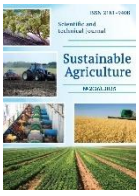
Sustainable Agriculture 2 (26) (2025) 52–55

Contents lists available at https://susagr.uz/index.php/ojs/issue/view/6

Sustainable Agriculture

journal homepage: https://susagr.uz/index.php/ojs



Geomembrane product in the Hydrotechnical Dams

Jumaniyoz Donoboyev[a], Sharifjon Sharopov[b], Abdulaziz Turdaliyev[c]

[a] *PhD Student, "Tashkent Institute of Irrigation and Agricultural Mechanization Engineers" National Research University, Tashkent, Uzbekistan*

[b] *PhD Student, "Tashkent Institute of Irrigation and Agricultural Mechanization Engineers" National Research University, Tashkent, Uzbekistan*

[c] *Independent Researcher admitted to PhD studies, "Tashkent Institute of Irrigation and Agricultural Mechanization Engineers" National Research University, Tashkent, Uzbekistan*

a r t i c l e i n f o

Keywords:
geomembrane, earth dam, reservoir, hydro power plant, filtration, wells, experimental pumping

a b s t r a c t

In water conservancy projects, such as reservoirs, dams, rivers, channels, and other buildings, geomembranes as anti-seepage layers can prevent groundwater or river water from entering the surrounding environment through leakage. They can be installed as a full-face liner, or to line parts of the dam where a higher risk of infiltration is expected, or as external water stop at peripheral and vertical joints and at contraction joints. They can be exposed to the water of the reservoir or be covered by a ballast layer; a watertight seal at all peripheries prevents water infiltration underneath the geomembrane liner. A geomembrane water barrier is a technically and cost-effective sustainable solution. A well is installed in the center of the massif, reaching the aquifer (soil layer in which moisture accumulates). Water will be pumped out of it or poured inside. The well is equipped with filters and a settling tank. The results revealed a decrease in relative seepage flow (Q/K.Hd), relative exit gradient ie.(B/Hd) and an increased factor of safety (FS) for all cases using a geomembrane on the dam.

1. INTRODUCTION

Geomembranes can prevent water waste. In water conservancy projects, such as reservoirs, dams, rivers, channels, and other buildings, geomembranes as anti-seepage layers can prevent groundwater or river water from entering the surrounding environment through leakage. This will not only reduce the consumption of groundwater resources but also avoid losses caused by massive leaks. Geomembranes can improve irrigation efficiency. Agricultural irrigation is one of the key links necessary to ensure the stable operation of food production and farmland ecosystems. Yet, large amounts of irrigation water are wasted under traditional irrigation methods due to leakage. Using a geomembrane to cover the irrigation area can reduce leakage during the irrigation process, transport more water to the roots of crops, and improve irrigation efficiency [Earth Shield Environmental Co.,2023]. The demand for utilization of electricity is increasing year by year across the world, which reflects the release of a huge amount of unwanted emissions from conventional coal or oil based power generation plants. The share of electric power generation from such conventional plants is gradually being replaced by locally available renewable energy source (RES) based generating stations. The advantages of RES are eco-friendly, harmless, almost zero emissions, easy to install anywhere by using the locally available sources with less investment [Krishna et al].

"On the other hand, the disadvantages, these are highly susceptible, and fluctuations will occur to the potential available. Except for solar, the remaining sources need the generator solution to generate the electricity from the mechanical energy of RES [Sandeep et al].

The use of renewable energy (RE) can play an important role in reducing GHG emissions while providing incremental financial resources to stimulate clean development mechanisms [Sahir], so offering a win–win solution for developing economies in particular. RE technologies can also help countries to meet the 'Sustainable Development Goal - 7' on reliable, clean and affordable energy, expand people's access to electricity and promote sustainable development [Singh et al]. In the face of climate change, environmental degradation and health issues, it is a huge challenge to provide affordable and clean energy to more than 1.2 billion people in the world living without electricity [Omer]. Globally, around 2.8 billion people still rely heavily on coal, wood, dung and charcoal for heating and cooking, resulting in over 4 million premature deaths per annum due to indoor air pollution. These challenges are more pronounced in South Asia, which is known as one of the most energy deprived regions globally. Many studies used the optimization model of energy supply systems (MESSAGE) to assess capacity expansion and energy production policies. In Saudi Arabia, China and South Korea, MESSAGE modeling is used to account for the CO2 emissions caused by power plants at all levels of the energy chain. These CO2 emissions are causing global climate change. [Roh & Kim].

* Corresponding author. j.donoboyev@tiiame.uz (J.Donoboyev)

E-mail addresses: sh.sharapov@tiiame.uz (Sh.Sharopov).

https://doi.org/10.5281/zenodo.16506583

Received 30 April 2025; Received in revised form 26 May 2025; Accepted 30 May 2025

Available online 1 July 2025

ISSN 2181-9408/© 2025 The Authors. Published by "TIIAME" NRU. The journal "Sustainable Agriculture" is registered in the Press Agency of Uzbekistan on the 12th of February in 2018 (license № 0957). In 2019, the journal is included in the list of recommended scientific publications by the Higher Attestation Commission of the Republic of Uzbekistan.

Hypothesis.

Using a geomembrane in hydraulic construction can be reduced the amount of seepage enough.

Identify a broad field or subject area. Geomembrane systems are used to provide, enhance, or restore water tightness in dams since 1959. In new construction, they are installed on embankment dams, RCC dams, and cofferdams, while in rehabilitation they are used on all types of dams.

They can be installed as a full-face liner, or to line parts of the dam where a higher risk of infiltration is expected, or as external water stop at peripheral and vertical joints and at contraction joints. They can be exposed to the water of the reservoir or be covered by a ballast layer; a watertight seal at all peripheries prevents water infiltration underneath the geomembrane liner. A geomembrane water barrier is a technically and cost-effective sustainable solution. The chapter discusses the design of the state-of-the-art solutions, the technical and economic advantages, installation aspects, performance, and references, with significant examples of all available options. A recent solution for underwater placement, developed for repair but applicable also in new construction, will be presented.



Preventing or minimizing water infiltration from the reservoir is crucial for the behavior of a dam because, over time, persistent seepage can make the dam deviate from its design conditions, ultimately jeopardizing its integrity. To ensure safe operation over their service life, dams are built to be intrinsically watertight or to have an upstream or an internal water barrier." [Gabriella Vaschetti].

Geomembranes provide additional advantages in terms of reduction of construction times, constraints, and costs. For example, in Uzbekistan, geomembranes used the construction persistent block dam's of the Pskom HPP which was located Tashkent region.



1. Problem identification: What is the problem? Sometimes problem is unknown and becomes visible after research (screening).

In the body of ground dams, the filtration consumption during the using period of the dam is higher than that of concrete shield dams, and the level of curved depression line in dams is high, and the fact that the construction of concrete shield dams' cost is high.

2. Diagnosis: What is the cause of the problem? Research aiming at finding the causes of the problem (empirical cycle)

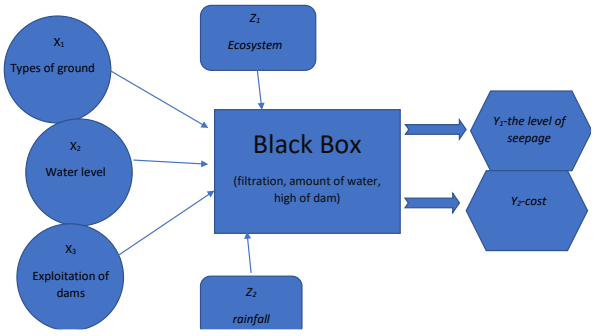
Relatively high filtration coefficient of the soil forming the body of the dam, fragility of the siltstone rock on the sides of the dam, high filtration coefficient and low strength of this rock.

3. Design: What can we do to solve the problem? Research that compares different interventions that might solve the problem (sometimes pilot research), and decision is made about intervention.

In the process of constructing the dam, it is necessary to cover the upper water surface of the dam and the part connected to the side boards with waterproof geomembrane material.

The desired result, that is, reduced filtration, was achieved through economic savings. The construction process was completed quickly and with high quality. After being covered with a geomembrane, the old channel of the main river was completely drained to construct the main dam.

General objective. The main task of our research is to ensure the safety of state-owned hydro technical structures, as well as the safety of hydro technical structures of enterprises that are part of the republican and regional energy systems, to develop and implement state programs that ensure the safety of hydro technical structures, to organize state control over the safety of hydro technical structures, including a number of necessary works, such as the organization of international cooperation on ensuring the safety of hydro technical facilities.



Where natural storage in the form of ponds is not available, reservoirs are often constructed if optimum development of the surface water is to be obtained. For countries in arid and semi-arid regions where the little rainfall is limited to the winter season and an acute deficit of water is an everyday fact of life, dams play a vital role in supplementing other water supplies. But there are many hydrogeological, geological and geotechnical problems associated with dams, among them seepage, which is of major concern because it threatens dams' storage purposes and may cause unforeseen failure [Abdallah].

It is typical that the water reserved behind the dams cause the seepage and sometimes leakage. The rate of seepage should be specifically controlled so that it would not pass the permissible limits. Cedergreen investigated the importance of seepage in all aspects and maintained that most damages to the water facilities can be from the seepage of underground water which are explained in two categories:

- that causes the soil particles move through an escape exit and cause piping or erosion failures;

- the damages caused by uncontrolled seepage patterns leading to saturation, excessive uplift or excessive seepage forces. The seepage control of the dam foundations was studied, and it was suggested that due to the discharge of the soil particles and weakening the foundations, the seepage of water occurred eventually leading to dam damage [Masoud Cheraghi].

2. METHODS AND MATERIALS

1.Methods for determining soil filtration coefficient

The filtration coefficient is determined directly on site or in the laboratory.



Field methods for studying filtration coefficient

The most accurate results are obtained directly on site. The filtration coefficient is determined on the entire array, and not on a separate small-volume sample. The soil being tested must be dry. Therefore, the best time to conduct research is the summer months (end of June, July, August).

The operating procedure is described in GOST 23278-2014.

Field research methods that are used to determine the filtration coefficient:

1.Experimental pumping (filling) - cluster or single

2.Pouring into the pit

3.Injecting water into wells at intervals

4.Well flow metering

The methods are intended for different zones of the soil massif. The first two are considered basic, the rest are additional.

The rules are described in the table.

1. Experimental pumping (filling)

A well is installed in the center of the massif, reaching the aquifer (soil layer in which moisture accumulates). Water will be pumped out of it or poured inside. The well is equipped with filters and a settling tank. Filters are not necessary if the properties of solid rock soils are being studied. In dispersed soil masses, a layer of sand or sand, cleared of clay and dust particles, is made around them. The top of the sprinkling should be above the filters.

2. Calculating the seepage

The influence of water movement on slopes and slopes is an important calculation factor. It is customary to take into account the so-called hydrodynamic force, which, in relation to stability calculations, is a shear force:

$$K_y = \frac{\sum_1^n P_i \cdot cos\alpha_i \cdot tg\phi_i + c_i \cdot l_i}{\sum_1^n P_i \cdot sin\alpha_i + D}$$

The hydrodynamic force D is determined as follows:

$$D = I \cdot \omega \cdot \gamma_w$$

- I — is the average slope of the segment of the depression curve cut off by the possible displacement curve;

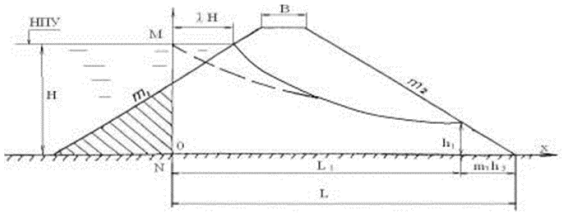
- ω — is the area of the filtration flow, limited above by a segment of the depression curve and below by the displacement curve;

- γw — specific gravity of water; is taken as 10 kN/m³.

This is one of those cases when the reliability of analytical (engineering) techniques is questioned. The above calculation method is very simplified and does not take into account all influencing factors, especially time, i.e. it is stationary.

The seepage of groundwater flow represents the position of the free surface of the groundwater or the piezometric surface of the confined water. To construct it, it is necessary to have data on the water levels H1 and H2 in two sections (wells) located at a distance L from one another. There are different options for analytical calculations of the position of the depression curve - according to G. N. Kamensky, according to V. I. Davidovich and N. N. Bindeman, etc. Tables with slope values for different soils are also common. Such tables are more often found in road practice.

1. The model of the dam is filled in filtration trays, the front wall of which is made of glass. To measure the position of the depression curve in the body of the dam, piezometers with a diameter of 8.0 mm are arranged, which are connected by rubber tubes to fittings installed in the bottom of the tray.



$$Q = \frac{(Q_1 + Q_2)}{2};$$

The soil filtration coefficient of dam models is determined by the formula

$$K = \frac{Q}{B \cdot T_{cp} \cdot i_{cp}};$$

There are: Q - model filtration flow;

B – flume width (length of dam model);

$$T_{cp} = \frac{(Y_n + Y_{n+2})}{2};$$

- average height of the depression line under the plane of comparison (Dam Base) between two arbitrarily taken piezometers;

$$i_{cp} = \frac{(Y_n + Y_{n+2})}{L_{n-(n+2)}};$$

- mean piezometric slope of the depression line in the same area;

The determination of the coordinates of the depression curve and seepage flow analytically for a dam without drainage is calculated in the following order.

As a result, the dynamic behavior of the structure is modified, impacting flow features close to the structure, leading to numerous challenges still poorly described.

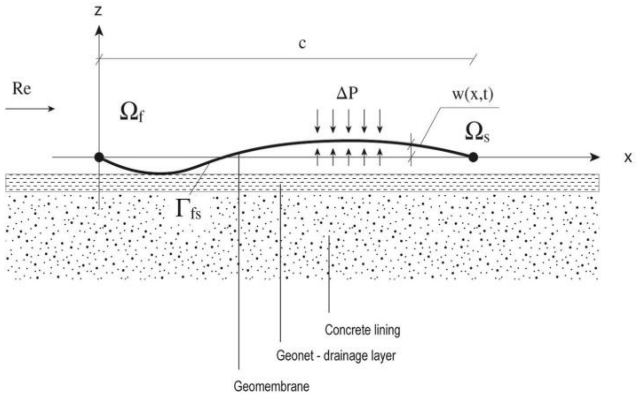


Fig. 9. Schematic representation of the dynamic behavior of geomembrane systems between two anchor points separated by a distance c; out-of-plane displacement w(x, t) of the geomembrane induced by the hydrodynamic load ΔP induced by the interactions between the fluid domain Ωf and the solid domain Ωs at the interface fluid-structure fs; the flow regime is described by the Reynolds number Re.

Design guidelines accounting for fluid-structure interactions are crucial as flow induced vibrations might be a challenge for geomembrane systems. To address this, it is mandatory to fully describe the processes of flow induced vibrations and their resulting effects on flow features, which ultimately impact hydropower operations. Outcomes might enhance and optimize the design, improving efficiency of hydropower plants rehabilitated with exposed geomembrane systems [Wiggert D].

3. RESULTS AND DISCUSSION

The results revealed a decrease in relative seepage flow (Q/K.Hd), relative exit gradient ie.(B/Hd) and an increased factor of safety (FS) for all cases using a geomembrane on the dam. This experiment contributes to the development and share of knowledge related to using geomembrane systems as rehabilitation and mitigation technology, and includes the main concepts related to their application in hydropower, as

well as their materials, historical development, durability, loads applied, state-of-the-art design. This was as expected, the main aim of this research to find variations in the seepage flow capacity of the dam (Q), hydraulic exit gradient (ie), and factor of safety. Two elements impacted these parameters: type of ground and the water level.

The rehabilitation and expansion of hydropower plants therefore requires innovative dependable solutions to ensure safe and optimized operations. Geomembrane systems are considered one of the most innovative and promising advancements in the field of hydropower in the last decades [Cazzuffi D].

In pressure waterways, they are applied as a protective layer to reduce leakage and increase energy efficiency. It is estimated that polymers and superhydrophobic materials used as lining systems can decrease energy losses in hydropower by 4 %–20% for pressure waterways (up to 90 % for free flow canals) [Quaranta].

In the long term, the potential impact of implementing geomembrane systems in hydropower more systematically could be significant in terms of increasing energy storage efficiency and energy production efficiency, thus favoring sustainable hydropower development, and ultimately contributing to the reduction of greenhouse gas emissions and mitigating climate change impacts. Geomembrane systems can be applied in all types of hydraulic structures, provided that the adequate design criteria are met. The policy makers could rely on the findings from this review to set standards for the use of geomembrane systems as rehabilitation and mitigation technology for safe and optimized hydropower operation and advocate further research projects.

4. CONCLUSION

The application of geomembrane products in hydraulic engineering has proven to be a vital advancement in ensuring the safety, efficiency, and sustainability of water-related infrastructure. These synthetic liners offer excellent impermeability, chemical resistance, and durability, making them ideal for use in reservoirs, canals, dams, and wastewater treatment systems. By preventing seepage and contamination, geomembranes help conserve water resources and protect surrounding ecosystems.

Moreover, the ease of installation and relatively low maintenance requirements contribute to their cost-effectiveness over the long term. Geomembranes also provide design flexibility, allowing engineers to adapt solutions to complex site conditions and diverse project requirements. Their use not only enhances the structural integrity of hydraulic systems but also aligns with modern environmental standards and regulatory demands.

As climate change increases the frequency and intensity of extreme weather events, the role of geomembranes in mitigating flood risks and supporting water management becomes even more crucial. Looking ahead, continued research and development in polymer technologies and installation techniques will further improve the performance and sustainability of geomembrane applications. In conclusion, geomembranes represent a key component of innovative and responsible engineering solutions in the management and protection of vital water resources.

REFERENCES

[1] Ranjit Kumar, Research Methodology 2011 p.29-30-132-133.

[2] A.Pulatov, Research Methodology lectures.

[3] Muise, Stacy (2019). HydroPower. Retrieved from studentenergy.org: https://www.studentenergy.org/topics/hydro-power p.200.

[4] Abdallah I.Husein Malkawi, Mohanned Al-Sheriadeh, Evaluation and rehabilitation of dam seepage problems. A case study: Kafrein dam, Engineering Geology,Volume 56, Issues 3–4,2000,Pages 335-345,

[5] V.B. Murali Krishna, SSSR Sarathbabu Duvvuri, Kishore Yadlapati, Tripura Pidikiti, Peddeeti Sudheer, August 2022, p. 510 https://doi.org/10.1016/j.measen.2022.100478.

[6] T. Adefarati, R.C. Bansal Integration of renewable distributed generators into the distribution system: a review IET Renew. Power Gener., 10 (7) (2016), pp. 980.

[7] S. Kumar Tiwari, B. Singh, P.K. Goel Design and control of microgrid fed by renewable energy generating sources IEEE Trans. Ind. Appl., 54 (3) (-June 2018), p.2050.

[8] T. Adefarati, R.C. Bansal Application of renewable energy resources in a microgrid power system J. Eng. (18) (2019), pp. 5400.

[9] B Murali Krishna. V and V. Sandeep “An Analytical Study on Electric Generators and Load Control Schemes for Small-Hydro Isolated Systems” In: Vadhera S., Umre B.S., Kalam A. (eds) Latest Trends in Renewable Energy Technologies. Lecture Notes in Electrical Engineering, vol 760. Springer, Singapore.2020, p.2500

[10] Sk Abdul Aleem, S. M. Suhail Hussain, Taha Selim Ustun A review of strategies to increase PV penetration level in smart grids Energies, 13 (3) (2020), p. 636

[11] G. Pathak, B. Singh, B.K. Panigrahi "Wind–Hydro microgrid and its control for rural energy system," IEEE Trans. Ind. Appl., 55 (3) (May-June 2019), p.3050

[12] M.H. Sahir, A.H. Qureshi Specific concerns of Pakistan in the context of energy security issues and geopolitics of the region Energy Policy, 35 (2007), p. 2040

[13] V.K. Singh, S.K. Singal Operation of hydro power plants–a review Renew Sustain Energy Rev, 69 (2017), pp. 712

[14] A.M. Omer Energy, environment and sustainable development Renew Sustain Energy Rev, 12 (2008), p.2300

[15] Roh and Kim, International Journal of Engineering Research & Technology (IJERT), 2017, p 510

[16] Gabriella Vaschetti Geomembranes in Dam Engineering Published: May 18th, 2022 Carpi Tech, Balerna, Switzerland, p.50

[17] Gunnarsdottir I, Davidsdottir B, Worrell E, Sigurgeirsdottir S. Sustainable energy development: history of the concept and emerging themes. Renew Sustain Energy Rev 2021 May 1, p.

[18] Cazzuffi D, Giroud J, Scuero A, Vaschetti G. Geosynthetic barriers systems for dams. In: Proceedings of the 9th international conference on geosynthetics. Brazil: Guaruja; ` 2010. p. 115.

[19] Quaranta E., Davies P. Emerging and innovative materials for hydropower engineering applications: turbines, bearings, sealing, dams and waterways, and ocean power. Engineering 2022; volume 8; 149.

[20] World Bank Group,2019 Stip,Clementine Marie; Mao,Zhimin; Bonzanigo,Laura; Browder,Greg J.; Tracy, Jacob.Water Infrastructure Resilience – Examples of Dams, Wastewater Treatment Plants, and Water Supply and Sanitation Systems (English). Washington, D.C. :

[21] Jenny Zhang, Dec 20, 2023, https://medium.com/@zl920827?source=post_page

[22] UN-Water/UNESCAP (Economic and Social Commission for Asia and the Pacific). 2022. Mid-Term Review of the UN Water Action Decade: Input from the Asia Pacific Consultation. Report Summary. www.unescap.org/sites/default/d8files/event-documents/UNWaterActionDecade%20AP%20consultation_0.pd.

[23] FAO (Food and Agriculture Organization of the United Nations). 2022.

[24] The State of the World’s Land and Water Resources for Food and Agriculture: Systems at Breaking Point. Main report. Rome, FAO. doi.org/10.4060/cb9910en.