forming elements

The introduction of recycling in the field of waste management of construction production will bring not only economic, but also social and environmental effects (see Table 5).

The economic effect mainly consists of reducing the costs of maintaining landfills and eliminating unauthorized landfills, reducing subsequent reclamation costs, as well as saving natural resources by returning construction waste to circulation.

The social effect of recycling lies in the creation of new jobs and, accordingly, a decrease in the level of social tension of citizens living in areas located next to landfills where industrial waste is stored.

The economic effect will be expressed by the amount of prevented damage to the environment from its pollution by construction waste and, accordingly, by reducing the environmental burden, improving the quality of the habitat [14, 15].

Table 5. Effects of the introduction of construction and demolition waste recycling.

№	Type of effect	Effect resulting from ...
1	Economic	- reducing the cost of transporting concrete and reinforced concrete scrap - reducing the costs of construction and operation of quarries or earth-deposits for the extraction of natural resources - reducing the cost of maintaining polygons - reducing the costs of eliminating unauthorized landfills - reducing the cost of reclamation - reducing the costs of sanitary and environmental control over the condition of territories adjacent to landfills
2	Social	- creating new jobs - reducing social tension of citizens living in areas located next to landfills
3	Ecological	- reducing environmental burden - preventing damage from pollution by construction waste

5 Conclusion

The research yielded the following conclusions:

1. Pretreatment of construction and demolition waste before crushing will allow to obtain energy savings of up to 3%, which amounts to 26.4 kW or 117.48 rubles per shift of the crushing and sorting complex DSK-48-13 work.

2. Replacement of wear-resistant parts of crushing machines with wear-resistant steels will increase their service life by 50%.

3. The use of the recycling method of construction waste processing at stationary crushing and sorting complexes and the maximum involvement of processed products into their secondary turnover will help reduce the loss of raw materials as well as material and energy resources of enterprises. It will also increase the efficiency of natural raw materials use and improve the environmental situation both in a certain region and in the whole country.

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