Wastewater sludge disposal in the claydite construction product

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Abstract. In environmental concern this paper relates to waste management, that is becoming a global challenge. The raw base municipal wastewater sludge (WSS) is submitted by crude types: excess activated sludge (EAS), deposit allocated precipitation at mechanical treatment stage, or also dehydrated mixture of the listed kinds of deposits. Claydite is an effective and rather popular material in the construction industry. The choice of sub-standard clay raw material of an overburden bench of Kalinovo-Dashkovskiy deposit, closely to the city of Serpukhov is provided by a location of opencast on close distance from wastewater treatment plant. As the additive to the specified raw material was chosen small-dispersed WWS with sludge from surface storm drains (SSD), which is poorly investigated. This allowed to specified traditional technology and to improve production light porous claydite, ecologically pure product. Claydite application is possible in production of light concrete on porous aggregate (filler) of the marks up to 600-700 with reduced thermal conductivity up to 0.175 W/m°C. Such a claydite-concrete manages to be received specially working with granulometry of aggregate, utilizing claydite-sand or wastage of dust-ablation. The design for real conditions with productivity 135 thousand m³/year showed the economical substantiation of mentioned claydite production based the identification of power reduction on 25.8% and specific fuel reduction on 25.7 – 38.0% in comparison with traditional values of claydite production.

1. Introduction
Population increase of megapolicies and scientific-technological development of imperfect technologies have caused accumulation of process wastages, including deposits of waste water (WWS- wastewater sludge), which is multicomponent wastage of wastewater treatment plants (WWTPs). Basically, WWS is hardly separated suspension, which need coagulants and flocculation agents during mechanical dehydration.

Utilization problem of WWS gets the special urgency, because has not only nature protection value, but also economic value, promoting to restore of raw and material resources. As a result of poor attention to processing and utilization only in Moscow and region stored more than 4 million m³/year of WWS. By virtue of it WWS directed to overflowed sludge retention basins, sludge beds and ranges, resulting to emergency downthrows of pollution.

From total amount of WWS utilized only about 1,5 % as fertilizers, because it is connected with presence of ecologically hazardous connections in composition. Besides this terrible scourge the
traditional technologies of industrial processing of WWS - burning due to high power consumption of processes result in the extremely irrational expenditure of organic component and formation of a new secondary wastage. At the same time, processing and utilization of process wastage during cooperation with branch of building industry will allow to receive quickly the real economic and social - ecological results at minimum expenses of resources.

In environmental concern the problem of sewage sludge disposal relates in two main directions of utilization:
- biofuel conversion from sewage characterization of lipid and sugar fractions, carbon to nitrogen ratio, organic loading, etc. [1 - 5];
- sludge reuse in structural building material: into concrete as aggregate, into ceramic materials (as sand and clay replacement), as cement replacement or filler, as fine aggregate for products from concrete, up to manufacture of synthetic coarse aggregate [6 - 12].

In the construction industry the claydite is a popular material with almost studied is the step of porization pellets, for which established the mechanism and physical and chemical basis of the process, taking into account the dependence of pressing conditions from intumescent ability of pellets [13 - 14].

Opinions [9, 15] relates to a present need for intensive use of local raw material resources; creating progressive, environmentally safe mineral binders and composite building materials, that are distinguished by low power consumption, low cost of the production establishment that allow to obtain the construction products with high functional properties and durability.

Present research paid attention to the production light porous claydite, ecologically pure product from wastewater sludge (WWS) with sludge from surface storm drains (SSD), a problem with much less attention, described by literature.

2. Materials and methods
An engineering methods and economical substantiation been used in order to improve the production light porous claydite from WWS.

WWTP of Serpukhov city been selected as the source of WWS. The raw base WWS is submitted by two crude types: excess activated sludge (EAS) - wastage of biological treatment and deposit allocated precipitation at mechanical treatment stage, or also dehydrated mixture of the listed kinds of deposits.

The analysis of clay deposits raw base of Russian regions has shown excess “resource” of sub-standard mild (adobe) clay raw material, and also overburden, suitable today only for claydite production, marks 400- 600, but which are inexpedient for production from them of light concrete in connection with increased requirements on a heat-shielding. It can be mutual solution for the questions of utilization of the submitted wastages and sub-standard clays.

The theoretical preconditions have all allowed to accept a rule - it is necessary to utilize WWS not only as a wastage, but mainly to utilize effect from a composition of specific additives, contained in them (mineral and organic part, heavy metals, detergents etc.), as bull complex process regulators in order to receive from sub-standard clay raw material and overburden ecologically pure porous aggregate.

The choice of sub-standard clay raw material of an overburden bench of Kalinovo- Dashkovskiy deposit, closely to the city of Serpukhov is provided by a location of opencast on close distance from aeration station. Incoming overburden clay is mean-dispersed, mean-tolerant to drying, it is polymineral and swells up with factor less than 2,8, concerns to mean bloating clay. It’s chemical and complex mineral compositions have caused the reduced bloating interval.

As the additive to the specified raw material was chosen small-dispersed WWS. For dehydration purpose of WWS the mineral coagulants, organic flocculation agents and natural dehydration been used. Furthermore, multicomponent sludge from surface storm drains (SSD) was also used, because it is poorly investigated.
Economical substantiation based the identification of power consumption of claydite production and specific fuel reduction.

3. Results
Presence of the specific additives, composition and the dispersity of deposits renders special influence allowing to lower (by an order of magnitude) their specific resistance, that reduce water content in sludge on average 20,5 - 25%, characterizing plasticizing effect of the additives. The adjusting additives with multicomponent composition are capable to display of plasticizing effect and in fusion mixture, raising up to 23,2 % number of plasticity and improving a number of moulding characteristics.

During furnacing were applied WWS and SSD in amount 15 - 35% and 25 %, which have increased factor of fusion mixture floating up to value 7,14 (for optimal composition), that makes possible transformation of overburden in condition of well bloating up. Two main experimental relationships represent the achievements: dependence of bulk specific weight from roast temperature (figure 1); dependence of endurance test from roast temperature (figure 2).

![Figure 1](image_url)

Figure 1. Relationship of bulk specific weight (kg/m³) from roast temperature (°C) with/without compensate additions:
1 – 100% clay; 2 – 75% clay + 25% wastewater sludge with coagulant; 3 - 85% clay + 15% wastewater sludge from sludge beds; 4 - 75% clay + 25% surface storm drains; 5 - 65% clay + 35% wastewater sludge with flocculants

The temperature effect and time of isothermal endurance for quality of furnacing (figure 3) was in detail studied. The presence of melt composition in WWS allows to lower temperature of furnacing on 90-150°C. Isothermal endurance during 7 minutes gives the decrease of bulk weight to 132- 249 kg/m³ is established in temperature interval 1020-1080°C. Submitted on the figure 3 relationships prove, that the increase of isothermal endurance about 10 minutes has given a stable additional decrease of bulk weight to 129-150 kg/m³ due to combustion of organics contained in sludge in amount 66 %, which have heating value, close to peat. Besides, the complex influence of a number of the additional factors has ensured rather sharp V-figurative change of viscosity with decrease up to 10⁵ Pa*s and subsequent increase up to 10⁸ Pa*s of composition, which at first promoted bloating effect at presence of gas-production, and after that gas-holding of allocated surplus light-end products.

The stabilization of a macrostructure is achieved not by an absolutely ordinary way. It consists in features of compositions, containing particles of a refractory crystal phase, capable with increase of
isothermal endurance time to be dissolved in glass into minimally possible viscosity (up to $10^5$ Pa*s) and to result significant increase of isothermal endurance time. The stable macrostructure, which have been achieved at increase of viscosity and excess gas-production, is characterized by angle 120° between cells of pores, i.e. “multiface” with strong bond and “overthing” walls of pores. Walls structure of pores have uniform thickness, increased flexibility, that interferes with merge of pores and their tearing up, so it allows to receive necessary uniform porosity.

Figure 2. Relationship of endurance test (MPa) from roast temperature (ºC) with/without compensate additions:

1 – 100% clay; 2 – 75% clay + 25% wastewater sludge with coagulant; 3 - 85% clay + 15% wastewater sludge from sludge beds; 4 - 75% clay + 25% surface storm drains; 5 - 65% clay + 35% wastewater sludge with flocculants

Figure 3. Relationship between mean bulk weight of claydite from variables: temperature and roasting time. Data refers to composition of fusion mixture: 75%- clay, 25%- wastewater sludge (WWS) with coagulant.
In order to establish the character of viscosity change due to time of isothermal endurance and in order to analyze stabilizing effect of refractory WWS and SSD impurities the fusion mixture was utilized with: 25% of WWS dewatered with coagulant, and mixture made from 50% of quartz sand and 50% of cullet (broken glass) was taken for comparison. The increase of reaction ability SiO₂ is caused by mutual influence of CaO, law viscosity, presence both ferrous and organic compounds. The stabilization of a macrostructure by the adjusting complex additives and detergents achieved during 10 minutes of isothermal endurance, increase of refractory amount in fusion mixture, acceleration of their transferring in a melt and dual influence of SiO₂. It has an effect for increase of gas-retaining property of a melt, on an optimal site of the curve “viscosity - time”, which has entailed a significant decrease of claydite bulk weight. Melting and formation of crystal component in the fusion mixture which has been heated up more than 1020°C at influence of isothermal endurance time brings in the essential contribution, reducing thermal conductivity to value less than 0,076 W/m°C due to excess of glassphase 80,4-92,2 % at porosity 80-92 %.

The WWS additives, which are homogenous allocated in fusion mixture, influence to the bloating interval, expanding it from 80 up to 150°C, i.e. up to 1,5 times. This extended interval of temperatures or “prolonged fusibility” - is necessary condition for achievement of uniform bloating, for stabilization of a macrostructure and increase of claydite reception reliability of guaranteed properties.

Modified, the polyhedral porous structure has following performances: increase value of porosity and decrease of its size (0,367-0,606 mm) with increase of temperature, decrease of bulk weight. Stability of proceeding processes allows to receive claydite of the required constant characteristics. It is possible to characterize process stability because of the following matters: practically invariable ratio of shallow and average pores in an optimum of temperatures and cymbate (in an interval of technological temperatures) rate of curves due to distribution of pores by sizes. The quality of claydite structure can be estimated follow-up on factors: qualities of a macrostructure, which value more than 3 and saturation of pores by water with minimum value of factor 0,123, also showing about uniform self-contained porosity.

The first skilled - industrial sampling on the basis of laboratory of technical ceramics GP “ELIDAP” of fusion mixture with 25 % mechanically dehydrated with a coagulant WWS has shown, that the given mixture has satisfactory foundry ability (by way of plastic foundry) for reception of strong adobe granules with continuous surface without defects. Due to this, was provided the possibility of claydite bloating increase at roasting with gaseous fuel on an optimal mode. The claydite, obtained on the specified technology from fusion mixture optimal on composition, is characterized by bulk weight of 289 kg/m³, increased more than 75 cycles by frost resistance, increased permissible strength limit, and characterized by reduced on 20-25% in comparison with normative values thermal conductivity 0,079- 0,076 W/m°C. It confirms reliability of the given laboratory research, the optimality of composition and parameters of roasting and makes claydite effective for use in building production and construction purposes.

Expediency of accepted solutions is proved by ecological and economic reasons. The design for real conditions with productivity 135 thousand m³/year showed: power consumption of claydite production is reduced up to 1,61 GJ/m³ (Gega Joule/ m³) in comparison with value 2,17 GJ/m³ for claydite mark 500, which let out production under the traditional way. So, for mentioned productivity nominal power of claydite production shows the reduction trend on 25,8%. Materials consumption set up 400 kg/m³ for claydite mark 200 and 500 kg/m³ for claydite mark 250. Specific fuel consumption set up till 52-62 kg of specific fuel on m³ of claydite, so this value decreased in comparison with traditional value 70- 100 kg of specific fuel on m³ of claydite. So, specific fuel consumption shows the reduction trend on 25,7 – 38,0%.

4. Conclusion
This study demonstrated that usage of various type of sludge as a raw material in the claydite construction product. The potential usage of wastewater sludge in construction materials is an alternative procedure to it’s treatment and disposal, taking in account the enormous cost and
sophistication involved in the treatment. From the economic and environmental view such technical application would provide a complete solution to the waste problem with support to eco-friendly environment and low life cycle cost of described technology.

On the basis of the carried-out research is developed closed-type ecological cycle, which is taking into account features of wastewater treatment and processing of WWS. This allowed to specified traditional technology and to improve production light porous claydite, ecologically pure product. The advantage of an original technological solution consists in reception of useful finished products on base of process wastage, disinfection of MWWS, complete use of ecologically “dirty” mineral component, burial of dangerous and extra hazardous components as the stable form of not collapsing silicates, and recultivation of the ground areas.

Claydite application is possible in production of light concrete on porous aggregate (filler) of the marks up to 600-700 with reduced thermal conductivity up to 0,175 W/m°C. Such a claydite-concrete manages to be received specially working with granulometry of aggregate, utilizing claydite-sand or wastage of dust-ablation.

Claydite can be useful as filtration filler in the stage of advanced wastewater treatment.

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