Application of Multimodal Logistics for the Use of Demolition Products for Damaged Areas

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Abstract. The relevance of the problem under study is due on the one hand to the need to reclaim disturbed areas formed as a result of construction activities, on the other hand to the need to find useful use of demolition products of buildings and structures. The purpose of the work is to study the possibility of using multimodal logistics for the use of demolition products in the reclamation of disturbed areas, using the example of granite quarries. Geoeconomic, technological and economic forecasting of multimodal logistics of urban agglomeration demolition products will allow to develop the most optimal schemes of their useful use. As a result of research, mathematical models have been developed for predicting the formation of a transport and logistics chain for the removal of demolition products from objects. For the first time, a scheme has been developed for choosing a method of moving demolition products depending on the range of the burial place for making substantiating decisions on their removal in the process of designing measures for the reclamation of granite quarries from the point of view of geoeconomic and economic expediency. It is scientifically justified to use demolition products as fillers of spent granite quarries for temporary storage, partial or complete filling with subsequent reclamation of spent quarries. The materials of the article can be useful for the development of technological solutions for the reclamation of disturbed areas using demolition products of buildings and structures.

1. Introduction
For large cities and urban agglomerations, one of the most difficult problems of protecting the environment and maintaining geo-ecological balance is the problem of managing the processes of recycling and removal of waste to places of recycling or processing. Of the total amount of waste generated, a significant proportion are demolition products of buildings and structures, formed in volumes that are an order of magnitude higher than the volume of solid household waste. So in St. Petersburg, ~ 30-40 million m³ of demolition products are annually formed, against ~ 5 million m³ of TBT. Along with this problem, the active development of the construction industry leads to a geoeconomic problem of recultivation of disturbed areas formed when natural materials used in construction are exhausted, such as sand, granite or clay. So, for example, today in the North-West region there are about 10 granite quarries, covering an area of up to 3 thousand hectares and requiring reclamation. Demolition products of buildings and structures are closest in nature to granite stone and large-scale waste, which allows predicting their use in the reclamation of granite quarries [1-8].

A quantitative and qualitative assessment of demolition volumes and a regulated, well-founded solution to disposal, disposal or reuse issues are important to address the fuller use of demolition products. This assessment, as well as the geo-environmental, technological and economic rationale for the use of demolition products, can be carried out using multimodal logistics. Therefore, the purpose of
the work is to study the possibility of using multimodal logistics for the use of demolition products in the reclamation of disturbed areas, using the example of granite quarries.

2. Material and methods
The object of the study in the work is the demolition products of buildings and structures. The object of the study is to study the possibility of using multi-modal logistics for the geoecological, technological and economic justification of measures for the use of demolition products of buildings and structures in the restoration of disturbed territories. The following research methods were used in the work: mathematical modeling methods (the method of statistical solutions, analysis and testing, "games with nature"), empirical methods of collecting information and data, simulation modeling, transport problem, machine simulation methods.

3. Results of the study
In accordance with Russian law, territories violated as a result of human activity are subject to restoration for subsequent use in national economic activities, that is, after exhaustion of the granite reserve, tenants are obliged to carry out reclamation measures. However, at present, granite quarries for the most part after rock production remain in the form of open mining. If possible, then the quarry is filled with water from the nearest reservoir (partial filling of the quarry, further filling occurred due to precipitation and melted snow). Or excavation remains and for a long time there is filling with sediments, groundwater (with shallow occurrence) and meltwater. Also, spent quarries can be covered with garbage of various origins (spontaneous landfills).

Among the solid mineral wastes generated during construction and economic activities, the products of demolition of buildings and structures are the closest in chemical nature and physical and mechanical characteristics to granite stone (Tables 1 and 2).

Table 1. Comparison of chemical composition of demolition products of buildings and structures and natural granite.

| Chemical composition | Demolition products, % | Granite, % |
|----------------------|------------------------|------------|
| SiO₂                 | 73,575                 | 70,18      |
| Al₂O₃                | 3,7235                 | 14,47      |
| Fe₂O₃                | 1,3016                 | 1,57       |
| CaO                  | 14,073                 | 1,99       |
| MgO                  | 0,3549                 | 0,88       |
| SO₃                  | 0,657                  | 0,12       |
| FeO                  | 0,1225                 | 1,78       |
| K₂O                  | 0,162                  | 4,11       |
| Na₂O                 | 0,065                  | 3,48       |
| H₂O                  | 5,75                   | 0,84       |
| TiO₂                 | 0,0325                 | 0,39       |
| P₂O₅                 | 0,0085                 | 0,19       |
| BaO                  | 0,0025                 | -          |
| C                    | 0,04                   | -          |
| CO₂                  | 0,1315                 | -          |
Table 2. Comparison of physical and mechanical characteristics of demolition products of buildings and structures and natural granite.

| Activities                        | Material                      | Battle of concrete |
|-----------------------------------|-------------------------------|-------------------|
| density, г/см³                   | Granite                       | 3,17              |
| compressive strength in a water-saturated state, kg/cm² | 550                           | 350               |
| water absorption, %              | 0,2                           | 4 - 8             |
| frost resistance, cycle          | 25                            | 50 - 500          |
| strength reduction factor        | 0,9                           | 1,4               |
| resolve                          | 6 – 7                         | 6 - 8             |
| rest, g/cm²                     | 1,4                           | 1,2               |

The granite quarry of the village was chosen as the object of reclamation. Kuznechnoe, Vyborg District, Leningrad Region (Table 3).

Table 3. Characteristics of the Vozrozhdenie quarry of NP GPSK Vozrozhdenie».

| Object-quarry development         |                             |
|-----------------------------------|-------------------------------|
| Quarry size, km (width, working height) | <1,0 x 0,7                   |
| Quarry area, ha                  | 51                            |
| Working distances, km             |                               |
| From Saint Petersburg (object Dachnoye 5), km | 159 ( railway message )       |
|                                  | 149 ( highways )              |

To study the issue of the formation of the volumes of demolition products to ensure the filling of granite quarries, a calculation scheme for the formation of a map of the objects of the formation of demolition products was constructed, taking into account the assessment of the probability of the reliability of the removal of demolition products from the objects of their occurrence. An analog scheme for the removal of demolition products from the site was formed, which takes into account such data as the volume and weight of the formed demolition products, as well as the distance of the objects of the formation of demolition products to the place of their burial in granite quarries. The results of the simulation model of the multimodal transport chain of transportation of demolition products of buildings and structures are shown in Table 4.

Table 4. Results of the simulation model of the multimodal transport chain.

| Containers | Volume, m³ | Overall dimensions, mm | Weight, kg | Commercial vehicles | Car brand     |
|------------|------------|------------------------|------------|---------------------|---------------|
|            | 20         | 2500×6285×1682         | 2250       | KAMAZ-16-01         | VOLVO FH12    |
|            | 27         | 2500×6285×2190         | 2530       | VOLVO F12           |               |
A mathematical model for predicting the formation of the transport and logistics chain for the export of demolition products from the place of their formation to the place of their use as a filler for granite quarries makes it possible to choose vehicles that allow the export of demolition products in urban conditions and in accordance with the requirements of the formation of railway trains. A distinctive feature of the developed model is taking into account important geoecological factors such as: existing methods of demolition / dismantling of buildings, methods of filling construction containers with demolition products, the choice of cargo vehicles transporting containers with demolition products, taking into account the urban road infrastructure, the remoteness of the filling object from the place of formation of demolition products and the rationality of the organization of disposal of demolition products.

According to the conducted research and the data obtained as a result of the simulation model, it follows that most of the objects that were identified, in accordance with the distance from the burial site in the territory of the North-West, it is possible to export demolition products by road and rail modes of transport. But also from some localities it is not possible to take out the demolition products only by one mode of transport, respectively, it is necessary to form a multimodal scheme for the export of demolition products from the objects of their formation to granite quarries for the purpose of burial.

To build a design scheme for the removal of construction waste, the following data were taken into account:

- remoteness of the object of demolition from the place of their burial (granite quarries of the village of Kuznechnoye, Leningrad region);
- time for transportation of demolition products from the place of construction waste generation to the place of their disposal;
- cost of transportation of demolition products.

The result of the simulation based on the criteria of the indicators is shown in Table 5.
Table 5. Criteria for data indicators for constructing the calculation scheme.

| №   | Name of criterion                        | Distance from the burial site, km | Shipping time | Cost               |
|-----|------------------------------------------|-----------------------------------|---------------|--------------------|
|     |                                          | motor transport                   | railway transport |                      |
| 1   | Average readings                         | 329                               | 416           | 3,66               | 2,03               | 1480 | 16940 |
| 2   | Minimum value of the indicator           | 20                                | 15            | 0,22               | 1                  | 1480 | 16940 |
| 3   | Maximum value of the indicator           | 1263                              | 1349          | 13,23              | 7                  | 1480 | 16940 |

When filling a granite quarry at a maximum point of volume/height, an area of ~ 51 hectares is formed. After the biological reclamation stage, the obtained area can be used for forestry purposes as a nursery, or used as a forestry territory (restoration of the geocological system in a particular region) [9-16].

With a known number of demolished buildings, it is possible to determine the volume and mass of demolition products formed.

Quarter 5 Dachnoye of the city of St. Petersburg, consisting of 56 houses of the series G-31, G-21, G-5, located between the railway stations of the October Railway "Sosnovaya Polyana" and "Ulyanka," was chosen as the object of demolition. The object was selected in connection with the program renovation of housing in St. Petersburg.

After determining the volume and weight of the resulting demolition products using the compiled algorithm implemented using a set of program modules, the number of containers of a certain volume was determined - 27 m³, which is necessary for the removal of the minimum volume of building waste to fill the minimum level in granite quarries and the maximum number of containers (Table 6).

When choosing the container volume using a set of program modules, important factors are taken into account, such as:
- Facility/territory infrastructure - oversized vehicles are prohibited within the city limits without a special permit, and heavy vehicles are prohibited;
- time of work with increased noise level - in St. Petersburg according to the Law on Silence, all construction and noisy works are carried out from 8 to 22 hours;
- ecological load on the territory of the demolition site and the road chain of removal of construction waste - closed containers during transportation minimize the load on the environment, since dust from construction waste on the way of road transport does not exceed the permissible limit values;
- The carrying capacity of motor vehicles is determined in accordance with road requirements - as noted above, in urban road infrastructure, a number of restrictions are imposed on the weight and carrying capacity of cars and their overall dimensions;
- the volume of construction containers should not exceed 32 m³, the most common volume of the container is 27 m³, which is installed on any type of car intended for the export of containers. Containers with a volume of 20 m³ can also be used, but only in cases where the buildings are extremely dense and it is not possible to use containers of a larger volume and, accordingly, cars of large size and carrying capacity, for example, in the historical part of the city of St. Petersburg.
Table 6. Required number of containers.

| Volume of demolition products, m$^3$ | Weight of demolition products, kg | Number of containers with volume 27 m$^3$ for removal of minimum for export of maximum volume |
|------------------------------------|----------------------------------|-------------------------------------------------------------------------------------------------|
| 8333000000                         | 189000000                        | 693674                                                                                           |
|                                    |                                  | 727896                                                                                           |

4. Conclusions

1. Geoecological, technological and economic forecasting of multimodal logistics of urban agglomeration demolition products allows to develop the most optimal schemes of their useful use.

2. For the first time, mathematical models have been developed to predict the formation of a transport and logistics chain for the removal of demolition products from objects, taking into account demolition/parsing techniques for buildings, methods for filling construction containers with demolition products and the distance of the filling object from the place of formation of demolition products.

3. For the first time, a scheme has been developed for choosing a method of moving demolition products depending on the range of the burial place for making substantiating decisions on their removal in the process of designing measures for the reclamation of granite quarries from the point of view of geoecological and economic expediency.

4. It is scientifically justified to use demolition products as fillers of spent granite quarries for temporary storage, partial or complete filling with subsequent reclamation of spent quarries.

5. References

[1] Hao L, Guo Y, Zeitvogel F, Schmid G, Ingino P, Byrne J M, Kappler A, Li J, Neu T R, Swanner E D, Obst M 2016 Binding of heavy metal ions in aggregates of microbial cells, eps and biogenic iron minerals measured in-situ using metal- and glycoconjugates-specific fluorophores Geochimica et Cosmochimica Acta T 180 pp 66-96

[2] Cui L, Wu J, Ju H Electrochemical sensing of heavy metal ions with inorganic, organic and biomaterials State Key Laboratory of Analytical Chemistry for Life Science (Department of Chemistry, Nanjing University, Nanjing) 210093

[3] Poh P E, Chong M F 2008 Development of anaerobic digestion methods for palm oil mill effluent (pome) treatment Bioresource Technology T 100 I pp 1-9

[4] Przydatek G Multi-indicator analysis of the influence of old municipal landfill sites on the aquatic environment: case study Environmental Monitoring and Assessment 191(12) 77

[5] Rusanova E, Abu-Khasan M, Sakharova A 2019 The control waste of communal services IOP Conference Series: 2019 Earth and Environmental Science 272(2) 022109 DOI: 10.1088/1755-1315/272/2/022109

[6] Maslennikova L, Abu-Khasan M, Babak N 2017 The use of oil-contaminated crushed stone screenings in construction ceramics Procedia Engineering 189 pp 59-64 DOI: 10.1016/j.proeng.2017.05.010

[7] Abu-Khasan M, Solovyova V, Solovyov D 2018 High-strength Concrete with new organic mineral complex admixture 2018-MATEC Web of Conferences193,03019 DOI: 10.1051/matecconf/201819303019

[8] Rusanova E, Abu-Khasan M, Egorov V 2020 The complex evaluation of geo eco-protective technologies taking into account the influence of negative temperatures IOP conference series: materials science and engineering 022042 DOI: 10.1088/1755-899X/753/2/022042

[9] Baidarashvili M, Sakharova A, Petriaev A 2017 The Modern Structure for Storm Sewage Purification of Roads Procedia Engineering 189 pp 576–581 DOI: 10.1016/j.proeng.2017.05.091
[10] Malchevskaya K, Sakharova A, Kabanov A 2017 Soil Reinforcement and Detoxication by Means of Mineral Binder Systems Procedia Engineering 189 pp 582–586 DOI: 10.1016/j.proeng.2017.05.092

[11] Sakharova A S, Petriaev A V, Kozlov I S 2019 New Construction Solutions for Geoenvironment Protection of Transport Infrastructure IOP Conference Series: Earth and Environmental Science 272(2) 022220 DOI: 10.1088/1755-1315/272/2/022220

[12] Sakharova A S, Svatovskaya L B, Baidarashvili M M, Petriaev A V 2017 Construction wastes application for environmental protection WASTES - Solutions, Treatments and Opportunities II - Selected papers from the 4th edition of the International Conference Wastes: Solutions, Treatments and Opportunities pp 345–350

[13] Sakharova A S, Svatovskaya L B, Baidarashvili M M, Petriaev A V 2017 Detoxication of the heavy metal ions in water resources by means of mineral geoantidotes Bearing Capacity of Roads, Railways and Airfields Proceedings of the 10th International Conference on the Bearing Capacity of Roads, Railways and Airfields, BCRRA pp 2187–2190 DOI: 10.1201/9781315100333-309

[14] Petriaev A, Svatovskaya L, Baidarashvili M, Sakharova A 2018 Green technology with geosynthetics prevent environment from railway dangerous pollutants 11th International Conference on Geosynthetics ICG 2018 2 pp 1554–1560

[15] Baydarashvili M, Sakharova A, Shrednik N 2020 Conservation of mineral resources in transport and civil construction Lecture Notes in Civil Engineering 50 pp 479–486 DOI: 10.1007/978-981-15-0454-9_50