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Technology to restore design parameters of irrigation pump discharge pipelines

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Abstract. The article discusses the restoration of irrigation pump station discharge pipelines' design parameters, based on sand-cement anticorrosion shotcrete coating technology. Repair of created cracks, damages during operation, and restoration of design parameters of discharge pipelines is performed using shotcreting with Kalmatron® (USA) additive. Besides, paper theoretically validates optimal design data of restored discharge pipelines, the thickness of the anticorrosion coating, and their influence on working characteristics of irrigation pump stations. Theoretical and applied tasks are resolved based on the practical implementation of foreign technology, local supplies, and the use of the Company's standards at water facilities throughout Uzbekistan's irrigation systems developed and implemented by the authors of this article.

1. Introduction

It is well known that pump station discharge pipelines are subject to failure due to constant power outages, chemical corrosion, erosion and abrasion in the inner walls of the pipelines, and metal fatigue. Currently, due to the lack of funding many pump stations are being forced to be repaired by welding of new metal sheets from the inside and outside of discharge pipelines to already cracked and weak pipelines. Not only this method is costly, but it still results in the loss of design parameters of the pipeline. It has been determined that to restore the design characteristics of the pipeline and to eliminate defects in the steel the most cost-effective and long-term solution to this problem is the use of monolithic concrete structure throughout the pipeline. To that end, existing pump station conditions have been studied in developed countries, such as the USA, Germany, and South Korea. Long-term and economical maintenance of existing discharge pipelines, their modern repair methods were examined. Modern technology and their implementation of water resource facilities were also studied.

It had been determined, that shotcrete coating with additive Kalmatron® (USA) is widely used in the design of pump station discharge pipelines, especially in the United States of America, with DN of 800-3000 mm. Shotcrete applied with Kalmatron® (USA) additive plaster consists of sand and cement mixture, can be applied to existing concrete and steel discharge pipelines provide increased strength to structures, durability to pipelines against water surges and vacuum, corrosion resistance. Due to it's capillary action, shotcrete with Kalmatron® (USA) additive can be applied to rusty metal surfaces.



2. Method

Over the last several years multiple discharge pipelines have been repaired using this method. Multiple pump stations – Ulugnor in the Andijan region, Isfairam-Shahimardon in Fergana region, Yangikurgan-4 in Namangan region, and Arnasay in the Jizzakh region that were under immediate risk of pipeline failure had seen tremendous success after applying shotcrete with Kalmatron® (USA) additive.

As a result of successful results of Arnasay pump station discharge pipeline #2 restoration works done using shotcrete with Kalmatron® (USA) additive large-scale nation-wide introduction of this technology was granted.

Shotcrete technology is a method of spraying cement-sand-water mixture with additives under compressed air in single or multiple layers to the surface. As a result, compared to regular concrete high mechanical strength shotcrete with abrasive resistance of surfaces, with high penetration to the applied surface (especially rusty surface) is achieved. Newly applied shotcrete has sufficient initial adhesion to even the vertical and circular surfaces, without the need for scaffolding. It is not difficult to deliver the material to the place of application as it is pumped through rubber hoses not only to wide-open areas but also too tight, confined spaces as well.

3. Results and Discussion

Initial trials on the internal shotcrete application to pipeline surfaces were carried-out at the Tashkent city work site of Zarbuloq Injiniring Ltd. Experiments were carried out based on the improved methodology suggestions by TIAME in line with the requirements developed by Zarbuloq Injiniring Ltd. for turbine surface coating.

The following mix-design was used for dry mix shotcrete with the addition of Kalmatron® (USA) additive:

- Portland Cement 400 – 400 kg.
- Washed sand, 0-5 grain size – 1670 kg, in accordance with State standart 8736-93.
- Kalmatron® (USA) additive – 10 kg.
- 1.0 kg basalt fiber per TU 64-16625423-01:07 was used.

The Allentown PC10 (USA) concrete mixer was used to make a shotcrete plaster with Kalmatron® (USA) additive. The nozzle from the USA was attached to a cart to spray the plaster. The concrete pump delivered plaster to the nozzle by the material hose. Compressor MZB 4V-3.0 / 10 (China) with the capacity of 3.2 m³/min delivered air to the nozzle to spray the shotcrete layer to the discharge pipeline.

For trial runs to determine the efficiency of the shotcrete layer pipeline with the DN of 1420 mm and length of 2000 mm and 6000 mm was used. For this experiment after cleaning the inner surface of the pipe with the rusty metal brush (Fig.1), the first layer of the pipeline was reinforced with the thickness of 10.0 mm.



Figure 1. DN1420 mm pipe before shotcreting

After about 25-30 minutes of technological break, the first shotcrete layer obtained structural strength, the second layer with the final thickness of 20 mm was applied.

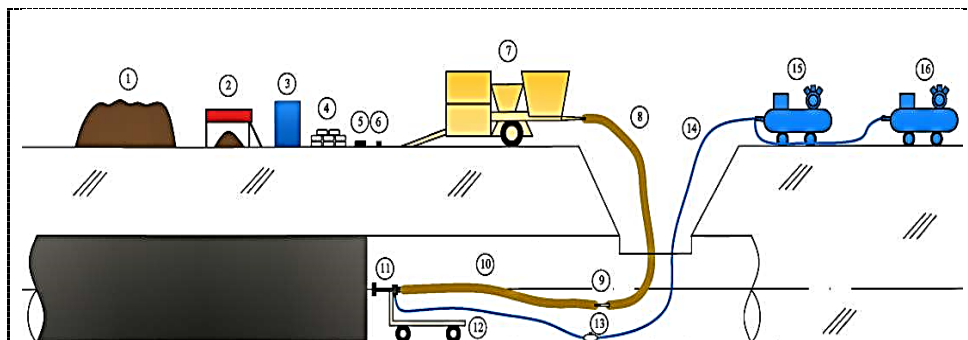


Figure 2. Schematic drawing of a work place to shotcrete DN 1020 mm – 2400 mm pipelines with Kalmatron® (USA) additive

1 – washed sand with 1-5 mm diameter fraction size; 2 – sieve; 3 – water tank; 4 – portland cement 400; 5 – kalmatron® (USA) additive; 6 – Fiber. 7 – shotcrete mixer. 8 – material hose. 9 – material hose connector. 10 – discharge pipeline. 11 – nozzle. 12 – cart. 13 – air de-oiler and dehumidifier. 14 – air delivery hose. 15, 16 – compressors.

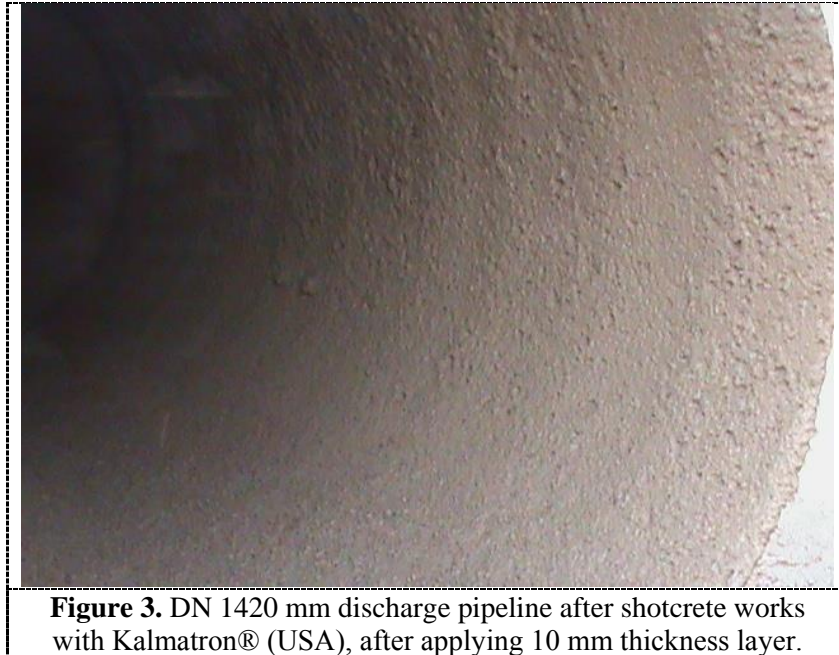
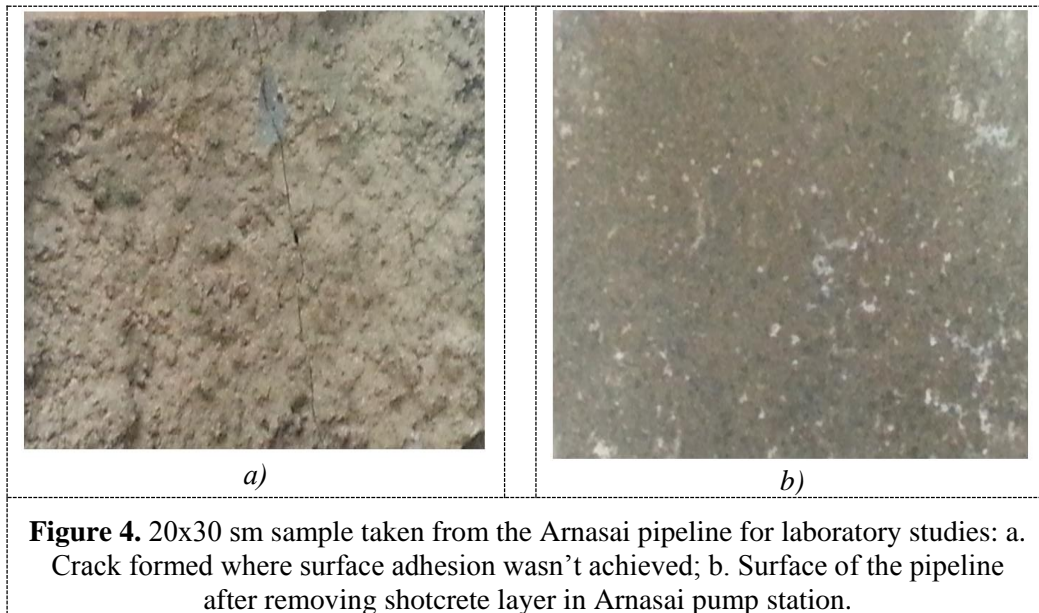


Figure 3. DN 1420 mm discharge pipeline after shotcrete works with Kalmatron® (USA), after applying 10 mm thickness layer.

As a result of visual inspection of the thickness of the shotcrete layer with Kalmatron® (USA) additive during the initial testing application, it was noticed that shotcrete nozzle and its cart had trouble uniformly applying same thickness throughout the pipe circumference due to centrifugal motion.

According to GOST 8736-93 for hydraulic concrete, the maximal grain size of the crushed sand should not exceed 0-5 mm. However, delivered sand had large rocks, and proper sieve was not used to clear large rocks out. During shotcrete spraying process shotcrete spraying nozzle rotates at about 1,000 to 1,500 revolutions per minute (RPM). Large-sized rocks that are greater than 5 mm would leave the nozzle at a high velocity to leave a mark on a newly applied shotcrete layer, effectively damaging it. As a result, some local thickness reduction in a newly applied shotcrete with Kalmatron® (USA) additive was observed (Figures 3, 5a).

After a successful trial run and some modifications very first shotcrete application was performed in Arnasai cascade pump station two out of six DN 1020 mm discharge pipelines were a success. One year operational observation proved the effectiveness of shotcrete application with Kalmatron® (USA) additive in practice as no pipeline failure or accident was observed. It is since shotcrete with Kalmatron® (USA) additive at 7 – 15 mm thickness (applied evenly) added an extra layer of protection to the pipeline.



The experiment also showed some limitations of the nozzle and the cart, as it was mostly designed to apply to DN 1020 mm pipelines. For larger sized pipelines with the DN of 2400 mm, the larger-sized nozzle can be used, but it cannot fit the cart due to its poor design, and it gets increasingly difficult to maneuver it at vertical slopes.

At Arnasai pump station discharge pipeline No. 2 rehabilitation with shotcrete, the internal surface was reduced by 20 mm. To evaluate its effect on the hydraulics of the pump station, all the loss factors were evaluated: leakage from cracks before repair works, loss of pipe diameter, pipe material, length, and water flow through the pipeline. Total head loss $\sum h_{lose}$ was calculated along the total length of the pipeline.

$L_k=1,1L$; m,

Where: length of pump unit 6 of the pump station 2, is 320 m:

$$\sum h_{lose} = \lambda \frac{L_k}{D} \cdot \frac{v^2}{2g} \quad (1)$$

where: λ is the hydraulic resistance coefficient, m^2/sec ;

D is the pipeline internal diameter, m;

g is the acceleration of free fall, m/sec^2 ;

v is the average water velocity in the pipeline, m/sec.

The hydraulic resistance factor depends on the pipe diameter and the smoothness of the inner wall. Its value is derived from references or estimated by the following formula.

The average velocity of water in the pressure pipe:

$$v = \frac{4 \cdot Q}{\pi \cdot D^2}; m/s \quad (2)$$

where, Q is the pipeline flowrate, m^3/s ;

We estimate the pipeline wall roughness equivalent from the table: for old pipelines $\Delta ekv = 0.1-0.15$; for shotcreted pipes $\Delta ekv = 3-9$.

We calculate the Reynolds number by the following formula:

$$R_e = \frac{v \cdot D}{\nu}; m/c \quad (3)$$

Knowing Reynold's number Re and the pipe wall equivalent roughness, this value is 100 for 4.91 shotcreted pipes.

$$10 < Re \frac{\Delta_{equivalent}}{D} < 500$$

so we have a transition zone (for shotcreted pipes).

It is advisable to use the A.D. Altshula formula for transition zones:

$$\lambda = 0.11 \left(\frac{\Delta_{equivalent}}{D} + \frac{68}{Re} \right)$$

It was calculated 0.0227 for steel pipes, and 0.028 for shotcreted pipes.

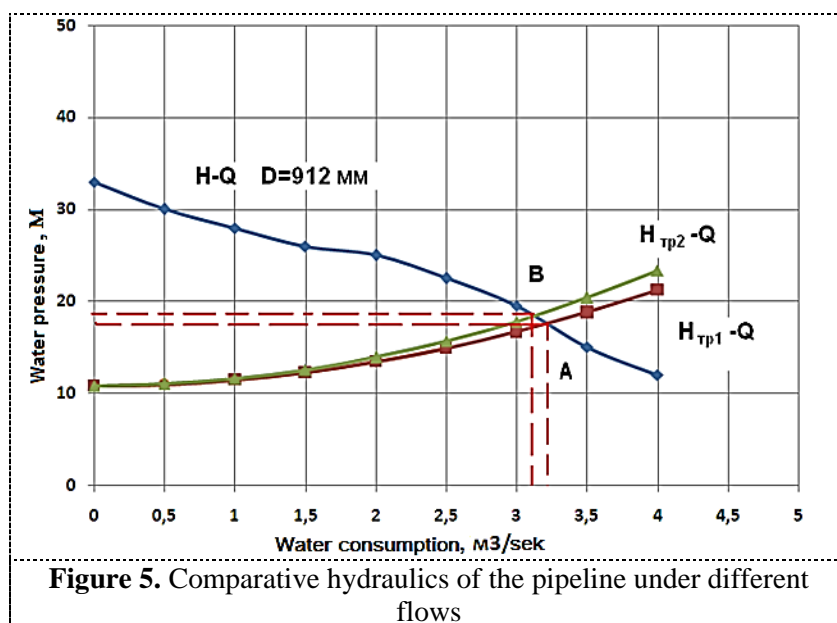
The results of the calculations are shown in Table 1, and the graph shows the change in pressure depending on the water flow rate (Figure 5).

Table 1. Hydraulic of the metal pipeline

$Q, m^3/c$	$V, m/c$	Nm	$\sum h_{lose}, m$	H_{tr}
0.00	0.00	10.8	0	10.8
0.5	0.612209	10.8	0.150	10.95
1	1.224419	10.8	0.599	11.40
1.5	1.836628	10.8	1.347	12.15
2	2.448838	10.8	2.394	13.19
2.5	3.061047	10.8	3.741	14.54
3	3.673256	10.8	5.387	16.19
3.5	4.285466	10.8	7.333	18.13
4	4.897675	10.8	9.577	20.38

Table 2. Hydraulics of partial metal and partial shotcreted pipe

Steel part				Shotcrete part				$\sum h_{loss}, m$	H_{tr}
$Q, m^3/s$	$V, m/s$	Length, m	$\sum h_{lose}, m$	$Q, m^3/s$	$V, m/s$	Length, m	$\sum h_{tr}, m$		
0.00	0.00	145	0.0	0.00	0.00	175	0.0	0	10.8
0.5	0.612209	145	0.068	0.5	0.637	175	0.111	0.179	10.979
1	1.224419	145	0.272	1	1.274	175	0.446	0.718	11.518
1.5	1.836628	145	0.612	1.5	1.911	175	1.003	1.615	12.415
2	2.448838	145	1.088	2	2.548	175	1.783	2.871	13.671
2.5	3.061047	145	1.701	2.5	3.185	175	2.786	4.487	15.287
3	3.673256	145	2.449	3	3.822	175	4.012	6.461	17.261
3.5	4.285466	145	3.333	3.5	4.459	175	5.461	8.794	19.594
4	4.897675	145	4.353	4	5.096	175	7.133	11.486	22.286



As can be seen from the abovementioned graphs A point corresponds to the parameters of the steel pipeline before shotcreting, and B point shows pipeline after shotcrete works with Kalmatron® (USA) additive have been done. The actual flow rate has been reduced by about 0.1 m³/s and the manometric pressure dropped by about 1-1.5 m (Figure 5).

4. Conclusion. After the first field test of shotcrete works with Kalmatron® (USA) additive in the Arnasai pump station discharge pipeline sample size 20x30 cm was cut for observations of its surface adhesion and laboratory analysis. Upon visual examination of shotcrete coating, it was observed that rusty metal surface and spiral welding pipeline seam marks were transferred to the shotcrete layer, penetrating the inner surface through capillary action, which formed monolithic not only physical but also chemical shotcrete-steel bond that is also waterproof (Figure 4a).

1. The result of the experiment and analysis (Tables 1 and 2) show that the shotcrete layer with uneven surface roughness for the total length of 175 meters has a total pressure loss of $\sum h_{loss} = 1.909$ m, as a result of relative reduction of pipeline inner diameter (by 15 mm).

2. For the large-scale introduction of this new technology, so far only one standard document (quality control) was developed – calibration standard – 2019, for the use of shotcrete with Kalmatron® (USA) additive in discharge pipelines has been developed. However, the development of other quality control documents continues (5). In close cooperation with specialists from Zarbuloq Injiniring Ltd. and TIAME scientists who introduced this technology to Uzbekistan widespread use of this technology is underway, and accredited testing laboratories continued in 2019, but results are not enough.

3. It has been determined that Kalmatron® (USA) additive reinforces the shotcrete layer, precast concrete, and reinforced concrete structures. It has also shown great waterproofing ability in hydraulic structures and the formation of protective coating on metal surfaces as well.

References

- [1] A R Muratov 2010 *The study of the costs of working time and the operating mode of the mechanized unit in the repair and construction and construction works on reclamation systems and structures using photo-timing monitoring* Republic scientific and practical. Conf. “Effective

- use of water resources in agriculture and current problems of improving the reclamation state of land” Tashkent 192-201.
- [2] O A Muratov A R Muratov 2010 *Calculation and research method of designing production standards for construction and land reclamation machines in the production of mowing collector - drainage channels from coarse vegetation* Republic scientific and practical. Conf. “Efficient use of water resources in agriculture and current problems of improving the reclamation state of land” Tashkent 201-216.
- [3] A R Muratov O A Muratov 2010 *Calculation and analytical method of designing and checking technically sound time standards in the repair and construction and construction works on reclamation systems and structures* Republic scientific and practical. Conf. “Effective use of water resources in agriculture and urgent problems of improving the reclamation state of land” Tashkent 216-235
- [4] A R Muratov G L Firlina 2007 *Organization and technology of irrigation and drainage works: Textbook-T.:* Publishing House of the National Society of Philosophers of Uzbekistan 160 p with il
- [5] Kamyshentsev L A *New progressive reclamation machinery and equipment* L 1978
- [6] Kamyshentsev L A Kazakov V S Sokolov Y A 1977 *New reclamation equipment* M: Rosselkhozizdat 184 p
- [7] Kamyshentsev L A Novikov V P Petrov L N and others 1982 *Mechanization of repair and maintenance of irrigation systems* L Kolos 192 p
- [8] Korzhevsky A N 1978 *Repair work on drainage systems* M "Kolos"
- [9] Maynulov Y G and others 1973 *Prospects for the development of machinery for the construction and maintenance of reclamation systems* Moscow
- [10] 1979 *Methodological provisions for the development of initial technical requirements for the creation of construction and road vehicles, equipment, special vehicles and mechanized tools* M.: VNIISstroy Dor Mash 15 p
- [11] Pulatov U Y 1977 *Fundamentals of mechanization of irrigation and drainage works in the irrigation zone.* M: Kolos 112 p
- [12] 1982 *Recommendations for comprehensive mechanized care of the channels passing in the earthen channel* Novocherkassk: Workprint of YuzhNIIGIM **42**
- [13] Tomin E D Gatman V G Kopiev E I 1968 *Mechanization of work on the arrangement and operation of reclamation channels* M: Kolos
- [14] Construction industry T Z 1989 *Labor organization and mechanization of work* Ed Onufrieva I A M Stroyizdat
- [15] 1988 *A system of machines for the comprehensive mechanization of agricultural production for 1986-1995. Part III, Meltration.* Moscow
- [16] 2015 *Ways to increase the reliability of pressure pipes of pumping stations.* Proceedings of the international scientific-practical conference "Problems of increasing the efficiency of electricity use in the agricultural sector." Tashkent pp 91-93.
- [17] A R Muratov PhD Assoc I Zh Khudaev PhD Assoc 2015 *Method of rehabilitation of pressure head pipelines of pumping stations and defects in hydraulic structures* Collection of Articles of the Republican Scientific and Technical Conference on "Melioration of Irrigated Land and Problems of Efficient Use of Water Resources" Tashkent pp 466-469
- [18] ShNK 5.01.23-08, sbornik **23** 2008 *“Tipove norm rasxoda tsementa dlya prigotovleniya betonov sbornyx i monolitnyx betonnyx, jelezobetonnyx izdeliy i konstruksiy” / Goskomarxitektstroy RUz-Tashkent* 30 p
- [19] Kiselev P G and etc *Handbook of hydraulic calculations* M Energy 1974 312 p
- [20] Technical Specification No. Ts 23330562-001: 2019 Uzbekistan Standard. "Protecting and restoring the surface tension of the pressure tube"