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Building Properties of Phosphogypsum as a Material of Sludge Dumps of Enclosing Dams

Khomitkhon Fayziev*, Sherzod Rakhimov , Mukhlisa Tashtanova , Yalgashev O. Adkhamova G.

Tashkent Institute Architecture and Construction, Department of hydraulic engineering structures, ground and foundations, 100011 Tashkent, Uzbekistan

ABSTRACT: In the process of production of phosphate mineral fertilizers, industrial phosphogypsum wastes are formed. As is known, the issues of processing and utilization of phosphogypsum on an industrial scale remain unsolved. So, the wastes generated at the chemical plants are stored, as before, in storage tanks of various types. One of the effective ways to reduce the cost of sludge collectors and increase their service life is the use of phosphogypsum for the construction of both primary and secondary dam banking. When studying the physicomechanical characteristics of phosphogypsum, the soil mechanics tools and methods have been used. The article presents the results of a systematic and comprehensive study of the physicomechanical and dynamic properties of phosphogypsum with the aim to determine the possibility of their use as a material for the construction of primary and secondary dam banking of sludge collectors. The main design solutions and technological methods have been developed, the technology for the construction of the dams of sludge dumps from phosphogypsum is considered. The possibility of using phosphogypsum for the construction of fencing sludge dams.

KEYWORDS : Multi-storey and low-rise helio houses, helio-facade, insolation, solar collectors, distances between helio houses, facade shading graphics, building density, yard space, planning structure.

I.INTRODUCTION

In the process of production of phosphate mineral fertilizers, industrial wastes -phosphogypsum - are formed. For each ton of primary product, depending on the raw materials used (apatite or Karatau phosphorus flour) from 4 to 7 tons of waste, respectively, are formed.

There are more than 52 countries in the world, on the territories of which similar dump tanks are located with a total volume of phosphogypsum of about 5.6 - 7.0 billion tons; at chemical enterprises of the CIS countries: in Ukraine - 33.2 million tons; in Kazakhstan - 22 million tons; in Russia more than 200 million tons; in Turkmenistan - 6.6 million tons; in Belarus - 13.1 million tons; in Lithuania - 7.7 million tons. On the territory of our country 55.2 million tons of phosphogypsum are stored in dumps [1,2,3].

As is known, the issues of processing and utilization of phosphogypsum on an industrial scale remain unsolved. So, the wastes generated at the chemical plants are stored, as before, in storage tanks of various types.

The accumulator tanks for the wastes occupy large areas of land, they look extremely unsightly and have a negative impact on the environment.

To create phosphogypsum dumps, it is necessary to alienate large areas, sometimes even cultivated worked lands. Storage of phosphogypsum in dumps, even after neutralizing soluble impurities of phosphogypsum and proper exploitation of the dumps, is harmful to the environment.

The negative impact of phosphogypsum dumps on the environment is manifested in pollution of atmospheric air, groundwater and surface water, soil plant cover by harmful substances leaking through the screen, and as a result, by their washing out with precipitation and dust content. In this regard, recently, the environmental requirements for ecology protection become strict and therefore the problem of rational and efficient storage of phosphogypsum has become one of the most important national economic tasks.

One of the effective ways to reduce the cost of sludge collectors and increase their service life is the use of phosphogypsum for the construction of primary and secondary dam banking.

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II. METHODS

When studying physico-mechanical characteristics of phosphogypsum, soil mechanics instruments and methods are used.[4,5,6,7,8]

Studies on the dynamic properties of phosphogypsum have been carried out using an odometer with dimensions of 20x20x40c[1]m mounted on a vibration stand of horizontal effect. The parameters of dynamic effects varied within the following limits: the amplitude of oscillations — 1–4 mm; oscillation frequency - 2-20 Hz; acceleration - 50-500 cm/s^2, duration of the effect - 5-60s or more. The experiments have been performed with/without load up to 0.1 MPa on the sample surface [9,10,11,12].

III. RESULTS

A. GENERAL INFORMATION

Phosphogipsum is the waste of the phosphor containing mineral fertilization production. It is the highly wet, practically monomineral material of grey-white color. The basic component of the waste is the di-hydratsulphatecalcium (CaSO4*2H2O), which is contained in the limits, of 79-water-soluble part of phosphorous acid (P205) makes up 0,5-1,0; uncrystallized free water - 23-29%. Actually free water got from the waste under pressing is being chemical acid solution.

By its structure, phosphogypsum belongs to the connected materials and by the research datas, the methods of analysys and estimation of connected soil 94% by mass. Phosphogipsumbelongs to the poor soluble salts (till 0,22% in unsalted water). There are also a little rich soluble solts(1,3-1,4%).

Chemical composition of phosphogypsum can be characterized with the next data [2], in per cents per dry substance:

Ca0	32-40	Fe203	0,3-0,4
S03,	46-57	Si02	10-13
P205	1-2	Mg0	0,3-0,5
F	0,3-0,5	H20	37-45
A1203	0,4-1,1	Unsoluble deposition	5-17

materials mechanics can be use

The density of mineral particles of phosphogypsum is in the limits of p=2,3-2,4 tonns/т3. While storing the waste in storages with the height till 50 meters, the density of waste skeleton pd can change in next variations: in initial mellow condition - 0,96-1,0 tonns/m^3, under the activity of its own weight in the lowest zones - 1,25-1,3 tonns/m^3.

Granulometric composition.

Structural particles of phophogypsumbasically have lamellar, pillar-acicular forms, which in wet condition form the small poor connected aggregates and clots. The granulometriccomposition of this waste (after drying, crushing and sifting through standard sieves) could be, introduce with the next datas: d>0,005 mm.-0,1-2,2%, d>0,01 mm - 5-6%, d>0,05 - 72-76% (d - diameter of sieve's hole).

Phosphogipsum permeability is shown by percolation coeficientK_p. The waste's percolation tests depending on density allowed fixing the next average values of $K_p(p_d$-t/m^3; K_p- m/day). We have got the empiric depending: K_p 3,85-2,2pd, which could be used in preliminary values estimation of K_p.

Toughness features of phophogypsum is defined by the angle of internal friction cp and specific cohesion C. Resistivity of material on influence of shear forces can be expressed by thenext dependence $\tau = \sigma tg\varphi + C$, where $\sigma$and τ-normal and tangent tensions. The experiements proved, that values of φ, Cwere raising with the increasing of the phosphogypsum stowing density, and this process mostly exposed in the field of p_d-shown on Picture-1

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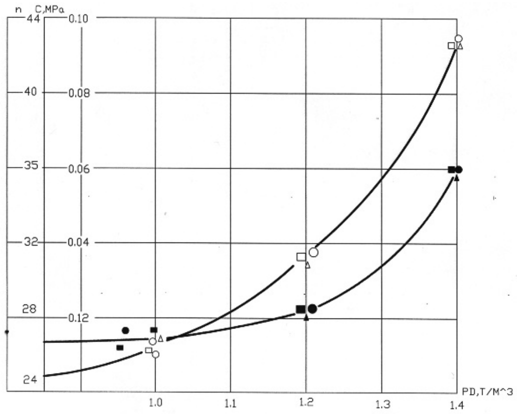
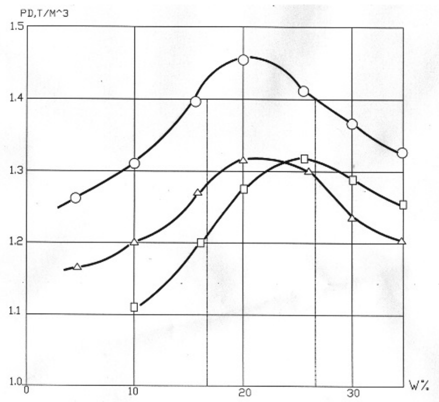


Pic. 1. Changes of values φ and Cwith size growth ρ_d phosphogypsum different types ○,●- otmetytye; □,■-neutralized; Δ,▲-initial.

The increasing of moisture brings to the decreasing of φ, C- values. The three types of studied phosphogypsum - initial, neutralized with limestone's milk and washed from the phosphoric acid; by their toughness features practically has no differences. The summed results of reaserches has shown that in the range of toughness changing 0,9<= p_d<=1,45 tones/$m^3$and moisture changing 14%<=W<=38%, the toughness features of phosphogipsum change in the range $26° <= \varphi <= 44°$ and 0,0<-=C<=0,08MPa.

We can see, that phosphogypsum in stowed condition have big cohesion forces. Due to this, the tearing toughness of phosphogypsumunder tension could achieve to 1,65-1,9 kPa.

Consolidation of phosphogipsum has been studied with the purpose of consideration of their optimal conditions of filling and consolidating fitting constructions of hydro banks - protection dams. The experiments were made with the samples of three above mentioned types of phosphogypsumunder different values of moisture. The results of the experiment are shown on Picture-2



Pic. 2. Compactibility фосфогипсов at the various W.Conditional designations of cm fig. 1

The character of chart changes shows that under the equal work expenses, the best consolidation of phosphogypsum can be achieved in certain range of moisture, whose differences of are not significant for the three types of material. The borders of moisture accepted to call the range of optimal moistures Wop, which can be arranged in the next limits 18-26%.

It is necessary to mark, that the biggest extent of consolidation were achieved by the washed phosphogypsum, meanwhile this factor was approximately equal for the other two types of material too. Due to bigger density factor under the equal conditions, the toughness features of washed phosphogypsum will be more than in two other types.

ISSN: 2350-0328
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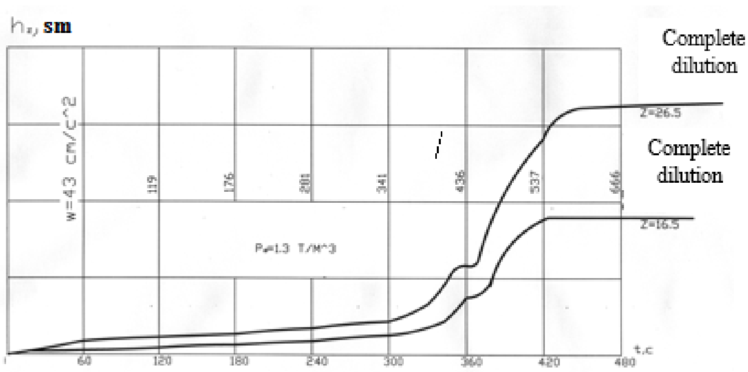
Vol. 6, Issue 7 , July 2019

IV. DYNAMIC FEATURES

While being dynamically influenced, phosphogypsum in moisture-loosened condition is subject to liquefaction with the loosing the lifting ability. Hereupon was, made the special researches of phosphogypsumdynamic features and dams seismic proofing, made from phosphogypsum. The liquefaction process of phosphogypsum, exposed by the appearing the surplus of pore pressured in material (h_Z), develops gradually, causing the partial (local) material liquefaction, without loosing the total lifting ability. The full liquefaction of material happens under achieving for some influence of critical acceleration (ω_{cr}). The dependence of war from density and moisture of phosphogypsum, frequency composition and duration of dynamic influence was studied [10].

As the example on the Picture-3 shows the curves of height changing of liquefied layer of phosphogipsum, with the initial density 1,23, depending on the duration of dynamic influence under two level of acceleration (537 and 665cm/sec^2). Moreover the raising of influence intensity is going the increases the volume of material, being turned into liquefied condition, what can be seen by incensement of surplus pressured hz in pore water.
shown on Picture-3



Pic. 3. Changes of sizesgrowth h_z of valuesω and t

After eliminating the external influence, the structural connections of material restore fast, enough. Herewith the last ones are stowed with more than ever density, before applying the dynamic influence. For recurrent liquefaction of reconsolidated phosphogypsum is required the influence with more intensity, than on preliminary stage. Obviously, that here we have got a case with the material's vibra-consolidation effect. It is established that overloading of experimental samples with vertical loading is being the factor of increasing the phosphogipsum's dynamic stability.

The exploring of dam's fragments behavior on vibraplatform and centrifugal simulation unit allowed to determine, that protecting constructions of hydro banks, phosphogypsum, with the stowing density 1,25-1,3 and material moisture no more than 28%; were having the necessary seismic proofing under earthquake with the 7-9 magnitude.

According to the principle, the sludge dumps can be of fill-in and inwash types [17]. In the first case, the enclosing dams are raised to the full design height and the waste is stored continuously until the storage tank is full. In the second case, the dams are erected in stages with a gradual increase in the tank to the full design height. In this case, the construction and operation of the sludge dumps occurs alternately, i.e. almost simultaneously. It is obvious that the sludge dumps of fill-in type have more complex design schemes and technological conditions of construction than the inwash sludge dumps. This can be seen, for example, from a comparison of the cross sections of sludge dumps; the schemes are shown in Fig.4.

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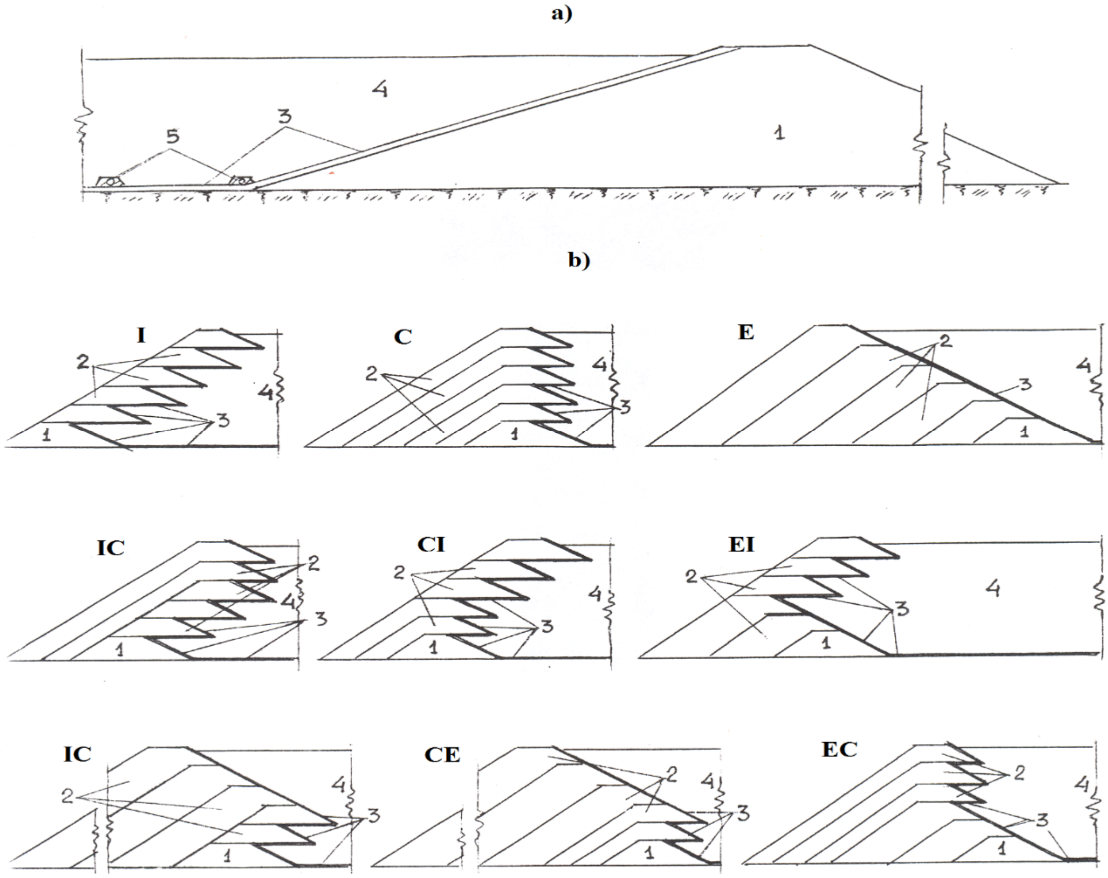

Fig.4. Sludge dumps of fill-in (a) and inwash (b) types: 1-primary dam, 2-secondary dams; 3 -anti-seepage screens; 4-phosphogypsum deposits; 5 - drainage devices

To prevent the penetration of polluted water from the sludge dumps into the base soils and exclude the flooding of the enclosing dams, anti-seepage screens are arranged along the bottom of the reservoir bowl and the internal slopes of the dams. In addition, to reduce the depression curve in the zones adjacent to the dams, annular drainage is provided, which runs along the base of the inner slopes of the dams. In order to dehydrate phosphogypsum deposits on the bottom of the reservoir, systematic or layered drains are arranged, which to some extent reduce the hydrostatic pressure of water on the screens. The removal of clarified waters from the surface of the sludge dumps and filtering waters from the drainage system is carried out using special devices used for these purposes.

In the practice of hydro-waste disposal, various schemes are used for increasing the storage capacity by height, of which the main ones are (6): internal (I), central (C) and external (E). In specific conditions, the combinations of these schemes can be used, such as: internal central (IC), central-internal (CI), external-internal (EI), internal external (IE), central external (CE) and external central (EC), given in Fig. 4[16, 17]. Proceeding from the condition for ensuring the overall stability of sludge dumps at the most compacted dam profiles, the minimum values of the rate of external (external) dam slopes (m_n) have been determined by calculations for these 9 schemes. In the calculations, the following initial data are taken: the total height of the sludge dump is 50m; the height of the primary dam - 10m and of the secondary dam - 3.33 m; the bodies of the dams are not flooded; phosphogypsum properties are: Pd = 1.3 t / m^3, $\varphi = 32^0$ and c = 0.04 MPa in dams and ρ_d = 1.0 t / m^3, $\varphi = 26^0$ and c = 0.02 MPa in the sludge dump; seismic effects intensity is 7-9 points; the standard values of the safety factors are $[K_u] = 1.2$ for main loads and $[K_y] = 1.1$ for special loads.

The results of calculations for the minimum allowable values of the rates of the external slopes of the dams are summarized in Table 3.

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Minimum permissible values of the rate of slope m_H
Table 3.

For a complete comparative analysis and selection of an acceptable option of the development of sludge dumps, along with the data of Table 3, it is necessary to have their technical indices. The results of the determination of the

Indices	Units of meas.	Options of raising the sludge dumps								
		I	C	E	IC	CI	EI	IE	CE	EC
1. The volume of enclosing dams:										
-primary	mln. m^3	1,77	0,34	0,29	1,62	0,84	0,85	0,78	0,77	0,77
-secondary	-//-	3,04	9,42	19,53	6,89	5,75	9,85	14,21	12,32	14,96
2. The volume of waste storage	-//-	37,41	43,81	50,15	42,40	42,46	43,45	47,68	46,57	48,07
3. Efficiency of land use	Thous. t/Ha	270	315	350	295	295	300	330	325	335
4. Duration of waste storage	years	39	45	51	42	43	44	48	47	48

latter are given in Table 4, where the following initial data are additionally adopted in the calculations: the area of the sludge dump section is 144 tonsannual waste yield is 1 million tons (in terms of dry dehydrate).

Technical indices of various schemes for increasing the height of sludge dumps

Table 4

Options for sludge dumps raising	Under main loads	Under main and seismic loads with an intensity		
		7 point	8 point	9 point
I	1,48	1,99	2,41	3,03
C	1,15	1,48	1,63	1,82
E	1,11	1,36	1,46	1,66
IC	1,20	1,45	1,65	2,03
CI	1,34	1,85	2,20	2,74
EI	1,24	1,74	1,92	2,57
IE, CE, EC	1,17	1,39	1,51	1,95

V. USING TECHNOLOGY

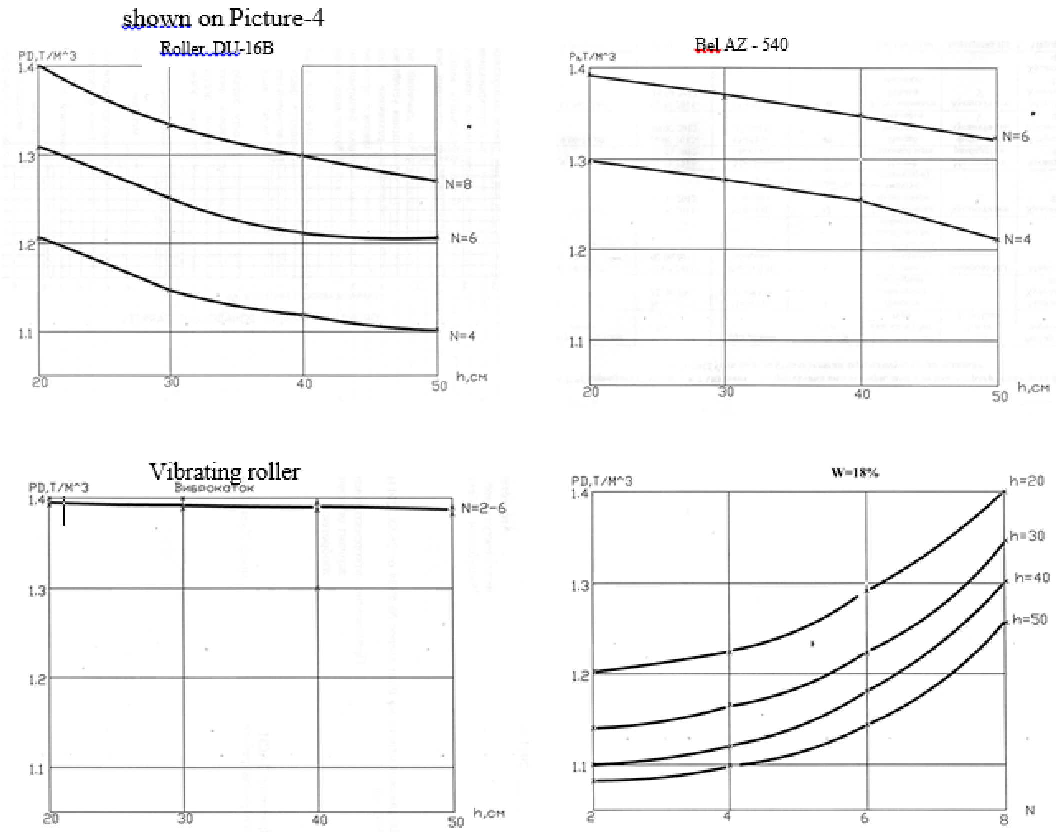
For the construction of storage's protecting dams the using phosphogipsum should have optimal moisture (W_{op}), what provides the high affectivity of its consolidation. If the material to be used has exceeding moisture, it should be dried. If the material's wet conditions are not enough for the optimal moisture content, it is necessary to moisten the material additionally. The dam construction should be done by the method of measuring off by the layers and phosphogipsum's consolidation with the assigned layer height.

For the material consolidation can be used special mechanisms, dump tracks, bulldozers or some other machines.

ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 6, Issue 7 , July 2019

Factors	Levels of factor variations			Intervals of variations
	-1	0	+1	
Optimal moisture (%) weight of consolidating mechanism	17,6 10	21,5 20	25,9 30	3,9 10
Quantity of passes thickness of consolidating layer	4 20	6 35	8 50	2 15

For the optimization parameter was accepted the density factor p_d=1,3 tones/m^3. For the consolidating of variable by their height layers of phophogypsum were used vibraroller with the weight 11,8 tones, smooth roller DU-16B -weight was 21 tones and dump truck BeIAZ-540 - weight was 30 tones (in embarked condition). The results of experiment are shown in Picture_4, where *h* is the initial layer's height (cm) and *N* is the passes quantity by one consolidating trace. The next factors were achieved: rolling density l,1-1,4 tones/m^{3}for the different layer's thickness; toughness conditions of rolled materials φ =28-41 ° and C=0,02-0,045Mpa for the according material density in the experiements [18].



Pic. 5. Results at a skating rink phosphogypsumsystem mechanisms

According to the dates of field explorations we can conclude that under measuring off 30-40 cm height's phosphogipsum and their consolidating till density pd=1,25-1,3 tones/m^3, the protecting phosphogipsum dam with results of experimental rolling in field conditions, at the construction of the Samarkand chemical plant's hydro-bank

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Vol. 6, Issue 7 , July 2019

[17].

The slope giving m=2,5 and more would posses the necessary lifting ability and seismic proofing in the limits, required by standards and norms. Such conclusion could also be subject to calculating inspection of common dam slope's seismic proofing under basic and special (seismic) loadings.

Toxicity. With the purpose to reveal the ecological danger of phosphogypsum, NIUIF NPO "Minudobreniya" (Moscow) carried out special researches of given waste's type. According to their conclusion, the toxic components contained in di-hydratphosphogypsum could not pollute the soil and fauna, exceeding the accepted PDK. Herewith the phosphogypsum waste's storages have negative effect on environment. This negative effect reveals itself on air, ground waters and soils pollution. As a result of dust waste, leakage drains from waste storages by draughts. Project defects, poor quality of building, and bad level of storage's exploitation. Are the reasons of it? Under the condition of eliminating all these reasons it is possible to exclude negative influence of this water to the natural environment.

VI. CONCLUSION

The possibility of using the wastes of phosphorus-containing mineral fertilizers - phosphogypsum - for the construction of the dams of sludge dumps, in seismically active areas as well, has been substantiated.

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