THE REHABILITATION OF PIPE NETWORK FROM SPRINKLER IRRIGATION PLOTS

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Abstract

The paper presents an analysis of the rehabilitation directions for the pipe network from irrigation plots used for aspersion watering. The rehabilitation and modernisation of the pipeline network is differentiated on the structural components: main pipelines - secondary - distribution, hydrants, hydraulic installations, anchorage blocks, undercrossing, overcrossing etc. The case study was drawn up for an sprinkler irrigation plot network, Doniceasa-Falciu Plot 7, Vaslui County. Tertiary irrigation pipes are fed by single-line pumping stations located in the canal. The discharge pipe of the pumping unit is made of 200 mm diameter steel. The tertiary irrigation pipe with a length of 1020-1400 m is made of asbestos and PVC-G with decreasing diameter from 200 mm to 125 mm for Q = 70-95 l/s and P = 6,50 - 7,50 bar. The pipeline has irrigation hydrants with diameters of 100 mm and 150 mm. The rehabilitation process of the pipeline network is based on a hydraulic and resistance calculation abstracts. The paper presents rehabilitation options for the pipes from the sprinkler irrigation plot.

Key words: single-line pipes, hydrant, design, hydraulic installation, rehabilitation options

The agricultural land ownership modifications after 1990 caused a continuous degradation of irrigation systems. Only part of the sprinkler irrigation plots established 30-40 years ago are still operated. At the present stage, the sprinkler irrigation plots which were part of large irrigation and drainage facilities are used the most. Most of these were executed during 1967-1985.

A number of irrigation systems have been fitted for mixed watering (furrow irrigation and sprinkler irrigation). The aspersion watering is currently mainly practiced. The irrigation plot was designed for two pumping units equipment options: a - plot equipped with a pumping station for raising the pressure (SPP encoded); b - plot fitted with single-line pumping stations (SPPM encoded), where the pumping station supplies a single irrigation water distribution pipeline. The SPP in the first option supplies a network of buried pipes designed for high pressures (7.0 - 8.0 bar) which irrigates 1200 - 2000 ha. In the second option, the pumping stations are located on the supply canal and supply a single high pressure tertiary irrigation pipe (6,5…8,0 bar). The irrigation systems from both options distribute water through aspersion wings. The first equipment option has a sub-case where two types of watering (aspersion + furrows) can be applied. The irrigation plot in this option has two pipe networks: the first network is for aspersion watering (high pressure, P = 8-9 bars); the second pipe network is for furrow watering (low pressure, P = 4.0 bar).

Irrigation plots in service exhibit significant physical wear and aging phenomena of the structure and hydraulic installations. At the same time, aspersion watering equipments have technically changed, having technological parameters which cannot be correlated with the current structure of the distribution pipeline network. Irrigation plots must be included in structural rehabilitation programs: pumping station / stations, pipeline network under pressure, pipeline constructions, power supply system, hydraulic shock protection installations, monitoring and automation system for the operational process, access roads and traffic, etc.

MATERIAL AND METHOD

The case study was drawn up for an sprinkler irrigation plot located in the „Albiţa – Fălciu Complex Facility" Vaslui County. The irrigation plot 7 is located at the southern boundary of Satu Nou - Berezeni village, Berezeni commune, Vaslui County (Luca M., 2015). The total irrigated area within the plot is 1222 ha. The irrigation system was designed by I.S.P.F. Bucharest in 1977 and was executed between 1977 and 1980.

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Figure 1 **Location of Doniceasa – Fălciu Irrigation Plot 7** (Google earth image)

The irrigation plot is exploited by O.U.A.I. Doniceasa - Fălciu (single-line pumping stations + internal pipeline network) in collaboration with ANIF, South Moldova Territorial Branch, Vaslui Administrative Unit (water supply from Prut River with main pumping stations and supply canals) (Luca M. 2015).

In order to obtain irrigation plot rehabilitation data, technical expertise has been carried out. The technical expertise analysed the current state of the constructive and functional structure of the pipeline network and pumping station after a 35-40 year service period. The technical expertise has analysed the current structural and functional state of the pipeline network constructions; chambers with hydraulic installations, supply canals and drainage canals overcrossings, anchorages blocks, etc.

The functional state of the pipelines was analysed by checking the admissible operational time, water flow conveyance at the designed pressure, the number of damages recorded, the degree of silting, etc.

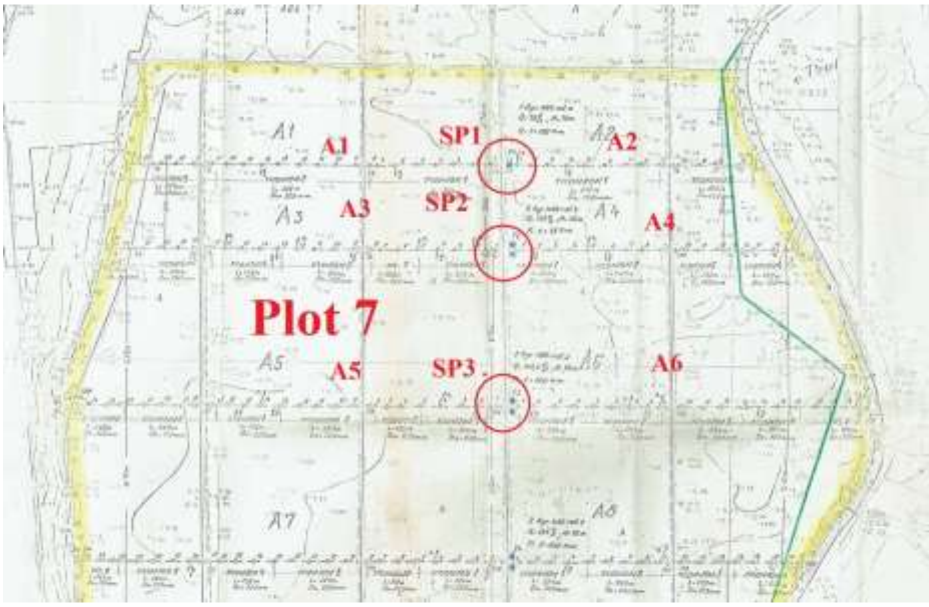

Figure 2 **Doniceasa – Fălciu Irrigation Plot 7 site plan (North area) for the designed version (Luca M., 2016)**

Figure 3 **Detail on the state of pipe sections made of asbestos tubes (damage to joints, tube breaks) (Luca M., 2016)**

The current status of the hydrants was analysed by checking the admissible operational time, structural integrity, water emission at the designed pressure, the number of damages recorded, etc. The pipe network chambers were analysed in regard to the structural condition and the state of the hydraulic installation (Luca M., 2016).

RESULTS AND DISCUSSIONS

The Albiţa-Fălciu irrigation system was designed by ISPIF Bucharest in 1977. The irrigation system was carried out between 1977 and 1978. From 1978 until 1989 the irrigation system was in permanent operation. From 1989 until 2006, the components of the irrigation system were partially operated or in conservation. Doniceasa-Fălciu irrigation Plot 7 was in permanent exploitation between 2006 and 2016.

The layout of Plot 7 covers 1222 ha and is supplied with water by the CSD82 canal connected to the CA5 canal (*figure 2*). Irrigation water is taken from Prut River with the reversible pumping station SRP4 Berezeni and introduced into the CA5 canal. Irrigation plot 7 Doniceasa - Fălciu was designed for watering by aspersion and the sizing was done for watering equipment used in the 1980s (IIAM-17 watering installations). The operation used two watering installations batteries, which imposed operational flows and pressures.

From the CS82 secondary canal, eight SPPM are supplied, in which there are 15 6NDS / RDN type electropumps with the following parameters Q = 270 m^3/h, H = 70 m, n = 3000 rpm, P = 110 kW). One or two tertiary irrigation pipes are supplied by a pumping station equipped with one or two 6NDS / RDN electropumps (Luca M., 2016).

Plot 7 consists of 8 singe-line pressurising pumping stations (SPPM 7/1-7/8) and 16 tertiary irrigation pipes (Luca M., 2015, Luca M., 2016):

- A1 and A2 pipes are supplied from SPPM 7/1 equipped with a 6NDS electropump;
- A3 and A4 pipes are supplied from SPPM 7/2 equipped with two 6NDS electropumps;
- A5 and A6 pipes are supplied from SPPM 7/3 equipped with two 6NDS electropumps;
- A7 and A8 pipes are supplied from SPPM 7/4 equipped with two RDN / 6NDS electropumps;
- A9 and A10 pipes are supplied from SPPM 7/5 equipped with two RDN / 6NDS electropumps;
- A11 and A12 pipes are supplied from SPPM 7/6 equipped with two RDN / 6NDS electropumps;
- A13 and A14 pipes are supplied from SPPM 7/7 equipped with two RDN / 6NDS electropumps;
- A15 and A16 pipes are supplied from SPPM 7/8 with two RDN / 6NDS electropumps.

Pumping unit discharge pipes are made of 200 mm diameter steel. Tertiary irrigation pipes for hydrants are made of asbestos and PVC-G. The pipe diameter decreases from 200 mm to 125 mm for conveying an initial flow rate of 70-95 l/s at a pressure of 6.50 - 7.50 bar (*table 1*). Tertiary irrigation pipes have lengths of 972 - 1720 m and are located at distances of 325-350 m from each other (Luca M., 2016). The pipes can be supplied alternately from the SPPM to which they are connected. Hydrants with 100 mm diameter are placed on the tertiary irrigation pipes at intervals of 72 m between them, except for the upstream hydrant which is located at 36 m from the end of the pipeline. Hydrants supply classic watering equipment. Hydrants may have drainage and ventilation functions on the tertiary irrigation pipe. Hydrants are provided with earthing elements for the protection of operating personnel.

The pipes crossing the supply canal and the drainage canal are made of 250-150 mm diameter steel pipe, Pn 10. The pipes rest on anchorage blocks made of simple concrete, located on both sides.

During the study period, on the surface of plot 7 were conducted aspersion watering. According to the data presented by the beneficiary, frequent damages occur on the single-line distribution pipes and at the single-line pumping stations in the irrigation system.

The technical expertise drawn up for the pipeline network and the single-line pumping stations in the aspersion watering "Doniceasa-Falciu irrigation Plot 7" has highlighted the overall unsatisfactory state of the hydro-technical objective after about 36 years of service. The technical expertise indicated a series of measures for the rehabilitation and modernization of the structural components of the sprinkler irrigation plot (Luca M., 2015, Luca M., 2016).

The analysis carried out in the technical expertise revealed the following:

- tertiary irrigation lines with serial connected pipe sections are degraded and the material is aged; the bursting percentage of asbestos pipes is high in the current state (*figure 3, 4, 6*);
- irrigation hydrants are worn out, have a high percentage of damage and do not allow the connection of modern watering equipments;
- simple and reinforced concrete chambers have degraded structural components, with internal infiltrations, uncovered plasterings, cracks in the wall, absence of covers, etc.;
- the hydraulic installation used for hydraulic shock protection is not complete or is missing;

Figure 4 **The state of replaced asbestos irrigation pipes (Luca M., 2016)**

- canal overcrossing pipes are worn out, corroded, show displacements from the original position; anchorage blocks made of simple concrete are structurally degraded, settled, and do not ensure anymore that the pipes are properly supported (*figure 5*);

- the tertiary irrigation pipe connection to SPPM has no chamber, a situation in which the hydraulic installation is physically and chemically degraded (*figure 6*);

- the improper quality of the irrigation water, due to the large quantity of alluviums transported, influences the degree of silting of the distribution pipes, especially on the final sections (*figure 5a*).

In the Doniceasa - Fălciu irrigation Plot 7, partial and incomplete rehabilitation and modernization works were carried out. Complex rehabilitation and modernization works have not been carried out since commissioning (1978) until now. The structural and functional state of the plot after 37 years of service and conservation is totally unsatisfactory. The plot's pipeline network has remained the same in regards to the geometry, constructive structure (asbestos pipes and PVC-G pipes) and was only partially rehabilitated and upgraded for reduced lengths (*table 1*).

The irrigation plot supply canal has an advanced degradation state, with intense silting processes and reed vegetation blockings. The concrete slabs are degraded (broken slabs, expulsion from the slopes), and large areas of the banks have no protection. This aspect greatly influences the irrigation plot operational process, through the distribution of sediment-filled water. Rehabilitation of the irrigation plot must be correlated with the rehabilitation of the supply canal (Luca M., 2016).

a b

Figure 5 **View of the structural condition of the supply canal crossing: a – general view of the pipeline location; b – the state of the right bank anchorage block (Luca M., 2016)**

Table 1

Characteristics of tertiary irrigation pipes A1-A6 in Doniceasa-Fălciu Plot 7 (Luca M., 2016)

Pipe	Section 1		Section 2		Section 3		Section 4		Section 5		Section 6		L_{tot} (m)	Q_{al} (l/s)	P (bar)	H_i no.
	L_{part} (m)	Dn (mm)	L_{part} (m)	Dn (mm)	L_{part} (m)	Dn (mm)	L_{part} (m)	Dn (mm)	L_{part} (m)	Dn (mm)	L_{part} (m)	Dn (mm)				
A1	504	200	616	150	324	125	-	-	-	-	-	-	1444	79,0	6,96	21
A2	612	150	360	125	-	-	-	-	-	-	-	-	972	67,0	6,47	14
A3	324	250	150	250	360	200	256	200	360	150	72	125	1502	72,4	7,25	23
A4	324	200	288	200	252	150	252	125			-	-	1116	67,0	7,46	17
A5	324	250	180	250	360	200	200	200	360	150	240	125	1720	60,7	7,55	25
A6	324	200	288	200	288	200	110	150	110	125	-	-	1362	70,2	7,16	20

Figure 6 **State of SPPM connections to tertiary irrigation pipe**

The rehabilitation of the irrigation plot aims at increasing the water use efficiency, which at the present stage is much smaller than that ensured at the design stage. Decrease in efficiency is due to water losses from the aging and degraded pipeline network. Also, the rehabilitation aims to improve the watering performance in the field using modern aspersion watering equipments, which have a high productivity and high reliability in service.

The rehabilitation and modernization of the sprinkler irrigation plot can be done in two ways:

- Option A – Rehabilitation of single-line pumping stations and single-line pipes by redesigning them in accordance with the requirements of the modified irrigation regime and the directions of the technical expertise.
- Option B – Conversion of the sprinkler irrigation plot with single-line pumping stations (SPPM) to a plot with a central pressurising pumping station (SPP) and a branch pipe network to serve the hydrants.

The first rehabilitation option involves lower execution costs, as well as a shorter execution time. The second option produces important changes in the structure of the irrigation plot, with higher costs and longer execution times.

The rehabilitation and modernization of tertiary irrigation pipelines for Option A involves the following analysis and calculation steps:

1. Analysis of the future operation of the sprinkler irrigation plot according to the expected watering equipment to be used. The following scenarios have resulted:

a. Scenario 1: Use of modern watering equipment which exploits the constructive structure of the initial tertiary irrigation pipeline (length, telescopic diameters, hydrant distances, hydrant type) and the SPPM. For the rehabilitated tertiary irrigation pipe the hydraulic characteristic will be determined with the equation (Burchiu V. et al., 1982):

$$H_c = H_g + MQ^2 \qquad (1),$$

$$M = 0{,}082\left(\frac{\lambda L}{D^5} + \frac{\sum \zeta_i}{D^4}\right) \qquad (2)$$

where: H_C is the hydraulic head of the pipe; *M*, *Q*, *D*, *L* – resistance modulus, flow rate, diameter and pipe length; λ - linear resistance coefficient; ζ_i – local resistance coefficient. Calculation of irrigation plot parameters: module flow, flow rate, pressure, efficiency and power for SPPM.

The SPPM flow is calculated with the relationship (Blidaru *et al.*, 1981, Cismaru C., 2004):

$$Q_{SPPM} = Sq_{u,pond}\frac{1}{\eta_c}\frac{1}{\eta_r}\frac{24}{t} \text{ (l/s)} \qquad (3)$$

where: Q_{SPPM} is the sizing flow rate of the pressurised pumping station (l/s), *S* – irrigated area (ha), $q_{u,pond}$ – weighted duty water (l/s.ha), η_c – field water efficiency, η_r – network efficiency downstream of the pumping station, *t* – actual operating hours of the watering equipment (hours/day).

The operating point of SPPM is determined with the equation system (Burchiu V. et al., 1982):

$$\begin{cases} H_c = H_g + MQ^2 \\ H_p = f_1(Q) \end{cases} \qquad (4)$$

where H_p is the pump head; Q_p – pump flow rate.

Design restrictions are:

$Q_{al} \le Q_{SPPM}$ (4), $P_{SPPM} \le P_{PT}$ (5)

where Q_{al} is the distribution pipe flow rate; P_{SPPM} – SPPM power; P_{PT} - available power of the energy transformer station.

b. Scenario 2: The use of modern watering equipment which require the changing of the constructive structure of the tertiary irrigation pipe (telescopic diameters, hydrant distances, hydrant type). Calculation of irrigation plot parameters: module flow, flow rate, pressure, efficiency and power for SPPM. Sizing of the irrigation tertiary pipe (diameters, number of hydrants, type of hydrants with Dn 100 and Dn 150) and the determination of the hydraulic characteristic. Sizing the pumping aggregate parameters and choosing it. Establishing the operating point of SPPM according to the new calculated values of the tertiary irrigation pipeline. Computed parameters must comply with the restrictions imposed by the SPPM fittings (Stăncescu L., et. Al 1984, Cunha, M.D., Sousa, J., 1999).

2. Analysis of the current pipeline condition and choosing of the rehabilitation option:

a. Replacement of sections from tertiary irrigation pipes (degraded sections are replaced, and those with good structural condition are preserved). The materials used must be mechanically and hydraulically viable for the irrigation plot (steel, HDPE, ductile iron, etc.). The materials used must allow quick interventions and repairs in case of damage.

b. Total replacement of the tertiary irrigation pipe. This option is more expensive but is recommended when the piping lifetime has been exceeded and the number of bursts is high during the irrigation season.

3. Analysis of the current hydrants condition and choosing of the rehabilitation option:

a. Rehabilitation option 1: Existing hydrants on the tertiary irrigation pipe are completely replaced by new hydrants with diameters of Dn 100 and Dn 150.

b. Rehabilitation option 2: Hydrants on the tertiary irrigation pipe are resized, both their number and diameter, according to the watering equipment used (pivot, longitudinal, fixed, etc.).

4. Analysis of the current state of the chambers used for bypass hydraulic installations, venting, draining, hydraulic shock protection. Rehabilitation is carried on the following domains:

a. Rehabilitation of the constructive structure through structural restoration of the construction or replacement of the chamber with a new one.

b. Rehabilitation of the hydraulic installation through complete replacement of the pipes, fittings and fixtures used for bypass and control.

c. Rehabilitation of the hydraulic system with ventilation and drainage facilities using modern devices.

5. Analysis of the current state of the installations and hydraulic shock protection installations:

a. Determination of the over pressure and depression values that may occur on the tertiary irrigation pipe;

b. Choice of protective means and design of the placement positions (on the pipe or inside chambers).

6. Analysis of the current state of the canal crossings and choosing of the rehabilitation option:

a. Preservation of the current pipe section with the rehabilitation of joining fittings and anti corrosive insulation. Verifying and restoring the assemblage slope.

b. Complete restoration of simple concrete anchorage blocks.

c. Installing the ventilation system.

7. Analysis of the current state of road undercrossing and selection of the rehabilitation option:

a. The use of high mechanical resistance pipes (steel) for the construction of the undercrossing sections (the case of the operational roads).

b. Use of steel protection tubes for the tertiary irrigation pipe located in the undercrossing (the case of roads with high axle load).

At the basis of the rehabilitation process of the tertiary single-line irrigation pipes is a complex calculation abstract. The calculation abstract will analyze the irrigation regime of the surface, hydraulic and mechanical calculation of the distribution pipeline, correlation of pipeline parameters with those provided by SPPM, calculation of hydraulic shock parameters and choice of protection devices.

CONCLUSIONS

1. Sprinkler irrigation plots have a current unsatisfactory structural and functional state given the long lifetime of service or conservation, about 35-40 years, the exceeding of the life service of some materials and the absence of maintenance and repair works.

2. Rehabilitation of the pipeline network in sprinkler irrigation plots is done in a complex way, taking into account the restrictions imposed by the value of the flow and the pressure they are supplied with.

3. Rehabilitation of tertiary irrigation pipes (main laterals) from sprinkler irrigation plots is performed according to the parameters of the modern watering equipments to be used.

4. The rehabilitation of sprinkler irrigation plot components is based on a calculation abstract that will take into consideration the irrigation regime, the technical characteristics of the watering equipment, the hydraulic parameters of the pipe network and hydrants and the available flow and pressure supplied by the pumping station.

REFERENCE

Blidaru V., Pricop Gh., Wehry A., 1981 - *Irigaţii şi drenaje*. Ed. Did. ;i Pedag., Bucureşti

Burchiu V., Santău I., Alexandrescu O., 1982 - *Instalaţii de pompare*, Edit. Did. şi Pedag., Bucureşti.

Cunha, M.D., Sousa, J., 1999 - *Water distribution network design optimization: simulated annealing approach*, Journal of Water Resources Planning and Management, ASCE, 125(4), 215

Cismaru C., 2004 – *Irigaţii: amenajări, reabilitări şi modernizări*. Ed. Politehnium, Iaşi.

Luca M., 2015 - *Expertiză tehnică „Modernizarea si retehnologizarea sistemului de irigaţii la Organizația Utilizatorilor de Apa pentru Irigaţii Doniceasa-Fălciu, Plot 7, SP 7/1, SP7/2, SP7/3 judeţ Vaslui”*. S.C. Polias-Instal S.R.L. Iaşi.

Luca M., 2016 - *Expertiză tehnică „Modernizarea si retehnologizarea sistemului de irigaţii la Organizația Utilizatorilor de Apa pentru Irigaţii Doniceasa-Fălciu, Plot 7, SP 7/4, SP7/5, SP7/6, SP7/7, SP7/8, judeţ Vaslui”*. S.C. Polias-Instal S.R.L. Iaşi.

Stăncescu, L., Moraru, N., Ionescu, V., Leinweber, L., 1984 - *Îndrumător tehnic pentru lucrări de îmbunătăţiri funciare*. Edit. Ceres, Bucureşti.

*** **Proiect nr. 4824-R 1987** - *Proiecte tip de construcţii pentru Îmbunătăţiri Funciare Catalog 4, subcapitolul Ploturi de irigaţie cu conducte sub presiune*, ISPIF, Bucureşti.