Comprehensive Survey of the Silt Reservoir Structures Technical Condition

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Abstract. The aim of this work is to obtain information about the condition of the sludge tank supporting and enclosing building structures, identifying and fixing existing defects in order to assess their possible impact on structures during its further operation. Archival surveys were carried out, site documentation was selected and studied, load-bearing structures engineering measurements were carried out, building structures were inspected, and the structural condition was photographed selectively, graphic materials were made, technical conclusions were drawn up with conclusions and recommendations for further structures safe operation in order to achieve this goal. The technical surveying included a building structures external examination with damages fixation. The structures general technical condition of the, the presence and nature of the defect’s propagation were previously visually recorded, and then refined using measuring equipment. Verification calculations were also carried out with the design and current load analysis on the sludge tank elements, and the tank supporting structures concrete strength was determined by the ultrasonic method.

1. Introduction
The sludge reservoir is non-residential, operated, underground, designed to pump sludge and to compact activated sludge. The tank has a rectangular configuration. The construction was carried out in a prefabricated solution (except the bottom which is monolithic reinforced concrete). The tank dimensions in the axes are 55.7x27.6 m. The tank has two compartments separated by a reinforced concrete wall. The height from the tank floor to the coating slabs is variable: from ≈ 4.36 m to ≈ 6.38 m to the ribbed slab shelf, from 4.13 m to 6.17 m to the ribbed slab edge. The object has one buried level with a floor mark from -4.36 m to -6.38 m. The depth is variable, from ground level is from ≈ 5.755 m to ≈ 7.795 m. The construction belongs to the 2nd responsibility level. The project was developed in 1961. The sludge tank foundation design was determined on the basis of archival design materials provided. The technical condition was determined by indirect signs - the presence/absence of defects in the surveyed building structures. The foundation is a monolithic...
reinforced concrete bottom. The bottom composition: 2 layers of shotcrete plaster - 20 mm grouting with cement mortar 3-5 mm with ironing, concrete coating (concrete class is B7.5), reinforced concrete slab - 160 mm, cement screed - 20 mm, bitumen coating for 2 times, concrete class is B3.5) - 100 mm, a matting layer, gravel - 100 mm, crushed stone compacted into the ground - 50 mm. The foundations for the columns are glass type, reinforced concrete, the sole sizes in terms are 1100x1090 mm, 1180x1130 mm, 1100x1100 mm, 950x950mm and 550x550 mm. The foundation depth is variable. It ranges from 5.755 m to 7.955 m. Defects and damages were not revealed during the foundation’s inspection by indirect signs. The foundation reinforced concrete bottom and the foundations for the columns are in working condition. The walls are made of precast concrete blocks with dimensions of 4000x2150x(150-250) mm. There are monolithic sections in the tank corners. The tank walls are coated on the inside with shotcrete in 2 layers, treated with a layer of cement mortar 3-5 mm thick on fine sand with a surface grout. The tank walls from the outside are covered with shotcrete plaster in 1 layer 10 mm thick, coated with bitumen for 2 times. Precast reinforced concrete columns have a cross section of 250x250 mm with capitals measuring 400x400x400 (h) mm. The load from the columns is transferred to the bottom through the prefabricated glass type foundations, having an expanded support part with the sole dimensions in terms of 1100 × 1090 mm, 1180 × 1130 mm, 1100 × 1100 mm, 950 × 950 mm and 550 × 550 mm. The columns are installed in a glass on a cement-sand mortar. Manholes with dimensions ≈1230x920x1850 (h) mm are equipped for descent into the tank. The manholes walls are made of monolithic reinforced concrete, the wall thickness is 180 mm. On the axes 10-1 / D, 2-8 / D, 5/A-I, 1-3/A-I, reinforced concrete partitions with a thickness of 100 mm and a height of 1200 mm were installed. The inspection revealed the following defects and damage to walls and columns: concrete chips, leaks traces and mortar leaching, local damages in the stairs, the reinforced concrete partitions dismantling, clamps exposure in the column due to insufficient thickness of the concrete protective layer, destruction of the concrete wall manhole with exposure and reinforcement corrosion. The tank walls are in good technical condition. The coating slabs are in good technical condition. Roof is operated. The roof composition is according to the project on prefabricated reinforced concrete slabs, from top to bottom: soil - 1250 mm, bitumen spread 2 times, the leveling layer of cement mortar - 5 mm, shotcrete-plaster - 20 mm. No defects were found during the inspection. The roof is in satisfactory condition. Single-section metal stairs are installed in the axes 2-3 / A-B, 7-8 / A-B, 10-11 / A-B, 2-3 / I-K, 15-16 / I-K for descent into the tank. The staircase bowstring is an equal-angle corner 75x75x8 mm, the equal-angle corner 70x70x8 mm (in the places of corrosion exposure the angles are up to ≈4 mm), the steps are round steel ø25 mm-ø28 mm (in places of corrosion up to ≈14 mm). Damages in the staircase fastening area, corrosion in the wall zone due to corrosion, metal elements delaminating corrosion were revealed during the technical survey., It was revealed at the measurement sites that, due to the corrosion effect, the individual step rods diameter in the lower stairs part changed from ≈ ø25-28 mm to ≈ ø14 mm, and individual metal stairs were partially dismantled. The sludge tank stairs are in a limited - operational technical condition.
2. Results of verification calculations

Verification calculations for the sludge tank elements were performed with design and current loads on analysis. The coating loads collection is presented in table 1.

| Element                        | Thickness, m | Density, kg/m³ | Standard load, kg/m² | Overload coefficient | Design load, kg/m² |
|--------------------------------|--------------|----------------|----------------------|----------------------|-------------------|
| Soil                           | 1.25         | 1700           | 2125                 | 1.15                 | 2443.75           |
| Bitumen spread 2 times         | 0.01         | 600            | 6                    | 1.3                  | 7.8               |
| Cement and sand screed         | 0.005        | 1800           | 9                    | 1.3                  | 11.7              |
| Sprayed plaster                | 0.02         | 1800           | 36                   | 1.3                  | 46.8              |
| Reinforced concrete slab       |              |                | 394.3                | 1.1                  | 433.7             |
| TOTAL constant, kg/m²          |              |                | 2570.3               |                      | 2943.8            |
| Temporary (snow), kg/m²        |              |                | 126                  |                      | 180.0             |
| Temporary, kg/m²               |              |                | 50                   | 1.3                  | 65.0              |
| TOTAL (permanent + temporary)  |              |                | 2746.3               |                      | 3188.8            |

No defects and damages that reduce the structures bearing capacity were revealed during the sludge tank inspection, as well as on the strength control basis, concrete was not lower than class B20, which confirmed that precast concrete elements strength is not lower than design class B15. The concrete strength obtained during the survey was taken into account. Based on the performed verification calculations for the actually acting loads, it was found that the prefabricated cover slabs bearing capacity is sufficient to absorb the actual loads: coating slabs. \( g_{\text{load}} = 3188.77 \text{ kg/m}^2 < g_{\text{sec}} = 3330.40 \text{ kg/m}^2 \). According to the project, the reservoir was designed for a load of 3340 kg/m², taking into account its own weight; columns maximally loaded. \( N_e = 4101.55 \text{ kg·m} < M_{\text{ult}} = 7557.67 \text{ kg·m} \). Based on the calculations, it can be concluded that the bearing capacity of all tank elements is provided under the existing load, the bearing capacity of all elements of the sludge tank is provided under the existing load. It is prohibited to store, place, install anything on the tank, as well as passing vehicles in order to prevent excess load on the tank structure [36]. Checking a rectangular section of a reinforced concrete beam bearing capacity (Figure 1).

![Figure 1](image_url)

The calculated cross section of the beam slab coating.

The reinforcement in the compressed zone is 2 Ø18. The reinforcement in the stretched zone is 2 Ø12. Design resistance of B20 \( R_0 = 105.3 \text{ kg/cm}^3 \). The working conditions coefficient \( \gamma_{(b,2)} \) is 0.9. The reinforcement design resistance of A240:
Reinforcement elasticity modulus is $E_s = 2,000,000 \text{ kg/cm}^2$. Estimated bending moment in the span is $M = 139987.6 \text{ kg·cm}$. The calculated bending moment on the supports $M = 279975.1 \text{ kg·cm}$. The compressed reinforcement cross-sectional area is $A_s' = 2.26 \text{ cm}^2$. The stretched reinforcement cross-sectional area is $A_s = 5.09 \text{ cm}^2$. The upper reinforcement in the beam center is negligible, and it was performed constructively [1]. The calculation for this case is performed as for sections with single reinforcement:

$$x = \frac{R_s A_s}{R_b} = 7.85 \text{ cm} < \xi_R \cdot h_0 = 26.0 \text{ cm}$$ \hspace{1cm} (2)

$$\xi_R = \frac{0.8}{1 + \frac{R_s E_s \cdot \varepsilon_{b,2}}{E_s \cdot \varepsilon_{b,2}}} = 0.8$$ \hspace{1cm} (3)

$\varepsilon_{b,2} = 5600$. For calculating the rectangular sections of bent elements by the formula $x < \xi_R \cdot h_0$, the section strength is checked from the condition:

$$M_c = R_s \cdot A_s \cdot x \cdot (h_0 - 0.5 \cdot x)$$ \hspace{1cm} (4)

$$M_c = 354118.4 \text{ kg·cm} = 3.54 \text{ t·m} > M = 279975.1 \text{ kg·cm} = 2.80 \text{ t·m}$$ \hspace{1cm} (5)

The bearing capacity in the span is provided, the safety margin is 20.94%.

2.1. The bearing capacity determination of a slab in a span of 1 m wide (rectangular section with a single reinforcement)

Concrete is B20, $R_b = 117 \text{ kg/cm}^2$. The reinforcement is $9\Omega 10$. $R_s = 2434.78 \text{ kg/cm}^2$. $A_s = 7.07 \text{ cm}^2$. $a = 1.5 \text{ cm}$. $h = 12 \text{ cm}$. $b = 100 \text{ cm}$. $h_0 = h-a = 10.5 \text{ cm}$. $L = 348 \text{ cm}$. The calculated section of the slab shelf in the span is shown in Figure 2.

Concrete compressed area height is:

$$x = \frac{R_s A_s}{R_b} = 1.47 \text{ cm}$$ \hspace{1cm} (6)

$$\xi_R = \frac{0.8}{1 + \frac{R_s E_s \cdot \varepsilon_{b,2}}{E_s \cdot \varepsilon_{b,2}}} = 0.636$$ \hspace{1cm} (7)

Relative concrete compressed area height is:

$$\frac{x}{h_b} = 0.14 < \xi_R = 0.636$$ \hspace{1cm} (8)

The condition is fulfilled. Section bearing capacity is:

$$M_c = R_s \cdot A_s \cdot x \cdot (h_0 - 0.5 \cdot x) = 168052 \text{ kgf·cm} = 1680.52 \text{ kgf·m}$$ \hspace{1cm} (9)

$$g_n = \frac{M_c}{L^2 b} = 33340.4 \text{ kg/m}^2 > g_{fr} = 3188.77 \text{ kg/m}^2$$ \hspace{1cm} (10)

The bearing capacity is provided; the safety margin is 4.25%. An additional maximum load on the slab is 141.63 kg/m².
2.2. Checking the eccentrically compressed reinforced concrete sections bearing capacity.

Calculation of the maximum loaded column of the tank.

Concrete is B20, $R_b = 117$ kg/cm$^2$. $E_b = 270,000$ kg/cm$^2$. The reinforcement is 4Ø1.6. $R_s = 2800$ kg/cm$^2$. $A_s = 4.0$ cm$^2$. $a = 2.0$ cm. $l_0 = 435$ cm. $b = 25$ cm. $h_0 = h-a = 23$ cm. $N = 39062.41$ kg·f. Checking the condition $\frac{l_0}{h} = 17.40$ cm $> 4$ cm.

$$e = e_0 \cdot \frac{h}{2} - a = 10.50 \text{ cm}$$

$$\eta = \frac{1}{1 - \frac{N}{N_{cr}}} = 1.45$$

$$N_{cr} = \frac{1.6E_b b h}{(\frac{h}{b})^2} \cdot \left[ 0.11 \frac{11+8}{\eta} + \frac{1}{3} \varphi + \mu \cdot \alpha \cdot \left( \frac{h_0-a}{h} \right) \right] = 125345 \text{ kg·f}$$

$$\varphi = 1.2 \cdot \xi = 0.62068.$$  

Check condition:

$$x = \frac{N - R_{sc} A_s + \sigma_s A_s}{R_b b} = 13.4 \text{ cm}$$

$$\xi = \frac{x}{h} = 0.58 > \xi = 0.62$$

The column bearing capacity calculation is performed according to the formula:

$$N \cdot e \leq R_b \cdot b \cdot x \cdot (h_0 - 0.5 \cdot x) + R_{sc} \cdot A_s \cdot (h_0 - a)$$

$$4101.553 \text{ kg·m} < 7558 \text{ kg·m}.$$  

The condition is satisfied, the section strength is provided. Safety margin is 45.7%.

2.3. Checking the bearing capacity of the outer wall for permanent, temporary and special loads.

Collecting loads and determining internal efforts

The normative permanent and temporary loads in structures were determined taking into account the survey results. The following types of loads were attributed to constant loads: from soils, from the dead weight of the tank structures. The temporary loads included vehicles effects. Special loads and special loads combination from a fire truck were taken into account; the reliability coefficients for loads were taken equal to 1.0, the coefficient for liability is equal to 1.0, the strength materials characteristics were taken equal to their normative values [2-5]. The normative load from the fire engine weight is equal to 36 kPa for each vehicle axle, and evenly distributed load over the passage cover on a site measuring 0.6 x 0.2 m was adopted. the load was applied directly to the outer wall axis and was taken as the most unfavorable position due to the fact that there is no through passage above the tank cover. The calculation results are presented in Figure 3.

Figure 3. Calculation results.
Internal forces in the tank wall: bending moment \( M = 12.3 \text{ kN} \cdot \text{m} \); compressive force \( N = 144.1 \text{ kN} \).

3. Calculation results and discussion

Concrete class is B20, reinforcement is Ø12 А300, protective layer size is 3.0 cm, reinforcement pitch is 150 mm. Reinforced concrete slab is calculated as an eccentrically compressed element. The bearing capacity provision is possible subject to the following conditions:

\[ N \cdot e \leq R_b \cdot b \cdot x \cdot (h_0 - 0.5 \cdot x) + R_{sc} \cdot A_{sc} \cdot (h_0 - A_{sc}) = 81,16 \text{ kN} \cdot \text{m} \]  

(19)

3.1. The eccentric-compressed reinforced concrete elements calculation

The cross-sectional shape of the reinforced concrete element is rectangular, reinforcement is without prestressing. \( M = 12.30 \text{ kN} \cdot \text{m} \) - bending moment from the full external load action. \( N_l = 144.10 \text{ kN} \) - longitudinal force from the full load action. \( b = 100.0 \text{ cm} \) - section width. \( h = 30.0 \text{ cm} \) - section height. \( L = 4,000 \text{ m} \) - element length. B20 - concrete class. \( a_s = 3.0 \text{ cm} \) - the protective layer of the stretched reinforcement. \( a_{sc} = 3.0 \text{ cm} \) - the protective layer of the compressed reinforcement. A300 - tensile reinforcement. A300 - compressed reinforcement. \( A_s = 6.786 \text{ cm}^2 \), is the cross-sectional area of the stretched reinforcement. \( A_{sc} = 6.786 \text{ cm}^2 \), is the cross-sectional area of the compressed reinforcement. \( l_0 = 2,800 \text{ m} \) - the estimated element length. A hinged support at one end and a rigid seal at the other one is a form of supporting the element ends [5-9]. The random eccentricity \( e_a = 1.0 \text{ cm} \). The initial eccentricity of the longitudinal force application is \( e_0 = 9.5 \text{ cm} \). The compressed zone relative height is \( \xi = 0.046 < \xi_R = 0.580 \). The compressed zone height \( x \) is determined by option 1, and \( x \) is 1.3, cm. The distance from the application point of the longitudinal force to the tensile reinforcement gravity center is \( e = 21.6, \text{ cm} \). Strength test is:

\[ N \cdot e = 31.19 \text{ kN} \cdot \text{m} \]  

(20)

\[ R_b \cdot b \cdot x \cdot (h_0 - 0.5 \cdot x) + R_{sc} \cdot A_{sc} \cdot (h_0 - A_{sc}) = 81,16 \text{ kN} \cdot \text{m} \]  

(21)

\[ 31.19 \text{ kN} \cdot \text{m} < 81.16 \text{ kN} \cdot \text{m} \]  

(22)

The strength condition is satisfied. Safety factor \( M_{ult} / M = 2.60 \). The tank wall bearing capacity is provided.

3.2. Concrete strength determination by ultrasonic method. Methodology for determining strength

The reinforced concrete structures strength of is determined by the ultrasonic method using the Pulsar-2.2 device with a universal calibration curve. The concrete class in terms of compressive strength is determined in the ultrasonic method for determining strength by static assessment [10-14]. At least three speed propagation measurements of ultrasound in each direction were made at the test site, the average value in the direction (V) was recorded with the PULSAR-2.2 instrument. The average ultrasound propagation velocity in each section (\( V_m \)) were calculated, according to which, using the universal calibration dependence (\( R = 0.016 \cdot V_m - 27.3 \)), concrete strengths were determined (\( R \), column 5, Table 2). The approximate conditional concrete class on the site is determined by the formula \( B = 0.8 \cdot R \) (V, column 6, Table 2). The concrete test results are presented below in table 2.
Table 2. Results of columns and slabs concrete class determining by the ultrasonic method using surface sounding with the PULSAR 2.2 device.

| No. | Design name | Ultrasound velocity, m / s | Average ultrasound velocity, m / s | Concrete strength, kg / m² | Concrete class |
|-----|-------------|---------------------------|-----------------------------------|---------------------------|----------------|
| 1   | Column      | 3330 3270 3340 3350       | 3323                              | 263,6                     | B20            |
| 2   | Column      | 3330 3320 3340 3330       | 3335                              | 265,7                     | B20            |
| 1   | Floor slab  | 3290 3280 3320 3300       | 3298                              | 259,6                     | B20            |
| 2   | Floor slab  | 3310 3270 3280           | 3320                              | 263,2                     | B20            |

4. Conclusions

Thus, it was revealed on the basis of the analytical work performed to analyze the actual technical condition that the technical condition of the examined sludge tank structure is assessed as a working condition. The exception is metal stairs - the technical condition is assessed as limited-functioning. It is recommended that all metal stairs be replaced with stainless steel stairs. Their technical condition may pass from a limited-functioning to an emergency state in case of failure to comply with the recommendations on the replacement of stairs [15-20]. In addition, verification calculations of the tank elements were performed with an analysis of the design and current load on the elements. No defects and damages that reduce the structures bearing capacity were revealed during the sludge tank inspection, as well as on the strength control basis, concrete was not lower than class B20, which confirmed that precast concrete elements strength is not lower than design class B15. The concrete strength obtained during the survey was taken into account [21-26]. Based on the performed verification calculations for the actually acting loads, it was found that the prefabricated cover slabs bearing capacity is sufficient to absorb the actual loads: coating slabs. $g_{load} = 3188.77 \text{ kg/m}^2 < g_{see} = 3330.40 \text{ kg/m}^2$. According to the project, the reservoir was designed for a load of 3340 kg / m², taking into account its own weight; columns maximally loaded. $N_e = 4101.55 \text{ kg m} < M_{ult} = 7557.67 \text{ kg m}$. Based on the calculations it can be concluded that the bearing capacity of all tank elements is provided under the existing load. Based on the survey results and verification calculations for the possible further reservoir operation, it is recommended to replace metal stairs with stainless steel stairs. It is recommended to restore the protective layer of concrete with increasing adhesion using Penetron technology or a specially developed project in places of the protective layer destruction, including reinforcing bars exposed and corrosion. Also, it is necessary to process walls, columns and slabs with a waterproofing composition. To remove dust and dirt from the surface, prime the crack surface with a special mortar at the crack formation site, expand the crack, rinse the resulting slurry with water under pressure, monitor the crack with mortar mixture with improved waterproofing properties with a trowel or putty knife, and protect the solution from evaporation until it is full hardening or injection crack [25-26]. It is prohibited to store, place, install anything on the tank, as well as passing vehicles in order to prevent excess load on the tank structure [36]. The outer wall bearing capacity for permanent, temporary and special loads is provided.
5. References
[1] Rimshin V, Aralov R 2019 Sustainable regeneration of urban areas (using the example of Moscow renovation program) *E3S Web of Conferences* 110 01011
[2] Merkulov S, Polyakova N, Rimshin V, Kuzina E, Neverov A 2019 Construction building systems protection under emergency exposure *E3S Web of Conferences* 135 02014
[3] Kuzina E, Rimshin V 2019 Experimental and calculated evaluation of carbon fiber reinforcing for increasing concrete columns carrying capacity *E3S Web of Conferences* 97 04007
[4] Kuzina E, Rimshin V 2019 Deformation Monitoring of Road Transport Structures and Facilities Using Engineering and Geodetic Techniques *Advances in Intelligent Systems and Computing* 983 pp 911-919
[5] Varlamov A, Rimshin V, Tverskoi S 2019 A method for assessing the stress-strain state of reinforced concrete structures *E3S Web of Conferences* 91 02046
[6] Rimshin V, Labudin B, Morozov V, Orlov A, Kazarian A, Kazaryan V 2019 Calculation of Shear Stability of Conjugation of the Main Pillars with the Foundation in Wooden Frame Buildings *Advances in Intelligent Systems and Computing* 983 pp 867-876
[7] Kuzina E, Rimshin V, Kurbatov V 2018 The Reliability of Building Structures Against Power and Environmental Degradation Effects *IOP Conference Series: Materials Science and Engineering* 463(4) 042009
[8] Karpenko N I, Eryshev V A, Rimshin V I 2018 The Limiting Values of Moments and Deformations Ratio in Strength Calculations Using Specified Material Diagrams *IOP Conference Series: Materials Science and Engineering* 463(3) 032024
[9] Varlamov A A, Rimshin V I, Tverskoi S Y 2018 The modulus of elasticity in the theory of degradation *IOP Conference Series: Materials Science and Engineering* 463(2) 022029
[10] Krishan A L, Rimshin V I, Astafeva M A 2018 Deformability of a Volume-Compressed Concrete *IOP Conference Series: Materials Science and Engineering* 463(2) 022063
[11] Varlamov A A, Rimshin V I, Tverskoi S Y 2018 The General theory of degradation *IOP Conference Series: Materials Science and Engineering* 463(2) 022028
[12] Rimshin V, Kuzina E 2019 Laboratory Tests Analysis of Reinforced Concrete Structures Strengthened with CRFP *IOP Conference Series: Materials Science and Engineering* 661(1)
[13] Kuzina E, Rimshin V, Neverov A 2019 Reserves and exposure assessment of reinforced concrete structures safety while reducing its power resistance *E3S Web of Conferences* 135 03010
[14] Kuzina E, Rimshin V, Neverov A 2019 Residual resource of force resistance to deformation *E3S Web of Conferences* 135 01069
[15] Kuzina E, Rimshin V, Neverov A 2019 Residual resource of power resistance during building structures deformation *E3S Web of Conferences* 135 03009
[16] Krishan A L, Rimshin V I, Troshkina E A 2018 Strength of Short Concrete Filled Steel Tube columns of Annular Cross Section *IOP Conference Series: Materials Science and Engineering* 463(2) 022062
[17] Telichenko V, Rimshin V, Kuzina E 2018 Methods for calculating the reinforcement of concrete slabs with carbon composite materials based on the finite element model *MATEC Web of Conferences* 251 04061
[18] Telichenko V, Rimshin V, Eremeev V, Kurbatov V 2018 Mathematical modeling of groundwaters pressure distribution in the underground structures by cylindrical form zone *MATEC Web of Conferences* 196 02025
[19] Rimshin V I, Labudin B V, Melekhov V I, Orlov A, Kurbatov V L 2018 Improvement of strength and stiffness of components of main struts with foundation in wooden frame buildings *ARPN Journal of Engineering and Applied Sciences* 13(11) pp 3851-3856
[20] Rimshin V I, Varlamov A A 2018 Three-dimensional model of elastic behavior of the composite *Izvestiya Vysshikh Uchebnykh Zavedenii, Seriya Teknologiya Tekstil'noi Promyshlennosti* 2018-January (3) pp 63-68
[21] Rimshin V I, Pudova A A, Shubin L I 2018 Evaluation of efficiency of use of photoelectric systems at operation of a residential house Izvestiya Vysshikh Uchebnykh Zavedenii, Seriya Tekhnologiya Tekstil'noi Promyshlennosti 2018-January (3) pp 287-293

[22] Varlamov A A, Rimshin V I, Tverskoi S Y 2018 Security and destruction of technical systems IFAC-PapersOnLine 51 (30) pp 808-811

[23] Cherkas A, Rimshin V 2017 Application of composite reinforcement for modernization of buildings and structures MATEC Web of Conferences 117 00027

[24] Telichenko V I, Rimshin V I, Karelskii A, Labudin B V, Kurbatov V L 2017 Strengthening technology of timber trusses by patch slabs with toothed-slab connectors Journal of Industrial Pollution Control 33 (1) pp 1034-1041

[25] Erofeev V, Kalashnikov V, Karpushin S, Rodin A, Smirnov V, Smirnova O, Moroz M, Rimshin V, Tretiakov I, Matvievskiy A 2016 Physical and mechanical properties of the cement stone based on biocidal Portland cement with active mineral additive Solid State Phenomena 871 pp 28-32

[26] Rimshin V I, Kuzina E S, Shubin I L 2020 Analysis of the structures in water treatment and sanitation facilities for their strengthening Journal of Physics: Conference Series 1425(1) art. 012074