Construction and repair of irrigation canals based on converged technologies

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Abstract. The irrigation network is the main hydraulic structure that performs the function of transporting irrigation water to irrigated lands. Channels built in the last century have a high physical and moral wear, requiring a decision on how to restore. It is proposed to use a composite of materials consisting of a concrete web and a geomembrane. The combination of these materials due to their characteristics can reduce the construction process due to the ease of installation and ease of materials, as well as completely eliminate the filtration of water from the channel, which is also a serious problem. The proposed technology is good because it uses the best qualities of each material to obtain an effective coating of the irrigation channel. The use of this technology provides a significant economic effect due to the saving of facing material in the amount of 5 percent of the total area of laying the concrete web, taking into account the cost of geomembrane.

1. Introduction
Agriculture has always been and will remain a priority industry in any country, and in order to maintain and increase the level of productivity, it is necessary to take care in advance of a stable supply of irrigation water to the irrigated lands. Water intake and supply of the required volume of water is carried out by an irrigation system that includes a large network of irrigation channels for various purposes. The main purpose of the irrigation system is to deliver the required volume of water with minimal loss of water resources. Accordingly, if the channels do not deliver the required amount of water, then a certain irrigated area will not receive proper irrigation. In Russia, the wear of some irrigation channels is more than 50%, these indicators are critical and require in turn construction and reconstruction works, while using advanced technologies and materials [1].

The object of the study is irrigation channels, the subject in turn is the lining coatings of the irrigation channel.

The purpose of the research is to offer a rational option for the construction and repair of irrigation channels based on convergent technologies. To achieve this goal, the following tasks were identified: to justify the need for technical improvement of existing irrigation channels and to offer a variant of cladding that justifies the investment and the resulting effect.

2. Methods
The study used the method of empirical cognition, which served as a synthesis for the theoretical analysis of the literature by the deductive method. The theoretical method included abstracting, summarizing, and quoting the general and special scientific works of scientists in this science-intensive field. Mathematical and statistical methods were used to obtain and establish quantitative
dependencies between the studied phenomena. The mathematical method involved registering data. The statistical method included determining the average values of the obtained indicators, respectively comparing and obtaining a quantitative or qualitative dependence of the studied process.

3. Results and Discussion
The analysis of the works of famous scientists (Abdrazakov F. K., Baev O. A., Kosichenko Yu. M., etc.) in the field of construction, repair, and operation of irrigation channels has shown that the channels must be constantly maintained and undergo current repairs. The absence of these measures leads to an annual increase in the cost of recovery (see Figure 1, 2) [2, 3, 4].
It is fair to note that the maintained channel will be much cheaper to sustain, and the overall life cycle of the channel in good condition will be increased. However, irrigation network channels have different maintenance and repair requirements. The main channel is the largest in the irrigation network and has high requirements for lining and cross-section dimensions. Also, the channels must withstand the speed of non-pressure flow in the open channel, and this indicator has a different value. The average flow rate can be calculated using the Manning equation [5]:

$$V = \frac{1}{2} R^{\frac{1}{3}} n^{\frac{1}{2}} I^{\frac{1}{3}}$$

where: $V$ is the average speed (m/s), $n$ is the roughness coefficient, $R_h$ is the hydraulic radius (m), $I$ is the hydraulic slope (m/m).

On the assumption of the aforesaid, it is possible to determine the best material and construction technology for each channel. In previous works, we have noted the advantages and disadvantages of such materials as concrete cladding, concrete web, and geomembrane. Each material has the best performance when used in places where it is really optimal [6, 7, 8].

The main channel must be as strong as possible and ready for the constant load. The main channel should best be lined with precast concrete slabs on a screen made of plastic film. This process is best described in the developed technological map by famous scientist of the all-Union state design Institute of technology "Soyuzorgkhvostroy" (L. N. Perevezentsev, A. I. Kuznetsov, G. G. Markina) and “Southern Research Institute of Hydraulic Engineering and Land Reclamation” Yuzhniigim (Yu. M. Kosichenko, R. R. Galitsky).

With significant costs and complexity of the construction process, concrete slabs for lining the main channel will be the best solution due to operational reliability. Concrete slabs do not have such indicators of water permeability and ease of installation as a concrete web and geomembrane, but in turn, they will not be able to ensure the reliability of the main channel.

At the same time, we note that the requirements for distribution channels are lower; the channels have a smaller size and a low flow rate relative to the main one. We suggest using a concrete roadbed on this section of the irrigation network. This material is superior to concrete cladding in several ways and will be more effective on distribution channels. According to research made by Yu. M. Kosichenko and O. A. Baev, water filtration in distribution channels take about 70 % of all water losses of the irrigation system (see Figure 3) [9].

![Figure 3. Total water losses in the irrigation system](image-url)
Respectively, based on the above said, during the construction and reconstruction of irrigation channels for distribution purposes, it is possible to use a concrete web as a substitute for concrete slabs. The concrete web is the invention of Brevin Peter Eric and Crawford William Campbell. The properties of the concrete web and the compared facing materials are presented in previous works [10].

Priority indicators are the speed of laying concrete, minimum equipment, and workers, as well as full water resistance. The general view of the concrete web is shown in figure 4.

![Figure 4. Structure of the concrete web](image)

This material does not have the same ruggedness as concrete lining, while it is much better suited for distribution channels and is economically sound.

However, it is significant that the joints of the concrete web are not sufficiently waterproof and need additional sealing. To do this, we propose to strengthen the joints of the concrete web with an additional segment of geomembrane equal to the overlap. The joint of the concrete sections will look like this (see Figure 5.).

Baev O. A. in his studies of covering the irrigation channel with geomembrane noted that geomembrane is the best waterproof lining material, but when the soil directly contacts the material, the structure of the geomembrane is damaged, and puncture harm is also possible. Our proposed technological innovation solves this problem because there is no direct contact of the soil with the geomembrane and the material is effectively used to seal the joints of the concrete web.
The overlap of the concrete web can be adjusted depending on the purpose of the channel. The proposed overlap options are presented in the following formulas [11].

\[
M_k \geq N_{15} \text{cm}, \\
M_x \geq N_{10} \text{cm}, \\
P_k \geq N_{5} \text{cm}.
\] (2)

where \(M_k\) is the main channel, \(M_x\) is the inter-farm channels, \(R_k\) is the distribution channels, and \(N\) is the overlap of the concrete bed.

Regarding our technology, we offer a ranked method of overlap width, depending on the type of channel and its parameters. A large area of the web’s fit is necessary, but only in places of high load and high flow rate. Like any innovative material, concrete sheets cost a lot of money, and therefore they should be used as efficiently as possible. Using our recommendations, you can save on the cost of the material from 5% to 10% of the total area of installation.

When using a 10 cm overlap, you must consider the cost of purchasing a geomembrane equal to the overlap.

\[
(S_{Yk,bp} \div 1.05) + \left(\frac{S_{Yk,bp}}{1.10} - S_{Yk,bp}\right) = \text{economic benefit 5%}
\] (3)

where \(S_{(S_{Yk,bp})}\) is the area of laying the concrete web.

The General meaning of the formula is that when using an overlap of 10 cm, we save 5% of the total area of laying and, accordingly, reduce the necessary material for coating, while we need to purchase a geomembrane equal to the width of the overlap, respectively, we calculate the total amount of material in the second part of the formula.

The formula is also valid for an overlap of 5 cm:

\[
(S_{Yk,bp} \div 1.10) + \left(\frac{S_{Yk,bp}}{1.05} - S_{Yk,bp}\right) = \text{economic benefit 10%}
\] (4)

**Conclusions.**

Thus, we have proposed and justified options for the construction and reconstruction of irrigation channels using advanced and traditional facing materials. The proposed technologies for laying concrete sheets completely exclude the possibility of losses of irrigation water, and will also have an economic effect from their use.
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