# Procedure of the preparatory works execution during the remediation of high-rise buildings debris due to the disaster

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**Abstract.** The article covers one of the preparatory works types, in particular – the debris clearance. The types of machines and machinery, the purposes of the debris clearance, as well as the tasks for decrease of debris mass and scope are specified herein. The purpose of the article is to show the current level of the domestic machinery, as well as to share the experience of preparatory works. The article describes one of the preparatory works types, in particular – the debris clearance during the high-rise buildings demolition. Given are the equipment and machinery types, covered are the purposes and procedure of debris clearance defined are the tasks on reduction of debris mass and sizes. Specified are the types and methods of the preparatory works execution. The purpose of this article is to demonstrate the domestic equipment current state, and to share the experience in preparatory works execution.

#### 1 Introduction

Nowadays the main task of preparatory works, under the conditions of new facility construction, is the development of required and safe conditions for the main works execution. To execute the preparatory works, upon management decision in some cases, developed is the project documentation concerning their execution procedure. The following shall be reflected in the work execution design: types of the preparatory works and their order of priority; the shortest and the most safe traffic routs through the facility territory, access ways to the certain buildings, facilities as well as the areas of sites development for the machinery arrangement; methods of walls demolition or dismantling, of the debris moving; technical solutions on the temporary fastening arrangement of the certain structures and elements, threatening to collapse failure; technical solutions on the equipment protection [1,2,3,4,5,6,7].

The preparatory works are divided at the site of their execution into the off-site works executed beyond the company territory, and the intrasite ones executed at the company territory. The preparatory works are divided into the following types:

- debris clearance;
- demolition of buildings and theirs parts;

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- temporary fastening of structures, threatening to collapse failure;
- equipment protection;
- use of materials from the debris clearance and storage of reusable materials and structures.

The debris clearance is executed for purposes of the site preparation for further reconstruction works at the facility, of remaining equipment withdrawal, as well as for assessment of damage and the opportunity of use of remaining structures, foundations, channels and utilities.

## 2 Materials and Methods

Depending on the task in hand the debris is cleared in part or in whole. The partial clearance is executed during the development of access ways and areas for the machinery arrangement and manipulation, as well as during the essential industrial equipment withdrawal.

The debris clearance in whole is executed during the territory clearing for further reconstruction. The general principle during the debris clearance is the works execution downwards and in all directions, where it is possible to clear the debris; if there is the insufficient quantity of such directions it is required to develop them intentionally.

It is recommended to clear the debris by straight-line flow method, which allows putting into effect promptly the available workforce and means, and using them in the most complete and smooth manner for the duration of works, as well as widely applying for overall mechanisation. To execute the debris clearance successfully along the separate directions, it is reasonable to develop the complex groups equipped with lifting machines, bulldozers, transport means, machines and apparatus for breakdown of shatters of structures and equipment, auxiliary and service machines. The group accepts the tasks and limits of works per shift, per day or several days. When executing the works in shifts, it is set the task for a day shift to clear the debris and dispose the structures, and for the night shift-to develop the working area for the day shift [8,9,10].

The development of access ways and areas is executed for the purpose of free access directly to the work areas and for arrangement of mechanical means.

The access ways are arranged as single-line ones of 3-3,5 m in width, with siding lines every 200-250 m as the areas of 2,5-3,0 m in width and of 15-20 m in length.

The clearance is executed by means of the shatters displacing out of the access way using the heavy hydraulic-motored bulldozer of work equipment. The operation of the single bulldozer is possible only in the debris consisting mainly of brick shatters. The making of access ways in the debris of mixed type with high content of reinforced concrete components is possible only by applying the complex of machines. The complex contains 3-4 machines, for example, one bulldozer with the capacity of 180-220 kW with ripper or with means for separation of the debris components, and two or three bulldozers with the capacity of 70-80 kW.

## 3 Results

The lead machine of the complex is the heavy bulldozer: it displaces, withdraws and removes the large-size shatters; the other bulldozers spread the access way for wheeled machines. In case of insufficient tractive force of even the heavy bulldozer, the heavy elements in debris are blasted or broken by the pneumatic tool. For these purposes, as a rule, the teams of construction machines are added with three or four persons with means for cutting of reinforcement and steel structures, as well as groups for works execution.

The debris clearance for purpose of the territory complete clearing shall be executed as follows:

- Firstly, withdrawn and removed are the certain beams, columns, roof slabs and other long-length elements raised from the debris;
- Large remnants of demolished reinforced concrete structures (beams, trusses, etc) are preliminarily free from the other elements of debris, are broken into the smaller parts and then removed from the debris;
- Large brick or concrete blocks are removed in whole, if it is allowed by a lifting capacity dimensions of construction machines and transport means; if it is impossible, then they are preliminarily broken and separated into the smaller parts;
- Small shatters and material debris are used for filling and planning of the territory or carted away beyond the facility territory and bulked in the specially designated area [11].

The machine sets for the debris clearance shall consist of the bulldozers, автокранов, excavators, tractor loaders, compressor station, pneumatic tool, machines with diamond tool, hydraulic wedges, etc.

As a first approximation, the addition of construction machines into complexes may be performed according to Table 1 (where given are the four groups of buildings and the appropriate machines complexes). These machines may be replaced by machines of equivalent types, if required and depending on their availability in the train.

The content of groups of industrial buildings and the list of machines, which may be used for the debris clearance, are given below.

**Table 1**. The four groups of buildings and the appropriate machines complexes

No. of group	Data on the building structure	Machines for selection of complexes for the debris clearance
1	Industrial single storey buildings with the height of 10-15 m  Industrial multi-storey brick buildings with number of storeys: 2, 3, 4, 5	Bulldozers of traction category 3-4t: DZ-29, DZ-101A, DZ-42G, etc.  Tractor loaders TO-18, TO-11  Hydraulic shovels, 3-4 grade, with the shovel capacity of 0,5-0,65m³: EO-4322A (MRO), EO-4121, EO-4221B  Truck cranes with a lifting capacity of 4-10 t (the short-baseline ones are preferable): KS-3662A, KS-3571  Tipping lorries (KRAZ-256B) with the lifting capacity of 5-7 t
2	Industrial single storey prefabricated buildings with bays of 12,18 m, with the height to the bottom of framework structures of 3,6-9,6 m, with mass of elements of 5-9 t, with the columns step of 6-12 m  Industrial multi-storey prefabricated buildings with a storey height of 3,6; 4,8; 6 m, the bay width of 2, 3, 4 m, mass of elements of 4, 7, 12 t	Bulldozers of traction category 10-15 t: DZ-27(160 h.p.), D-35 (180 h.p.) with widener of blade  Tractor loaders: TO-21, TO-24  Tipping lorries with the lifting capacity of 7-16 t  Hydraulic shovels, 3-4 grade, with the shovel capacity up to 1m³: EO-4121, EO-3322A; EO-4125  Truck cranes with a lifting capacity of 10-16 t: KS-5263, MKG-10A, MKT-25  Tipping lorries with the lifting capacity of 7-16 t

3	Industrial single storey prefabricated buildings with bays	Bulldozers of traction category 15-25 t: D-34, D-59, D-384, D-685, D-439A
	of 18, 24, 30 m, with the height to	Tractor loaders: TO-21, TO-24
	the bottom of framework	Hydraulic shovels, 4-5 grade: EO-4121, EO
	structures of 6-15 m, mass of	-5122, EO-5124, EO-5015A
	elements of 8-16 t, with the	Truck cranes with the lifting capacity of 25-
	columns step of 12 m	40 t: KS-5363, KS-5122, KS-6371 short-
		baseline, MKG-25, SKS-40
	Industrial multi-storey	Tipping lorries with the lifting capacity of
	prefabricated buildings with the	9-25 t
	mass 7-12 t	
4	Industrial single storey	Bulldozers of traction category 25 t: DZ-34
	prefabricated buildings with bays	Tractor loaders: TO-21, TO-24
	of 24, 30, 36 m, with the height to	Hydraulic shovels, 5 grade: EO-5122, EO-
	the bottom of framework	5124, EO-5015A
	structures of 12-18 m, mass of	Truck cranes with the lifting capacity of 40
	elements of 15-35 t, with the	t, 63 t
	columns step of 12 m	Tracked jib cranes 40-100 t: SKG-40, SKG-
		100
	Industrial multi-storey heavy-	Tipping lorries with the lifting capacity of
	duty buildings of mixed type with	16-45 t
	the height of 15-35 m, mass of	
	elements of 15-25 t	

The calculation on number of machines and machinery for the debris clearance is based on the following:

- actual scope of works mass of debris in tons or its volume in m<sup>3</sup>;
- -fixed time limits of clearance, under the specified shiftwork and shifts duration;
- production capacity of available mechanical means;

While calculating the actual scope of works it is recommended to use Table 2; the production capacities of mechanical means on the debris clearance are given in Table 3.

The volume weight of debris, its content and structure during the demolition of some types of buildings.

•		Content of shatters, weight %				
	V - 1	Brick	Shatters of			Material
Type of buildings	Volume weight of debris t/m <sup>3</sup>	blocks up to 1m <sup>3</sup> brick rubble	Reinforce concrete and concrete structures up to 0,8m <sup>3</sup>	Wooden structures	Steel structures (including the machining equipment)	debris
Brick production buildings	1,514- 1,297	25	55	3	10	7
Brick residential buildings	1,087- 0,931	50	15	15	5	15
Wooden buildings	0,478- 0,399	10	-	80	-	10

**Table 2.** The actual scope of works

Large- panel	0,982- 0,819	-	75	18	2	5
buldings	0,819					

**Table 3**. Production capacities of mechanical means on the debris clearance

Name of works	Unit	of	Production
Tunic of Works	meas.	01	capacity per
	1110000		working hour
Debris clearance by excavator with loading to transport			77 6 5 5 5 6 5 6 5 6 5 6 5 6 6 6 6 6 6 6
means, with a shovel capacity, m <sup>3</sup> :			
0.3	$m^3$		12
0.5	***		18
1,0			40
Debris clearance with displacing of mass by tractor-			
bulldozers, type C-100 and T-141 at the distance of, m:			
10	$m^3$		50
20	***		35
30			30
Debris clearance of access ways by bulldozers, with the			
width of access way of 3,5 m, with a medium height of			
debris, m	m		
Up to 0,3 m			170-200
Up to 0,5 m			100-150
Transportation of blocks and material debris from the			
debris clearance by using the tipping trucks, with loading			
by excavator at the distance of, km:			
1	$m^3$		5-8
2			4-6
3			3-5
5			2-3
Loading of blocks to transport means by mobile cranes.			
Demolition by tractor of buildings walls with the height			
of storeys:	$m^2$		
Up to 3			35
More			20

During the clearance of debris made by the brick buildings, the hydraulic shovel with convertible attachments (back or front shovel, pneumatic hammer or jack hammer) will take the lead in the complex. The shovel is used for clearance and loading of debris structure to the tipping trucks and for breakage of large brick blocks. The debris elements for loading will be displaced and grouped using by applying the bulldozer. In case of clearance of mixed type debris, consisting of demolished reinforced concrete and steel structures, at the first process stage the crane with the lifting capacity of 25-100 t will be held the key place, with the radius of working range up to 30-40 m. Such crane shall operate together with machine and equipment for cut through the reinforcement of reinforced concrete structures and steel structures. To decrease a mass and dimensions of debris shatters used are the methods equivalent to ones of buildings demolition or applied are the demolition means, specified in Table 4. The grinding is executed in situ or at the specific areas. The demolition means of the construction structure materials recommended during the preparatory works execution.

Table 4. The demolition means

Making of beaming lammers   Namers of lambdar   Namers of lambdar	Demolition	Productio	Effect of	Process technology	Recommended complex	Possibilit
Hydraulic wedged wedged plants   Diamond form   Possible one wedged of wedged plants   Possible one wedged of wedged of wedged of wedged wedged pneumatic hammers   Possible one wedged plants   Possible one wedged plants   Possible one wedged plants   Possible one wedged proceeding wedged processing device in a blast hole. Breaking of wedged processing device in a blast hole. Breaking of wedged processing wedged processing device in a blast hole. Breaking parts   Possible one several breaking devices)   Possible one several breaking devices   Possible one several breaking devices   Possible one wedged breaking device on a blast hole. Breaking of which wedged breaking device on a blast hole. Breaking of demolition   Possible one wedged breaking device on a blast hole. Breaking of which wedged breaking device on a blast hole. Breaking of demolition   Possible one western breaking devices   Possible one wedged breaking device on a blast hole. Breaking of which we wedged breaking device on a blast hole. Breaking of which we were demolition.   Possible one we several breaking device on a blast hole. Breaking of which we were demolition.   Possible one we several breaking device on a blast hole. Breaking of which we were demolition.   Possible one we were demolition.   Possible one were demolit				1 rocess technology		
Hydraulic-wedged wedged of plants   Proparation to works: blast-hole drilling arrangement of hydraulic-wedged breaking device in a blast hole. Breaking of wedged breaking device in a blast hole. Breaking of wedged breaking device in a blast hole. Breaking of wedged breaking device in a blast hole. Breaking breaking device (it is possible to use several breaking devices)		1 3	mean to a		machinery	applicatio
wedged plants   m/hr per one plants   m/hr per one plants   m/hr per one preaking device (nad reinforced (hydraulic—wedged)   hydraulic—wedged breaking device in a blast hole Breaking devi						
plants one breaking device (hydraulic wedged device (hydraulic wedged of breaking device in a plast wedged of pieces pieces masses to pieces m			_			Possible
Diamond drilling plant   Diamond drilling of opening, Disposal of demolished material   Diamond drilling machine, set of diamond drilling of openings. Disposal of demolished material   Diamond drilling machine, set of diamond drilling of openings. Disposal of demolished material   Diamond drilling machine, set of diamond drilling of openings. Disposal of demolished material   Diamond drilling machine, set of diamond drilling of openings. Disposal of demolished material   Diamond drilling machine, set of diamond drilling of openings. Disposal of demolished material   Diamond drilling machine, set of diamond drilling of openings. Disposal of demolished material   Diamond drilling machine, set of diamond drilling of openings. Disposal of demolished material   Diamond drilling machine, set of diamond drilling and price openings. Disposal of demolished material   Diamond drilling and price   Diamond drilling machine, set of diamond drilling and price   Diamond drilling and drills, severing of openings. Disposal of demolished material   Diamond drilling and price   Diamond drilling   Diamond						
device (hydraulic wedged)   masses to pieces   Disposal of demolition   Diamond drilling plant	piants					
Diamond drilling plant   Diamond drilling pl		_				
Jack hammers and pneumatic hammers   Jack hammers						
Diamond drilling plant   Diamond drilling machine, set of diamond drilling demolished material   Disposal of severing Seve				<u> </u>		
Severing of reinforced concrete demolition hammers   Diamond drilling plant   Diamond drilling plant   Diamond drilling plant   Diamond drilling plant   O,25-0,6 and electric demolition hammers   Diamond drilling machine, set of diamond drills, compressor ZIF   SVE 4,8/1,0SHR   Demolition hammer   Diamond drilling machine, set of diamond drills, compressor ZIF   SVE 4,8/1,0SHR   Demolition hammer   Disposal of demolished material   Disposal of demolished material   Disposal of demolition   Diamond drilling machine, set of diamond drills, compressor ZIF   SVE 4,8/1,0SHR   Demolition hammer   Disposal of demolished material   Disposal of demolished material   Disposal of demolished material   Disposal of demolished material   Disposal of separated material   Disposal of demolished material   Disposal of separated material   Disposal of demolished material   Disposal of demolish		weagea)	preces			
Diamond drilling plant   Disposal of demolished concrete from the area of demolition.   Diamond drilling plant   (opening/ (opening/ opening, formation of slots, severing of reinforced concrete, and brick structures   Pneumatic demolition hammers   Possible   Preparation to demolished material   Diamond drilling machine, set of diamond drills, compressor ZIF   SVE 4,8/1,0SHR   Preparation. Breaking. Disposal of demolished material   Demolition hammer   Possible   SVE 4,8/1,0SHR   Preparation. Breaking. Disposal of demolished material   Demolition hammer   ZUBR ZM-40-1700 K   Preparation to severing. Severin	Jack	1,5-3,5	Complete	Preparation to works:		Possible
Diamond drilling plant   Diamond drilling pl	hammers and	m³/hr	demolition	material demolition.	4121, jack hammer SP-	provided
Diamond drilling plant   Diamond drilling machine, set of diamond opening, formation of slots, severing of reinforced concrete, concrete and brick structures   Pneumatic demolition hammers   Diamond drilling machine, set of diamond drills, compressor ZIF   SVE 4,8/1,0SHR   Possible   SVE 4,8/1,0SHR   SVE 4,8/1,0SHR   Possible   SVE 4,8/1,0SHR   Diamond drilling machine, set of diamond drills, compressor ZIF   SVE 4,8/1,0SHR   SVE 4,8/1,0SHR   Possible   SVE 4,8/1,0SHR   SVE 4,8/1,0SHR   Possible   SVE 4,8/1,0SHR   SVE 4,8/1,0SH	1				62	
Diamond drilling plant   Diamond drilling of opening, formation of slots, severing of reinforced concrete, concrete and brick structures shift hammers   Preparation to demolition   Diamond drilling of openings. Disposal of demolished material   SVE 4,8/1,0SHR   Pressible	hammers					
Diamond drilling plant   Diamond drilling machine, set of diamond openings. Disposal of demolished material   SVE 4,8/1,0SHR   Possible						-
Diamond drilling plant   Diamond drilling machine, set of diamond drills, compressor ZIF SVE 4,8/1,0SHR   Preparation to openings. Disposal of demolished material   Diamond drilling. SVE 4,8/1,0SHR   Preparation to severing of reinforced concrete and brick structures   Disposal of demolished material   Diamond drilling. SVE 4,8/1,0SHR   Preparation to severing of concrete and reinforced concrete made in any position   Diamond drilling. SVE 4,8/1,0SHR   Preparation to severing. Disposal of demolished material   Diamond drilling. SVE 4,8/1,0SHR   Preparation to severing. Svering. Disposal of separated reinforced concrete made in any position   Diamond drilling. Sve 4,8/1,0SHR   Preparation to material   Diamond drills, compressor ZIF Sve 4,8/1,0SHR   Preparation to material   Diamond drilling. Sve 4,8/1,0SHR   Preparation to material   Diamond drilling. Sve 4,8/1,0SHR   Preparation to works. Cutting to the depth of demolished material   Diamond drills, compressor ZIF Sve 4,8/1,0SHR   Preparation to works. Cutting to the depth of demolished material   Diamond drills, compressor ZIF Sve 4,8/1,0SHR   Preparation to works. Cutting to the depth of dem				demolition.		
Diamond drilling plant						
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Pneumatic and electric demolition hammers				<u>.</u>		
Pneumatic and electric demolition hammers	31					
Pneumatic and electric demolition hammers		hr)	of slots,	demolished material	SVE 4,8/1,0SHR	
Pneumatic and electric demolition hammers			_			
Pneumatic and electric demolition hammers						
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Pneumatic and electric demolition hammers						
Pneumatic and electric demolition hammers						
and electric demolition hammers  Flame jet burner  - Severing of concrete and reinforced concrete made in any position  Oxygen lance. Powder-oxygen cutting plant  Blasting materials  Blasting materials  Blasting materials  Blasting generator  VN-2  Breakage in my/hr, any position of blasts per laminute  Breakage  Disposal of demolished severing. Severing. Disposal of separated material to to severing. Severing. Disposal of severing. Severing. Disposal of severing. Disposal of severing. Disposal of severing. Severing. Disposal of severing. Disposal of severing. Severing. Disposal of severing. Set. Oxygen containers Possible provided the safety and ventilation oversity and ventilatio	Pneumatic	0.25-0.6		Preparation Breaking	Demolition hammer	Possible
Severing of concrete burner			_			1 0331010
Flame jet burner  - Severing of concrete and reinforced concrete made in any position  Oxygen lance. Powder-oxygen cutting plant  Blasting materials  Blasting materials  Blasting generator VN-2  Breakage  Blasting generator VN-3  Breakage  Breaka						
burner    burner	hammers					
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Powder- oxygen cutting plant  Blasting materials  Discreption  Blasting materials  Discreption						
oxygen cutting plant         Cutting         demolished material         UPKR-2         overventil ation           Blasting materials         0,55-0,59 m³/hr. Thickness of the material to be demolishe demolishe downlishe VN-2         blast. Disposal of products after the blast         Blasting materials         Blasting materials         Limited due to seismic effect and shatters distributio n           Blasting generator VN-2         45-150 m³/hr, number of blasts per 1 minute         Breakage in position of blasts per 1 minute         Preparation to works. Breakage         Blasting generator VN-2. Hydraulic shovel, 3 grade, or machine KrAZ-257K         Limited due to seismic effect and shatters distributio n		m/hr				1
cutting plant  Blasting materials  Materials  Blasting materials  Materials  Description of the demolishe de-any  Blasting generator  VN-2  Blasting material  Application of the demolishe down of th			_			
Blasting materials    Description of material and position of material and position of demolishe demolishe generator VN-2   VN-2   N-2   N			Cutting	demolished material	UPKR-2	
materials m³/hr. Thickness of the position of material to be demolishe d - any VN-2 NN-2 NN-2 mumber of blasts per 1 minute		0.55.0.50	Breaking to	Drangration to works:	Blacting meterials	
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of the material to be demolishe d - any	materials					
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Description of blasts per 1 minute   Description of the content						
Blasting generator VN-2 number of blasts per 1 minute						distributio
Blasting generator VN-2   Markage in m³/hr, number of blasts per 1 minute   Breakage in a structure   Breakage   Preparation to works. Blasting generator VN- 2. Hydraulic shovel, 3grade, or machine krAZ-257K   dimensions						n
generator VN-2   m³/hr, number of blasts per 1 minute   m³/hr, number of blasts per 1 minute   Breakage   2. Hydraulic shovel, 3grade, or machine KrAZ-257K   dimensio ns	DI :		D 1 '	D (1)	DI C YEY	T
VN-2 number of blasts per a structure 1 minute 3 grade, or machine large dimensions			_			
blasts per a structure KrAZ-257K dimensio ns		,		ыгеакаде		
1 minute ns	V 1N-2					_
			a structure		NIAL-23/N	
		80-1500.				115

Thickness		
- any		

After the withdrawal and clearance of large components of the debris started working the universal hydraulic shovels with the shovel's capacity of 0,65-1,25 m<sup>3</sup>, and the wheeled tractor shovels. The final process of the debris clearance is the loading and disposal of damaged structures shatters and material debris to the waste tips. When selecting the transport diagram of the debris clearance, it should be considered that the favourable ratio of capacity of the excavator shovel and the tipping lorry body is the ratio 1:4 or 1:5.

The preliminary lifting capacity of transport means depending on the excavator shovel capacity is accepted as per Table 5.

**Table 5**. The preliminary lifting capacity of transport means

Capacity of the loading Lifting capacity of the tipping lorry [t] machines shovels [m<sup>3</sup>] 0,3-04 3,5-10 0,5-1 7-10 1,25-2 10-25 3-4 25-40

In Fig. 1. given are the process flow diagrams of the lumped debris clearance (characterized by the side lengths ratio as 1:1) and the extended debris clearance (characterized by the side lengths ratio as more than 1:2) [12].

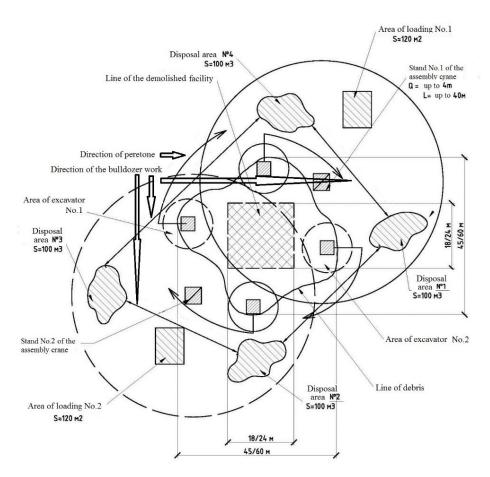


Fig. 1. Debris clearance of the lumped facility.

# 4 Conclusions

The upgrading and use of new machinery allow applying the new design and process solutions. The types and purposes of the debris clearance, the selection of machines and machinery, tasks for decrease of the debris mass and dimensions, selection of a certain type of motor transport depend on the technical-and-economic characteristics, characteristics of the machines, duration and length of haul. Generally, it is preferable to use the specific types of transport for the debris clearance – the hydraulic-motored bulldozers and excavators.

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