Construction waste as a disperse system

N V Bakaeva [1a], M Y Klimenko[2b], A A Zamorov[2b]

[1]Southwest State University, 305040, Kursk, 50 Let Oktyabrya Street, 94, Russia
[2] Platov South-Russian State Polytechnic University (NPI), 346428, Novocherkassk, Prosveschenia Street, 132, Russia

E-mail: [a] natbak@mail.ru, [b] klimdaver@bk.ru

Abstract. The authors studied and classified some parameters of construction waste properties, construction waste energy parameters and their stability in the building technical state recovery system by means of the application of basic tenets of the theory of disperse systems. Key parameters determining the properties of a dispersion medium and dispersed phase were formed; such groups as geometric, physical and mechanical, chemical, hydrophysical, thermophysical, optical, aerodynamic (for construction waste) and space-planning, structural, technical state, climate (for the building technical state recovery system) were distinguished. Construction waste stability is considered as a resulting criterion, characterizing its behavior in the environment and making it possible to manage waste in order to decrease their stability and, eventually, providing ecological safety of construction projects.

1. Introduction
The increase of man-induced load on the environment negatively impacts the safety area of human life and activities. The existing scale of construction waste generation and accumulation poses topical social issues of the decrease of its release into the environment by means of waste recycling [1-8]. To decrease the environmental pollution it is necessary to define construction waste properties and their classification, energy parameters and stability in the system of building technical state recovery.

2. Problems of construction waste release into the environment
From 2010 to 2014, 74.1 mln.t. of construction waste was generated in the Russian Federation; only 48.3 mln.t was recycled and neutralized [9]. There is a downward dynamics in the formation of a dilapidated housing stock which needs major repairs (reconstruction). In 1990 the area of such housing was 3.3 mln.m^2, and in 2015 it increased to 19.62 mln.m^2 [10].

The presented above figures and the modern state of the process of construction speak for the existence of problems of ecological safety of construction projects, connected with the low level of the use of construction waste generated during major and minor repair and reconstruction of buildings.

3. Results
Analyzing design and estimate documentation passed the State Expert Review for major and minor repair and building reconstruction performed on the basis of laws and regulations of the Russian Federation, it can be concluded that the concept of construction waste utilization typically includes the algorithm for a waste disposal (storage) method for the purpose of their further transportation to solid waste landfills and disposal sites which is shown in Table 1.

Most researches now propose consideration of any polluting substance as a disperse system [ ]. This approach implements the theory of disperse systems based on the classical framework of colloid and physical chemistry. Basic classification features of disperse systems for construction waste are presented in Table 2.

Table 1. Method for reduction of negative effects of construction waste according to design and estimate documents of the Russian Federation

Constructionwaste	Waste generation site	Ways of construction waste utilization	Ways of construction waste disposal
Concrete scrap	Wall and partition brickwork	Stored on hard stand	–
Crushed bricks	Cement brickwork mortar, cement-sand mortar screed, wall and partition brickwork	Stored on hard stand	Solid waste landfill
Wood waste	Finishing work	–	Solid waste landfill, fuel resource
Plaster scrap	Foundation block, foamed concrete block partitions	Stored on hard stand	Solid waste landfill
Quartz sand	Preparation of foundation trenches for roadway paving and grounds	Stored on hard stand	Solid waste landfill
Cement mortar, cement waste	Demolition works	Stored on hard stand	Solid waste landfill
Crushed stones, demolition waste and chips	Demolition works	Stored on hard stand	Solid waste landfill
Ceramics waste	Construction work	Stored on hard stand	Solid waste landfill
Asphalt concrete waste	Construction work	Stored on hard stand	Solid waste landfill
Bitumen waste	Perimeter walks	–	Solid waste landfill
Polymeric pipe waste	Welding	–	Solid waste landfill
Ferrous scrap	Water supply and sewage system assembly	Stored on hard stand	To a licensed ferrous metals recycling plant
Welding electrode waste	Demolition works	–	To a licensed ferrous metals recycling plant

Based on the data of previous research in accordance with the theory of disperse systems, construction waste is a polydisperse system comprising some solid dispersed phases (separate fractions of construction waste) and gaseous dispersion medium (airspaces between construction waste fractions) [11,12,13].

Table 2. Construction waste according to classification features of disperse systems

Classification feature of a disperse system	Characteristics of construction waste according to the feature
Fraction, mm	0.016-1000
Dispersion degree	Coarse, polydisperse
Type of dispersion medium and dispersed phase interaction	lyophobic
Type of dispersed phase particles interaction	Freely dispersed
Type of dispersion medium particles interaction	Freely dispersed
Aggregate state of a dispersed phase and dispersion medium	Solid/gaseous

Processes determining properties and state of construction waste cannot be studied separately. Commonality of the nature of these processes highlights the strong interrelation between them. This mutual influence depends on the number of factors: dispersed phase (d.ph.) and dispersion medium (d.m.) properties of construction waste, environmental characteristics. Having analyzed the processes taking place in a disperse system, construction waste was classified into groups whose key parameters are presented in Table 3.

Table 3. Key parameters determining construction waste dispersed phase and dispersion medium properties

Parameter group	**Parameter determining dispersed phase properties**	**Parameter determining dispersion medium properties**
Geometric ($G_{d.ph.}$), ($G_{d.s.}$)	Thickness, height, length and area of construction waste debris; fraction size, cross section area, d.ph. volume, etc.	D.m.volume
Physical and mechanicl ($FM_{d.ph.}$),($FM_{d.s.}$)	Mass, density, strength, hardness, elasticity, plasticity, d.ph. mass, etc.	Density, d.m. (gas) molecular mass, etc.
Chemical ($Ch_{d.ph.}$, $Ch_{d.s.}$)	Resistance to chemical and corrosion attack, d.ph. solubility, adhesion, crystallization, etc.	d.m. aggressivity, chemical composition, etc.
Hydrophysical ($Hy_{d.ph.}$, $Hy_{d.s.}$)	Dispersed phase humidity, hydroscopy, capillary suction, water absorption, etc.	d.m. humidity
Thermophysical ($Th_{d.ph.}$, $Th_{d.s.}$)	Thermo conductivity, specific heat capacity, fire resistance, refractoriness, temperature expansion, thermal storage, dispersed phase particles temperature, etc.	d.m. particles temperature, thermal conductivity, etc.
Optical ($O_{d.ph.}$, $O_{d.s.}$)	Dispersed phase light transmission, transparence, absorption coefficient, etc.	d.m. light transmission
Aerodynamic ($Ae_{d.ph.}$, $Ae_{d.s.}$)	Density, air inertness and viscosity, material roughness, dispersed phase sedimentation rate, etc.	d.m. dynamic (kinematic) viscosity, etc.

As a result of examination of the parameters determining dispersed phase and dispersion medium properties, a part of parameters determining construction waste properties can be in general terms presented as a functional relationship of the groups of parameters of phase elements of construction waste:

$$PP_{cw}=f_1((PP_{d.ph.}),(PP_{d.s.}))=f_1(f_{1\text{-}1}(G_{d.ph.}, FM_{d.ph.}, Ch_{d.ph.}, Hy_{d.ph.}, Th_{d.ph.}, O_{d.ph.}, Ae_{d.ph.}), f_{1\text{-}2}(G_{d.s.}, FM_{d.s.}, Ch_{d.s.}, Hy_{d.s.}, Th_{d.s.}, O_{d.s.}, Ae_{d.s.})), \quad (1)$$

where PP_{cw}, $PP_{d.ph.}$, $PP_{d.s.}$ are the group of parameters determining construction waste properties, its dispersed phases and dispersion media in the system of building technical state recovery.

Analyzing the processes taking place in building structures during recovery works the following dispersed phase and dispersion medium parameters presented in Table 4 can be distinguished.

Hence, while determining key properties of a dispersion medium and dispersed phase, phase element parameters, revealing characteristics of the building technical state recovery system (BTSRS) were found in terms of the theory of disperse systems and are expressed by the formula:

$$PP_{brs}=f_1((PPP_{d.ph.}),(PPP_{d.ph.}))=f_1(f_{1\text{-}1}(GS_{d.ph.}, VP_{d.ph.}, K_{d.ph.}, TS_{d.ph.}, KP_{d.ph.}), f_{1\text{-}2}(GS_{d.s.}, VP_{d.s.}, K_{d.s.}, TS_{d.s.}, KP_{d.s.})), \quad (2)$$

where PP_{brs}, $PPP_{d.ph.}$, $PPP_{d.s.}$ are the parameters determining medium parameters, its dispersed phases and dispersion media in the system of building technical state recovery.

Such generalization of parameters makes it possible to add into each group of dispersed phase and dispersion medium parameters new characteristics in the process of the development of theoretical fundamentals of ecological safety of construction, and carry out targeted, consistent assessment of all the sides of the dynamics of formation, accumulation, distribution and destruction of construction waste.

According to the works of a number of scholars, stability is the resulting characteristics determining the behavior and existence of a pollutant (construction waste) as a disperse system, i.e. its "viability" parameter [14-20]. The more stable the system is, the slower its parameters change, and vice versa.

Table 4 Key parameters for construction waste determining dispersed phase and dispersion medium properties

Parameter group	Parameter determining dispersed phase properties	Parameter determining dispersion medium properties
Geometric ($GS_{d.ph.}$), ($GS_{d.s.}$)	Element thickness, height, width, length and area; cross-section area, dispersed phase volume, etc.	D.m. volume
Spatial-planning ($VP_{d.ph.}$), ($VP_{d.s.}$)	Shape in the plan, length, width and height of the building, distance between separate dispersed phase volumes, etc.	
Structural ($K_{d.ph.}$, $K_{d.s.}$)	Building frame diagram; enclosure; partition type; coating and flooring; door and window filling; roofing system; dispersed phase type, etc.	
Technical state ($TS_{d.ph.}$, $TS_{d.s.}$)	Dispersed phase damage, reliability, durability (time between total building renovation, time before emergency state), etc.	
Climate ($KP_{d.ph.}$, $KP_{d.s.}$)	Mean air temperature, wind and snow region, specified frost depth, etc.	Mean temperature of d.m. particles

Acquisition, distribution and expenditure of energy of construction waste are quantified by energy parameters (W_{cw}) of the dispersed phase ($W_{d.ph.}$) and dispersion medium ($W_{d.s.}$) of construction waste, which assumes the possibility for redistribution its separate kinds, reflecting specific features of construction waste being. With a certain content of total free energy (energy of activation), construction waste shows some specific features of its behavior, which eventually impacts its stability: $W_{cw} \sim U_{cw}$. This implies that construction waste stability (U_{cw}) is the resulting characteristics determining the ability of construction waste to resist external effects, which occurs while changing construction waste energy (W_{cw}), which in its turn depends on the parameters of construction waste properties (PP_{cw}), formed by the system of building technical state recovery (PP_{brs}).

4. Conclusion

Based on the research findings the following conclusion can be made:

1. Basic types of construction waste generated during buildings and facilities reconstruction were defined.
2. Classification properties and relevant construction waste characteristics in terms of their recycling were specified.
3. Based on the results of the analysis of the processes taking place in construction waste, groups of their properties parameters were proposed (formulae 1, 2).
4. Parameters defining construction waste state as a dispersed phase and dispersion medium were described.
5. Factors determining the stability of construction waste and building technical state recovery systems as disperse systems were found.

Hence, considering construction waste in terms of the theory of stability of disperse systems, it is possible to find out that main solutions for the issue of the reduction of waste release to the environment are its destruction as a disperse system by means of complete loss of stability. Based on the conducted research, some parameters of construction waste properties were described, which makes it possible to control its behavior and, eventually, reduce environment pollution.

5. Conclusion

According to housing statistical data about dwelling total area and wear, buildings should be dismantling when carrying out repair and recovery works. They are included into existed 450 million tons of damaged structures. It also should be done according to practical application of recycled construction wastes use. On the other hand, in case of inactivity, building wastes will negatively influence ecological safety of construction as ecological safety component of the Russian Federation.

This developed technique implementation for major overhaul and current repairs of buildings in the Russian Federation is necessary as one of possible ways for technologies development and also for biosphere progressive harmonic development.

References

[1] Geoffrey Hamer 2003 *Solid waste treatment and disposal: effects on public health and environmental safety* (article) (Biotechnology Advances, Volume 22, Issues 1) pp 71–79

[2] Rajeev Pratap Singh, Pooja Singh, Ademir S.F. Araujo, M. Hakimi Ibrahim, Othman Sulaiman 2011 *Management of urban solid waste: Vermicomposting a sustainable option* (article) (Resources, Conservation and Recycling, Volume 55, Issue 7) pp 719–729

[3] Forbes R. McDougall, Peter R. White, Marina Franke, Peter Hindle 2008 *Integrated Solid Waste Management: A Life Cycle Inventory* (text)

[4] Alexis M. Troschinetz, James R. Mihelcic 2009 *Sustainable recycling of municipal solid waste in developing countries* (article) (Waste Management, Volume 29, Issue 2) pp 915–923. 5

[5] Adamyan R.G 2013 *Analiz ekologicheskih osobennostey tehnologii zahoroneniya tverdyih othodov potrebleniya v usloviyah Armenii* (III Mezhdunarodnaya nauchno-prakticheskaya konferentsiya «Sovremennaya shkola Rossii: voprosyi modernizatsii») pp 10-14

[6] Bespalov V.I., Paramonova O.N 2012 *Klassifikatsionno-metodicheskie osnovyi borbyi s zagryazneniem okruzhayuschey sredyi tverdyimi othodami potrebleniya. Sbornik nauchnyih trudov SWorld. Materialyi mezhdunarodnoy nauchno-prakticheskoy konferentsii «Nauchnyie issledovaniya i ih prakticheskoe primenenie. Sovremennoe sostoyanie i puti razvitiya 2012»* Vyipusk 3. Tom 9 (Odessa: Kuprienko) p 89

[7] Bakaeva N.V 2010 *K postanovke zadachi upravleniya sistemami zhizneobespecheniya goroda na osnove kontseptsii biosfernoy sovmestimosti* (N.V. Bakaeva Sb. mat. VII Kryimskoy Mezhdunarodnoy nauchno-prakticheskoy konferentsii «Geometricheskoe i kompyuternoe modelirovanie: energosberezhenie, ekologiya, dizayn» Simferopol, Natsionalnaya akademiya prirodoohrannogo i kurortnogo stroitelstva, 27 sentyabrya - 01 oktyabrya 2010) pp 423-427

[8] Klimenko M.Yu., Kasharina T.P 2014 *Zagryaznenie territoriy gorodskoy zastroyki valovyimi vyibrosami v atmosferu i othodami pri stroitelstve* (Ekologiya urbanizirovannyih territoriy №4) pp 68-70

[9] 2015 *Rossiyskiy statisticheskiy ezhegodnik* (Stat.sb. Rosstat.: M., Rosstat) p 727

[10] 2016 *Zhilischnoe hozyaystvo v Rossii* (Stat. sb. Rosstat. - Zh72 M) p 63

[11] Bespalov V. I., Paramonova O. N 2012 *Fizicheskaya model protsessa zagryazneniya okruzhayuschey sredyi tverdyimi othodami potrebleniya* (Inzhenernyiy vestnik Dona #4 (chast 1)) URL: ivdon.ru/magazine/archive/n4p1y2012/11

[12] Paramonova O. N 2013 *Rassmotrenie tverdyih othodov potrebleniya kak dispersnoy sistemyi* (Inzhenernyiy vestnik Dona №3) URL: ivdon.ru/magazine/archive/n3y2013/1933/

[13] Bespalov V. I 1997 *Fiziko-ehnergeticheskaya koncepciya opisaniya processov i proektirovaniya inzhenernyh kompleksov zashchity vozdushnoj sredy* (BZHD. Ohrana truda i okruzhayushchej sredy. Rostov-na-Donu: RGASM) pp 65- 70

[14] Il'ichev V.A 2013 *Biosfernaya sovmestimost' – princip, pozvolyayushchij postroit' paradigmu zhizni v garmonii s planetoj Zemlya* (Biosfernaya sovmestimost': chelovek, region, tekhnologii) №1 pp 4-5
[15] Eliseeva T.P 2013 *Sovremennye problemy razvitiya social'no-ehkonomicheskih i ehkologicheskih sistem* (Monografiya, pod obshchej red. Eliseevoj T.P.: SHAHTY, ISOiP (filial) DGTU) p 291
[16] Magomadova H.A 2012 *Problemy social'no-ehkologo-ehkonomicheskoj ehffektivnosti vzaimodejstviya obshchestva i prirody* (Inzhenernyj vestnik Dona, №1) URL: http://www.ivdon.ru/magazine/archive/n1y2012/666
[17] Goponov V. L., SHevchenko I.S 2006 *Sbor i utilizaciya tverdyh othodov potrebleniya v Rostove-na-Donu* (Pravovye voprosy ohrany okruzhayushchej sredy: ehkspress-informaciya) № 3 pp 14-19
[18] Vajsman YA. I., Korotaev V. N., Slyusar' N. N 2012 *Upravlenie othodami. Sbor, transportirovanie, pressovanie, sortirovka tverdyh bytovyh othodov* (Perm': Perm. nac. issled. politekhn. un-ta) p 236
[19] Klimenko M.YU 2016 *Metodika snizheniya zagryazneniya okruzhayushchej sredy sistemy vosstanovleniya tekhnicheskogo sostoyaniya zdanij gorodskoj zastrojki* (Inzhenernyj vestnik Dona, №4) URL: ivdon.ru/ru/magazine/archive/n4y2016/3793
[20] White R.R 2002 *Building the ecological city* (Cambridge: Woodhead Publishing Limited) p 239