

COMPARATIVE ANALYSIS ON THE PERMEABILITY OF CLAYS AND GEOMEMBRANES

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Abstract

Sealing materials used in sealing waste landfills are construction materials that are characterized by permeability to water and the values, very low.

Clays are dispersed systems assigned to the hydrophilic category of the anorganic porous material wet by the water moving under the action of a pressure gradient, across them on their thickness by a process described by Darcy's law.

The drying process is connected to the difference in resource of water vapours of soil as well as of the conserving environment (atmospheric air) and the changes at drying contraction are connected to the water suction out of the pore as well as to the percolation capacity of soils.

Geomembranes are polymeric materials that show low permeability to water, yet are permeable. Passage of water molecules in these materials is done through a process of diffusion described by Fick's first law, the process resulted in the appearance of a concentration or pressure gradient between the two sides of geomembranes.

Key words: clay, geomembrane, permeability, diffusion of water vapor, isotherm

1. PERMEABILITY CLAY

Porous materials are permeable to water, their permeability, in saturated condition is expressed by the coefficient of permeability k , usually in $\text{cm}\cdot\text{s}^{-1}$.

Suitable Darcy's law (1856):

$$v = k \cdot i \quad (1)$$

the coefficient of permeability k is a factor of proportionality - characteristic of a material or a class of materials with similar porosity and pore structure - between the apparent velocity of filtration v and hydraulic gradient i .

In porous materials, such as clays, pore size is reduced by circulating water.

It is considered that the capillary pore diameter of $0.2\text{-}1\mu\text{m}$, water can move only at high pressure and low speed and therefore manifest threshold permeability porous system and to overcome its very low permeability. If the threshold permeability porous materials, the relationship (1) takes the form:

$$v = k(i - i_0) \quad (2)$$

where:

- i_0 - is the initial gradient.

The flow of water through the foam begins only after the hydraulic gradient has exceeded initial gradient, or in other words, in conditions

where the pressure gradient exceeds the threshold of permeability (fig. 1).

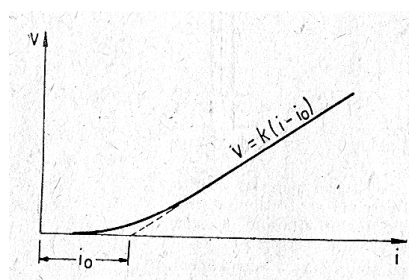


Fig. 1. The threshold of permeability (initial gradient i_0)

Threshold of permeability increases and permeability decreases with the decrease of pore diameter and increasing the amount of adsorbed water, which depends on the interaction of pore water solid and adsorbents ion concentration and species, in conditions where ions adsorbed on the solid surface show high hydration capacity, thickness start of adsorbed water increases and, consequently, permeability is reduced so explicate that the ions Na^+ descending influences permeability clay.

To the unsaturated clays water migration occurs under the action differences suction, pressure gradients, temperature or concentration.

Between two areas of the clay mass, in which water is different suction, takes a transfer of water held in smaller suction area to one with greater suction. Moving water can take place and capillary condensation, distillation process known isotherm (fig. 2).

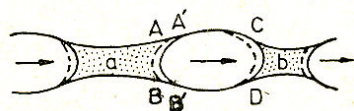


Fig. 2. Diffusion of water vapor distillation isotherm

Water vapor from the surface of a meniscus concave radius greater will condense on the surface of smaller radius concave meniscus. Moving water can be held also by capillary height [3].

In terms of the space occupied by pore water alternates with the gaseous phase, the transfer can produced only through a succession of local processes of evaporation and condensation, water evaporation and condensation a barrier against water and forming the evaporation on the other.

Clays occur due to low water permeability p_a adsorbed on the surface and mineral particle which reduces porosity, porosity retained water afferent called specific retention capacity.

Presently only specific retention capacity adsorbed water, clay present threshold of permeability, water filtrate through the clay took place only after overcoming initial gradient.

The filtrate water through clay is associated with adsorbed water movement through the pores, it results that the permeability depends on the size of the complex absorption particle minerals, that the mineralogical composition of clay. Thus, have kaolinitic clays permeability coefficient of the order 10^{-7}cm/s^{-1} , montmorillonit - that around $3 \cdot 10^{-9} \text{cm/s}^{-1}$ and

montmorillonit - Na is the coefficient of diffusion which can fall up on $10^{-11} \text{cm.s}^{-1}$.

For clays which are used as protective layer impermeable to landfills, how compaction affects their permeability.

Compacting the clay to a moisture content lower than optimal humidity w_{opt} result in the formation of a structure with contacts side - edges between particles, called aggregate structure, this structure favors the permeability increase compared with that obtained at optimum compaction. Compaction in the soil moisture conditions by about 2% higher than optimum moisture, on the contrary, permeability register a significant decline is explained by the formation of a structure countenance contact between particles, called structure-type dispersion [3].

2. PERMEABILITY MECHANISM OF GEOMEMBRANES

Moisture transport through geomembranes is a process of diffusion, differences in water vapor concentration, of depression, of temperatures, between the two opposite sides of geomembranes cause a gradient under the action of moisture which diffuses through the material. So, this gradient constituted actualing force of diffusion process [1; 5]. Diffusion in polymers occurs by moving molecules into diffused jumps through gaps that form the free volume. *Iso-free volume* theory consider that the specific volume of the polymer is composed of the sum of two volume parts: the volume occupied by the macromolecular chains and pore volume of these, called *free volume*.

With increasing temperature above the temperature of vitrifying free volume recorded an increasing variation around linear fig. 3 [6;4].

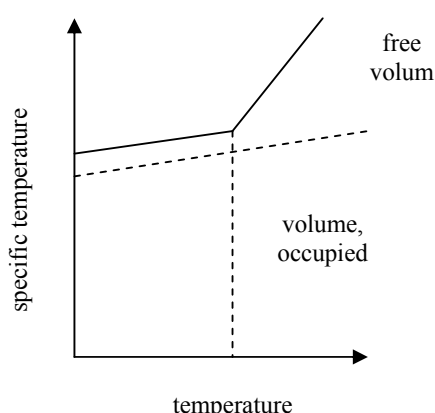


Fig. 3. Changes in specific volume, occupied and free, with temperatures of amorphous

The relationship between flow of diffusion and concentration gradient concentration, in an isotropic medium is described by Fick's law I.

$$J_w = -D \cdot \frac{d_c}{d_e} \quad (3)$$

where:

- J_w – quantity of vapor that diffuses into the unit time, through geomembrane, after a normal direction on this surface, area is equal with the unity in $\text{g} \cdot \text{s}^{-1} \cdot \text{cm}^{-2}$ or $\text{mole} \cdot \text{s}^{-1} \cdot \text{cm}^{-2}$.
- D – diffusion coefficient, in $\text{cm}^2 \cdot \text{s}^{-1}$:
- c – values of water concentration, in $\text{g} \cdot \text{cm}^{-3}$ polymer or in $\text{mol} \cdot \text{cm}^{-3}$ polymer:
- e – thickness of geomembranes in cm.
- d_c/d_e – concentration gradient on the thickness of geomembranes, after a direction normal to its surface.

Similarly for a transmission fluid pressure generated by a gradient can write the relationship

$$J_w = -\Pi \frac{d_p}{d_e} \quad (4)$$

where:

- Π - is the permeability, the quantity of vapor that fluid passing through an area equal to the unity, after a normal direction on it, through the thickness of a geomembrane to a unit pressure gradient unit, in $\text{g} \cdot \text{s}^{-1} \cdot \text{cm} \cdot \text{atm}$.

If a constant gradient through geomembrane

$$\left(\frac{d_c}{d_e} = 0, \quad \frac{d_p}{d_e} = \text{const.}, \right.$$

$\left. \frac{d_p}{d_t} = 0 \right)$ by integration we obtain [1]:

$$J_w = \int_0^e d_e = -D \int_0^e d_c = \frac{D}{e} (c_1 - c_2) \quad (5)$$

$$J_w = \int_0^e d_e = -\Pi \int_{p_1}^{p_2} d_p = \frac{\Pi}{e} (p_1 - p_2)$$

Equaling two J_w relationship is obtained:

$$\Pi = D \frac{c_1 - c_2}{p_1 - p_2} \quad (6)$$

or,

$$\Pi = D \cdot A \quad (7)$$

where:

- A – is the coefficient of sorption.

Therefore, according to relationship (7), coefficient of permeability Π depends on the diffusion coefficient (D) and coefficient sorption (A), sizes of which are controlled by the polymer characteristics, the particularity molecules of water, of temperature. Polymer affects the permeability through molecular and intermolecular chemical structure, the packing density, the degree of crystalline, density of curing, flexible macromolecular chains. Sorption capacity depends on the molecular and intermolecular chemical structure of polymer. Water retention occurs by binding water molecules to polar functional groups of the polymer by hydrogen bridges; the connection is even stronger as the polarity of the group is higher.

In table 1 shows the relationship is established between sorption water (moles) and polar groups (in moles) reported 100g/polymer [2]. There is likewise increases of both sizes. Some polymers (polyesters, polyamides) although containing strong polar groups, showing low water sorption because of their high crystallization. Sorption capacity is reduced and the conditions in which functional groups are engaged in other connections, and surface water is related to marginal functional groups and structural deficiencies [6].

Hydrophilic or hydrophobic character of the polymer influences the diffusion coefficient (D).

Table 1. Sorption water, in moles (the $p^s/p^s = 0.9$) according to the polar groups of the polymer (polymer moli/100g)

Polymer	Polar groups (moles/100g polymer)	Sorption water moles
Polyvinyl alcohol	2,27	2,011
Polyacrylonitrile	1,89	0,42
Polyvinylbutyrol	1,40	0,18
Polyvinyl acetate	1,16	0,17

Sorption isotherms given in figure 3 highlight sorption reduced capacity of polyethylene - whose moisture is non-polar structural - sorption comparative ability of polystyrene, vinyl polyvinyl whose polarity increases in the order of enumeration [2; 4].

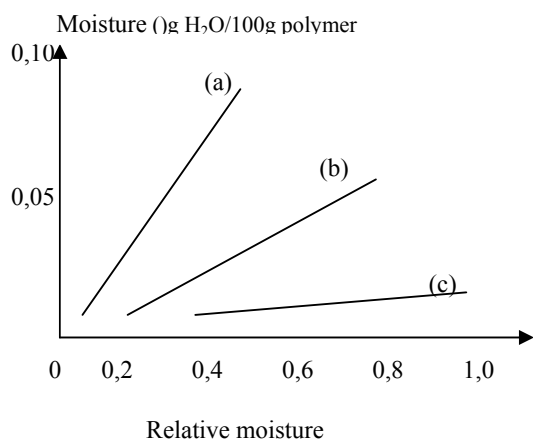


Fig. 3. Isotherms of (25° for: a) - polyvinyl acetate b) - polyvinyl chloride, c) - polyester,

Packing density influence the coefficient of diffusion and through his influence permeability [6]. For example shown, based on experimental research that density polyethylene of 0.922 g.cm^{-3}) permeability over seven times density presented (at (temperature 25°C) polyethylene 0.960 g.cm^{-3} [2]. With increasing crystal diffusion coefficient and permeability decrease. The presence of crystallites reduces the effective cross-sectional area of diffusion and increases the effective path traveled by

molecular diffusion, also restricts the volume fraction of amorphous phase.

Increasing reticular of a network density crystalline by increasing the percentage of crystalline phase macromolecules decreases mobility and, therefore, determine decreasing the diffusion coefficient and the permeability. Permeability is presented in table 2 are made of different polymers geomembranes

Table 2. Water vapor permeability of polymers

Polymers	Permeability ($\Pi \times 10^9$) $\text{cm}^3 \text{ (STP)xs}^{-1}\text{cm}^{-1}\text{xcm}^{-1}\text{Hg}$
Butyl Rubber	40 - 200
Butadiene Rubber	4900
Natural Rubber	3000
Polyethylene	12-210
Polypropylene	70
Polyvinyl chloride	260-630

Presence of pores and crazing in polymers can significantly increase the permeability of geomembranes. Some pores, characterized by very small but varied ($10^{-4} \dots 40\text{n.m}$), are structural defects that may occur in the process of cooling and formation of polymer. Pore sizes are significantly larger but manufacturing defects.

The rubber, butyl rubber have the lowest permeability, much lower than butadiene rubber.

3. REFERENCES

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