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Original Research

Assessing Diffusion and Conductivity on Waste Tire Crumb and Rock Flour for Constructing a Barrier Liner in a Landfill

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Abstract

For this study we investigated 2 series compounds by 2 waste materials – rock flour and tire crumbs – for use as barrier liner material. The first series used marble rock flour-clay (RF-C) mixture and the second used series clay soil-tire crumb (C-TC) mixture. The compounds were mixed, compacted, and tested for diffusion and permeability. The obtained diffusion coefficients (predicted and observational data) were compared with the recommended diffusion coefficient for a compacted clayey liner. The results of research showed that the compounds contain maximum 50% RF and 40% TC in the first and second series, respectively. Due to the presence of a sufficient amount of clay minerals, it has an appropriate ion absorption property that is necessary for landfill liner. Then the permeability of compounds in various pressures was determined. The obtained permeability are in the range of values recommended for the compacted clayey liners, and therefore this material is acceptable in terms of molecular diffusion and permeability. It could be said the compression capability and adsorption characteristic of this material are comparable to clayey liners, and this material could be recommended as an alternative material for landfill liner construction.

Keywords: landfill, barrier liners, diffusion, tire crumb, marble rock flour, permeability

Introduction

Because of economic problems and the high potential for contamination absorption, compact clay (clay liner) has been widely used in landfills [1-3]. In the event of the unavailability of clay soil or to improve some of the parameters required for the Liner, other synthetic materials such as a sand-bentonite mixture, GCLs, etc. have been used as a barrier layer in landfills [4-6]. Furthermore, by conducting experiments, sand-bentonite mixture and GCLs as liner materials, permeability coefficients of this compound have been measured and have been compared with clay liner. Use of fine-grained materials such as ash from incinerators as well as powdery materials such as rubber silica (Silica fume) as additives to clay or other materials are investigated by researchers to different application [7]. Kalkan and Akbulut [8] by experimental study, positive effect of micro silica on the permeability, swelling pressures, and compressive strength clay liner was shown. Kayabali [9] modified Zeolite with bentonite has been used as an additive to clay and indicated that this compound can be used to make landfill liners. Prashanth et al. [7] mixed Pozzolanic ash with clay and

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during the tests showed that this material can be used to make liners. The influence of various parameters such as pH, the amount of clay and copper metal concentration with the aim of removing copper ions in the making of a landfill liner was investigated by [10].

Numerous criteria in terms of controlling contamination are recommended to evaluate the liners [11-12]. Among these criteria, low permeability and molecular diffusion coefficient are more important and liners made with clay or other synthetic materials for these 2 properties must be controlled [13-14]. In recent years, scientists have taken a new approach toward unusual soils and materials found in nature as a waste material. It should be noted that the existence of some of the hidden properties in these soils often would solve a lot of problems. Of course economic justification and frequency in a region may be one of the most important reasons for the attention of researchers. Use of recycled bassanite as a stabilizer material produced from gypsum for improving the ground and highway was first used in Japan [15], but the use of gypsum wastes in cold and rainy areas has many challenges, because gypsum is a soluble material [16]. Guney et al. [17] presented a kind of soil, called Sepiolite, to examine its feasibility as a clay liner. This type of soil is abundant in parts of Europe and Turkey and Western America.

Disposal of rock flour is one of the major important environmental issues in a stone mine and stone factories. Studies show that the waste produced in Iran is twice the global standard. Only 25% of this waste is recycled and the rest is released as waste in nature. The best solution is technical waste management, recycling these wastes and using them in the conversion industry. A review of the background indicates that conducted research is not sufficient. And the scope of knowledge about this material is low in engineering applications. Due to this fact, cutting down stones into small pieces, waste materials called rock flours are produced, which are usually discarded. These materials in terms of grain size are comparable to silt and clay granules and could be used as additives to make liners. Since Iran is one of the top 5 countries around the world in terms of rock production [18], in this study, the usability of marble rock flour and tire crumbs has been evaluated as additive material in 2 series compounds in landfill liners. There is very little information about engineering properties of rock flour as a main or additive material for improving the soil in engineering application. In recent years, some studies have been reported about fly ash, mining tailings, metallurgical slags, and biomass incinerator ashes for different purposes such as load bearing, producing brick, etc. [19-24]. Use of waste marble dust as additive material in brick has been investigated by Bilgin et al. [25]. He found that this additive increased its positive effect as a strength on industrial brick.

Tire was used as the second waste material in this study. With development of cities and the increasing number of cars and the ever-increasing scrap tires in urban solid waste landfills and due to space limitations for landfills, and the vast number of these tires and the high cost of the landfill, nowadays it has become one of the greatest environmental problems. To solve this problem, the use of tires in different shapes and value has been considered by researchers. Various aims have been evaluated in the research. Some of these aims include:

1) Using soil-tire mixture behind a retaining wall to reduce the shear force and make lightweight material or reinforcement of the soil in order to slope stabilization [26-28].
2) One of the other benefits of rubber tire is its high energy absorption capacity, causing the soil-tire mixture to be considered a part of a damper system to reduce vibration under dynamic loads. Such studies use rubber as part of a damping system to reduce vibration. This problem can be a benefit for areas that may be subjected to seismic loads [29].
3) Thomas and Gupta [30] made usable concrete in pavement and structural applications using tire as a part of the concrete material in combination with copper slag and increased concrete strength up to 50%.

The efficacy and properties of this substance (RF and TC) for construction of the liners in landfill have not yet been evaluated and the properties of this waste material for this purpose remain hidden. This issue has been investigated in this study.

Materials and Methods

Used Materials

Two series of combinations have been investigated for this study. Materials used in the first series of experiments were marble rock flour as an additive material to be mixed with a specified amount of clay, and in the second series clay soil is used as a main material and tire crumb (TC) as an additive. Rock flour was produced as a waste of stone cutting factory and clay soil suitable for brick collecting around Marivan city. These materials were mixed by weight, and 10 samples were

Table 1. Mechanical characteristics of soils used in the experiments.

Parameter	Clay Soil	Pure Marble Rock Flour
Liquid Limit (%)	21.8	-
Plastic Limit (%)	7.6	-
Plastic Index	14.2	-
Specific Gravity	2.72	2.66
Maximum Dry Density (g/cm^3)	1.97	1.61
Optimum Water Content (%)	14.2	19.7
Soil type (USCS)	CL	-

Table 2. Some properties of the mixtures.

Test name	Parameter	Maximum dry density (kg/m^3)	Optimum water content (%)
DIF-0	Pure marble rock flour	1610	19.7
DIF-C	Clay soil	1940	14.2
DIF-1	90% Clay+ 10% RF	1922	14.4
DIF-2	80% Clay + 20% RF	1895	14.6
DIF-3	70% Clay + 30% RF	1872	15.1
DIF-4	60% Clay + 40% RF	1845	15.7
DIF-5	50% Clay + 50% RF	1815	16.3
DIF-6	90% Clay + 10% TC	1905	14.1
DIF-7	80% Clay + 20% TC	1830	13.8
DIF-8	70% Clay + 30% TC	1760	13.3
DIF-9	60% Clay + 40% TC	1686	12.6
DIF-10	50% Clay + 50% TC	1604	11.6

made. Clay soil in the first series and tire crumb in the second series were added in varying proportions of 10 to 50 wt.%. Aggregation, specific gravity, Atterberg limits, and standard compaction tests were performed with the samples. The results from these experiments are shown in Tables 1-2. Fig. 1 shows the aggregate curve of clay soil, pure rock flour, and tire crumb.

Theoretical Basics of Transmission of Pollution Among Liners

Transporting contaminants among the contamination barrier layers (liners) with movement mechanisms of advection and diffusion, as well as absorption and decomposition, is defined by the following equation [31]:

$$(\theta + \rho K_d)\frac{\partial c}{\partial t} = \theta D\frac{\partial^2 c}{\partial z^2} - \theta v\frac{\partial c}{\partial z} - \theta\lambda c \qquad (1)$$

…where θ = soil volumetric water content degree = n in the saturated soil (porosity), ρ = dry density of the soil (M/ L^3), Kd = distribution coefficient of ions in the soil (L^3/M) that is zero for Cl ion, c = ion concentration in the soil at the time (M/ L^3), D = the hydrodynamic diffusion coefficient formed from a total of effective diffusion coefficient (De) and mechanical diffusion coefficient (Dmd) (L^2/T), z = soil depth (L), v = groundwater flow velocity (v = v_a/n, L/T), and λ = disintegration constant (Ln2/ Half-life chemical). Transmission by molecular diffusion occurs in the case of chemical difference existence of element concentration between 2 points of soil (concentration gradient) and in the absence of water flow. Transferring chemical elements by water flow are called advection. Boundary condition on the top of the liner in which the contaminants containing chemical ions with specified concentration move down through a liner and decrease the concentration at the bottom of the liner, during a time, is defined by the following equation:

$$c_s(t) = c_o - \frac{1}{H_f}\int_0^t f_s d\tau - \frac{q_c}{H_f}\int_0^t c_s(\tau)d\tau \qquad (2)$$

…where *cs* (*t*) = concentration of contaminants (certain chemical ion) in the top of the liner after time t (M/ L^3), c_o = ion initial concentration in the top of the liner, H_f = equivalent height of leachate containing ions at the top of the liner (L), *fs* = the mass of the ions passing through the liner per unit area and per unit time (M/L^2/T), and q_c = the volume of leachate collected from the surface of the liner per unit area and per unit time. Boundary condition on the bottom the layer and in contact with environmental receiver contaminants (such as an aquifer beneath the layer like a groundwater) in which chemical ions enter through the liner during a certain time, is defined by the following equation:

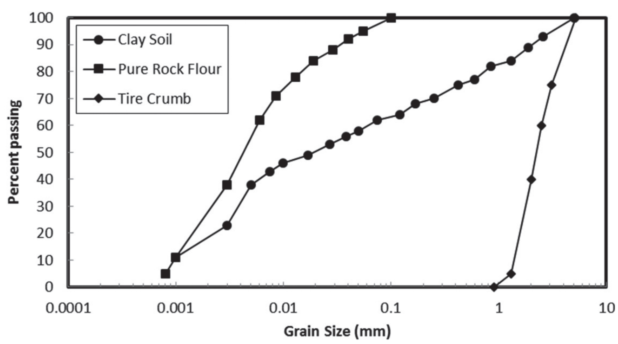

Fig. 1. Particle size distribution curves for the clayey soil, rock flour and tire crumb.

$$c_R(t) = \int_o^t [\frac{f_R(\tau)}{h}] d\tau \quad (3)$$

…where $C_R(t)$ = ion concentration in aquifers (border between aquifers and liner) at the time of t, $f_R(\tau)$ = mass entering the aquifers per unit area and per unit time ($M/L^2/T$), and h = thickness aquifers (L). If the liner in its bottom would be in contact with an impermeable layer (such as rock layer), water doesn't flow through the liner and, as a result, movement mechanism of advection did not have a role in transferring ions, and ion movement would be possible only by diffusion. In this case, Equation (1) is written as follows:

$$(\theta + \rho K_d)\frac{\partial c}{\partial t} = \theta D \frac{\partial^2 c}{\partial z^2} \quad (4)$$

If chemical ions with soil minerals (liner layer) have no interaction and do not ion adsorption and desorption (such as chloride ions that do not absorb by soil), and also there is no decomposition, thus, in this case, equation (4) is written as follows:

$$\frac{\partial c}{\partial t} = D \frac{\partial^2 c}{\partial z^2} \quad (5)$$

Equation (5) shows the specific conditions of contamination transmission in the soil in which there are no transmission mechanisms such as advection-diffusion, absorption, and decomposition, and the only factor for ion movement is pure molecular diffusion. Equation (5) is known as Fick's second law, like consolidation equation in soil. Solving Equation (1) with defined boundary conditions, by Equations (2) and (3), and a special state of which defines the pure molecular diffusion state on the form of Equation (5), defines pure molecule distribution, which is posed by using the finite layer method [Rowe and Booker], is embedded in the POLLUTE computer code [31], which uses the finite-element method for analysis. This method provides the possibility of analyzing transmission of contamination among the several horizontal layers within the soil with less volume and computation time. The most common use of this code is in the transmission of contamination through the landfill layers.

Molecular Diffusion Experiments

Molecular diffusion tests were carried out on the provided 10 compounds to determine the molecular diffusion coefficient of specific chemical elements (in this study, CL ion) in these materials. So that the coefficient obtained by the molecular diffusion coefficient recommended for compacted clay liner in a landfill site, compared to the same chemical element, and determine which sample in terms of transmission of contamination through molecular diffusion have required standards and could be used in making a clay liner on the bottom of the landfill. Molecular diffusion experiments carried out by using a pipe of polyethylene with an inner diameter of 10 cm and a height of 20 cm that one side is blocked by a glass plate. First, the materials were mixed (by weight) in dry state (according to Table 2). Then water was added to samples – about 3% more than the optimum moisture level. The moisture content, in order to achieve minimum permeability in samples, is essential and recommended for making landfill liners. After adding water, the compounds have moisture content of about 11% to 20%. In the next step, the samples were compacted (inside the tube) in 3 layers using standard Proctor compaction (ASTM D698). After compaction, the final surface of the samples became flat and the final heights of the samples were measured. To determine moisture content, a little sample from each admixture was taken prior to testing. NaCl solution with specific concentration of chloride ion was previously prepared and poured inside the tube at the top of the compacted samples. The height of the solution was measured immediately, and initiation time during the experiment was recorded. The tank containing the solution is called the contamination source.

During the experiment, almost 2 ml in the contamination source was sampled to determine the concentration of chloride and observe process changes over time. And equal to the stored samples, distilled water was added to the contamination source so that the level of solution would remain constant. We considered diluting the solution inside the tank by adding distilled water in the calculations for determining the concentration by the used theoretical model (polluted). Before and after sampling, the solution inside the tank was stirred by hand carefully until the solution concentration became uniform. During the molecular diffusion test, chloride and sodium ions due to concentration differences (high concentration in contamination source above the sample and low concentration within the sample) by the phenomenon of molecular diffusion penetrates the inside of the sample. Because of the movement of ions from

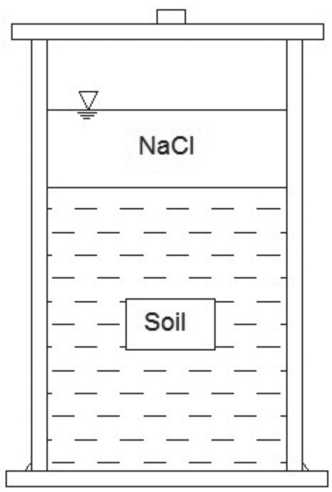

Fig. 2. Schematic Molecular Diffusion Test.

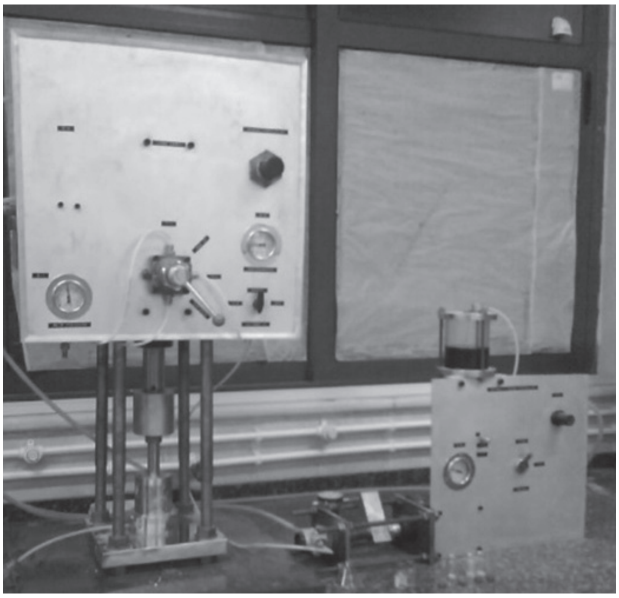

Fig. 3. Soil pore water extraction device.

the sample during the test, the concentration of ions is reduced gradually in the source of contamination and its concentration increases within the sample. To ensure test results, 2 diffusion tests were conducted on each sample and similar results were obtained. Results from the test for each sample follow.

At the end of the experiment, the last sampling was conducted from the contamination source, end times during the experiment were recorded, and the solution above the sample discharged. A glass plate was separated from the bottom of the tube, the tube containing the sample was placed horizontally on the table, by a wood mandrel samples out from the tube, and by a wire saw was cut into 1.5-cm pieces. Cut pieces were numbered until each piece would be specified in terms of height position. To determine the final moisture content in the sample height, a little sample for determining the moisture content of each piece was produced and the degree of moisture in sample height was specified. Then profiles of moisture-depth for the tested samples were drawn. To determine the concentration of chloride ions in the sample height at the end of the molecular diffusion test, pore water of cut pieces was extracted using the soil pore water extract apparatus (Fig. 3). For this, the sample contaminated with chloride element was then embedded into the special cylinder by applying gradual pressure at slow velocity and, proportional with characteristics of sample consolidation, its pore water was extracted. Pure water extracted from samples, proportional to the height of the sample numbered, and then the chloride ion concentration of each sample was determined. For each tested sample we drew a concentration-observational height diagram. Chloride ions determination using the concentration measurement apparatus (ion meter), which has a chloride electrode, was carried out. At the end of each molecular diffusion test 3 graphs using the observational data were drawn: 1) source concentration-time plot according sampling contamination source, 2) concentration-depth of the sample, and 3) (degree of moisture) water content-depth of the sample. For all tests in the laboratory ambient temperature was 24ºC±2. Table 3 shows parameters and data relating to the molecular diffusion tests. Pure marble rock flour, clay soil, and all mixtures were numbered 0 to 10 as DIF-0, DIF-C, and DIF-1 to DIF-10, respectively. Diffusion coefficients obtained from the samples are listed in Table 3.

Permeability Testing

In addition to having an ability to absorb, the compounds must also be controlled for having the required standard in terms of permeability. For this purpose, the permeability coefficient of this compound was measured by using triaxial permeability [32] and

Table 3. Results from pure marble rock flour and tire crumb diffusion tests.

Parameter	DIF-0	DIF-C	DIF-1	DIF-2	DIF-3	DIF-4	DIF-5	DIF-6	DIF-7	DIF-8	DIF-9	DIF-10
Soil thickness (cm	12	12	12	12	11	12.6	12.5	12	12	11	12.6	12.5
Leachate height (cm)	6	6	6	6	6	6	6	6	6	6	6	6
Volumetric water content (cm^3/cm^3)	0.38	0.28	0.27	0.286	0.3	0.32	0.332	0.28	0.3	0.33	0.38	0.39
Degree of saturation (%)	93	95	98	97	98	95	93	98	96	99	100	100
Average water content (%)	24.8	16.2	16.7	17.4	18.2	19.5	20.8	17.3	19.8	22.8	29	33
Initial source chloride concentration (mg/l)	3500	3500	3550	3550	3500	3600	3600	3550	3550	3500	3600	3600
Soil chloride background concentration (mg/l)	350	250	340	322	311	300	290	245	242	233	215	200
Soil dry density (g/cm^3)	1.53	1.79	1.64	1.64	1.64	1.64	1.63	1.58	1.51	1.44	1.31	1.19
Duration of test (days)	11.6	11.6	11.09	12	12	12	12	11.09	12	12	12	12
[Cl-] effective diffusion coefficient $De \times 10^{10} (m^2/s)$	5.5	4.35	5.2	5.2	5.25	5.3	5.3	8.3	8.8	9.9	11.3	13.6

the ASTM D5084 standard [33]. The samples were cylindrical, with 101 mm height and 114 mm diameter, and were saturated prior to measuring permeability. In these experiments, back pressure was used to remove air spaces in the soil samples for saturation. The permeability values were determined at normal pressures of 55, 120, 225, and 320 kPa by simulating various possible overburden pressures. To ensure reproducibility of the results, two similar samples were tested from the compound synchronically.

Results and Discussion

Molecular Diffusion Test

Figs 3 to 7 show results of the molecular diffusion test on pure marble rock flour and other compounds, respectively. In these figures, the results of each test concentration-time, concentration-depth, and moisture content-depth graphs, is shown. In this diagram, observational data are obtained from the test and predicted data are obtained by computer code POLLUTE as curves fitted as seen in observational data.

Numerical Result

To obtain the molecular diffusion coefficient of chloride ion in the tested sample, geometric, physical, and chemical data of the test with estimate molecular diffusion coefficient presented to computer code, and the results of calculated concentration-time and concentrations-depth drew on the results of observation (fitted) and are compared with each other. This is conducted by trial and error and finally the molecular diffusion coefficient that results in best fitness between the observed data and calculated one was selected as the molecular diffusion coefficients of chloride ion in the sample. According to Table 3, molecular diffusion coefficients obtained from experiments are suitable. However, the pure rock flour during the experiments showed that it has low-compaction capability. To solve this problem, it must be mixed with clay. This problem is solved by mixing rock flour with at least 40% clay. Accordingly, the combination of 40% and more clay with rock flour makes it possible to use it as a liner in the landfill in terms of molecular diffusion.

Permeability Tests

According to the acceptable results of the first and second series compounds in terms of molecular diffusion and having enough clay to absorb, this material must also be controlled to have the required standard in terms of permeability. For this purpose, the permeability coefficient of these compounds was measured by using the triaxial permeability and ASTM D5084 standard. The permeability tests were conducted on the pure rock flour, clayey soil, tire crumb, and the mixtures under different loading conditions in a triaxial permeability test apparatus setup. The samples were saturated prior to measuring permeability. And the results are shown in Fig 11. To ensure reproducibility of the results, 2 similar samples were tested at the same time from the

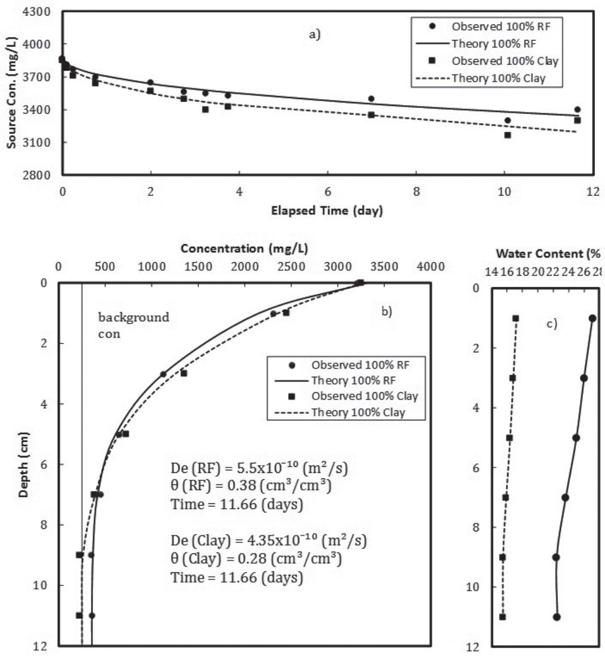

Fig. 4. Observed and predicted results of diffusion test conducted on DIF 0 & DIF C: a) the changes of chloride concentration with time, b) the change of chloride concentration in depth, c) the change of moisture content in depth.

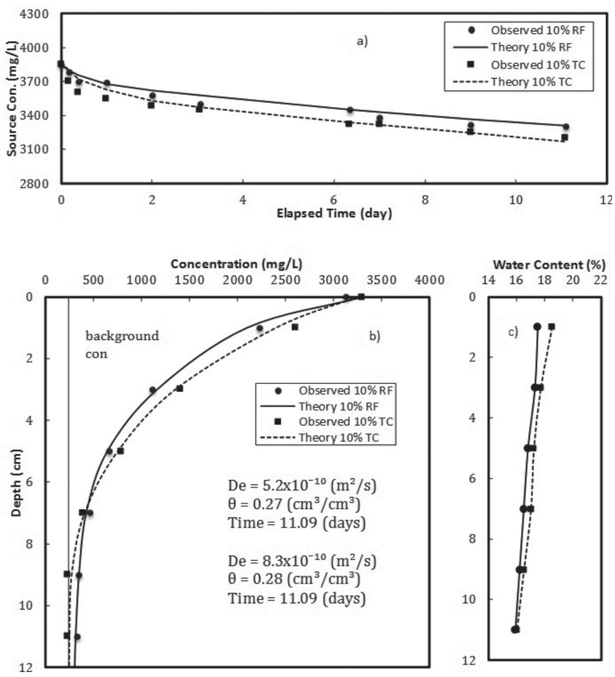

Fig. 5. Observed and predicted results of diffusion test conducted on DIF 1 & DIF 6: a) the changes of chloride concentration with time, b) the change of chloride concentration in depth, c)3 the change of moisture content in depth.

compounds. Figure 10 shows flow-time diagram for (DIF 5) 50% RF+50% clay. By using this graph, seepage (Q) was calculated. Then, using the Darcy formula Q = kiA and having applied hydraulic gradient during the test, the permeability coefficients of all compounds were calculated. Permeability coefficient of the clayey soil singly and all mixtures are low (x10^{-10} – 10^{-9} cm/s) which are consistent with typical low-permeability clayey soils.

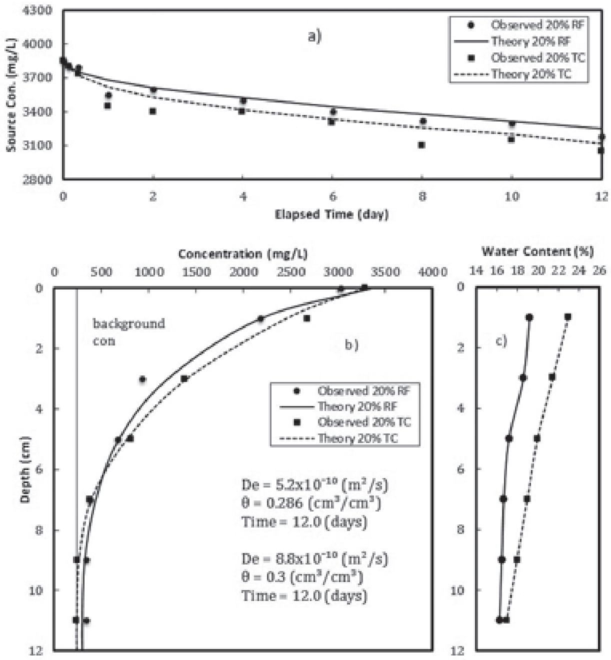

Fig. 6. Observed and predicted results of diffusion test conducted on DIF 2 & DIF 7: a) the changes of chloride concentration with time, b) the change of chloride concentration in depth, c) the change of moisture content in depth.

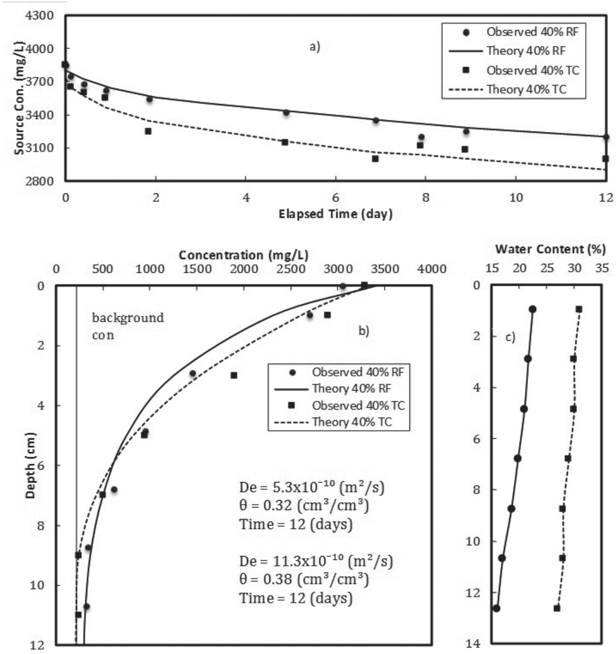

Fig. 8. Observed and predicted results of diffusion test conducted on DIF 4 & DIF 9: a) the changes of chloride concentration with time, b) the change of chloride concentration in depth, c) the change of moisture content in depth.

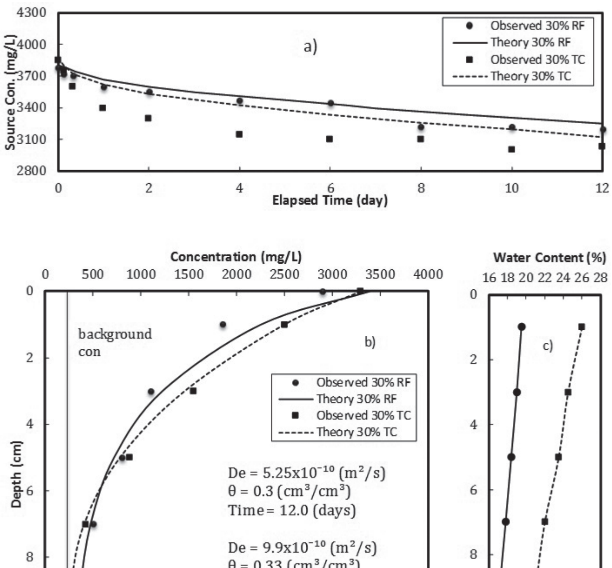

Fig. 7. Observed and predicted results of diffusion test conducted on DIF 3 & DIF 8: a) the changes of chloride concentration with time, b) the change of chloride concentration in depth, c) the change of moisture content in depth.

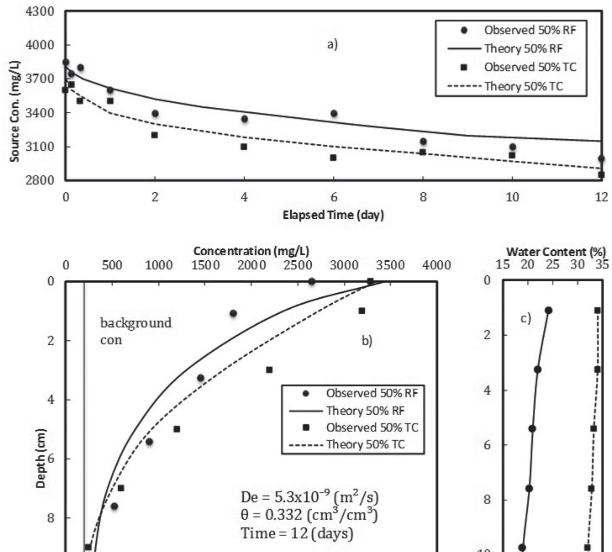

Fig. 9. Observed and predicted results of diffusion test conducted on DIF 5 & DIF 10: a) the changes of chloride concentration with time, b) the change of chloride concentration in depth, c) the change of moisture content in depth.

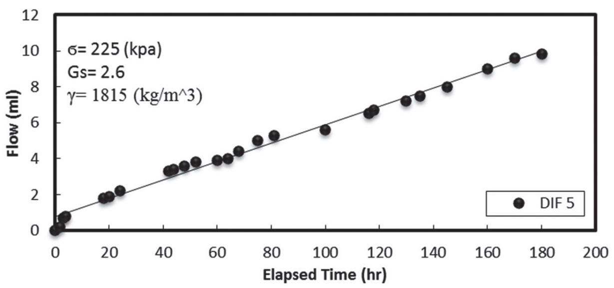

Fig. 10. Flow-time plot in the triaxial permeability test on the compound DIF 5.

The amount of permeability coefficients is within the range recommended for dense clay liners [34].

Permeability increase as the percentage of tire crumb amount increases and the normal pressure decreases. These results indicate that the compounds can be used where low permeability are necessary. The results of permeability test on the compounds show that this material has acceptable permeability to prevent the movement of contaminants and water flow through the advection movement phenomenon.

Figs 4-9 show good adaptation between results of Pollute software and experiment models. Reducing the concentration along the time in the (TC) mixture is more obvious than (RF) mixtures. This difference increase with increases of TC%. With increase TC%, adaptation between Observed and predicted results in concentration-depth plot has been reduced. Fig. 11 shows that permeability increased with increased tire crumb. The effect of the increase of permeability also is visible in water content-depth plot because the moisture content has been increased in depth. With this display to avoid an excessive increase in permeability, the amount of tire crumb is limited to a maximum of 40%.

Landfill liners should have sufficient ion absorbent so that some of the chemical's elements in leachate would be absorbed and refined by some of the leachate harmful elements. Because of suitable minerals, clay soils have good ionic absorption property. According to the gradation curves shown in Fig. 1, pure marble rock flour has about 28% equal grain size of clay (grains smaller than 0.002 mm). However, this material lack of clay minerals, therefore, does not have the property of ion absorbing. Pure marble rock flour, because of granularity and poor cohesion at the runtime of the liner, cannot be compacted easily. Therefore, due to lack of compressibility and ion sorption, pure marble rock flour cannot be used as liner materials alone. Although in terms of molecular diffusion, it can have acceptable diffusion coefficients. The molecular diffusion coefficient and permeability of mixture containing rock flour almost are equal to the molecular diffusion coefficient as compacted clay liner [34]. DIF 4 has 40% clay and 17% the equal grain size of clay. This amount of clay improved compressibility of the material and results in be compacted below the rollers. Furthermore, the existence of this amount of clay gives enough ion absorption potential to the compound, and it has the property of acceptable refinement in terms of absorbing harmful chemicals. The standards recommended a minimal amount for similarly grain size of clay used in making liners is 20% [14]. Therefore, rock flour compounds with a minimum 40% clay compared to pure rock flour in terms of molecular diffusion and ion sorption have an adequate standard. The use of TC based on the molecular diffusion coefficient and permeability should be limited to 40% in combination with clay.

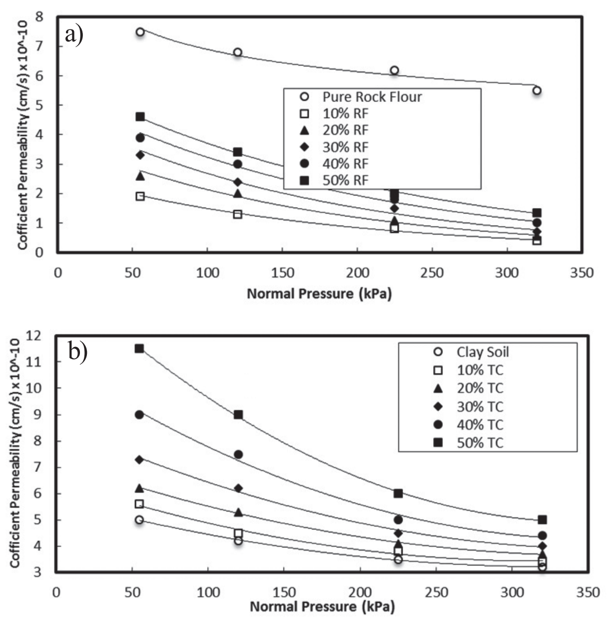

Fig. 11. Relationship between permeability coefficient and normal pressure for a) Clay-Rock Flour mixtures, b) Clay-Tire Crumb mixtures.

Conclusions

Standards recommend a certain amount of diffusion coefficient and permeability coefficient for liners made of clay soils. This compound was prepared, first, in terms of molecular diffusion studied then for hydraulic conductivity. The results showed that the combination made by rock flour has a lower molecular diffusion coefficient than tire crumb compounds. However, use of tire crumb in a maximum of 40% as an additive to clay useable as a liner in terms of molecular diffusion and conductivity in the landfill. The results of the experiments show that the molecular diffusion coefficient increases with the increase of tire crumb and rock flour. Although the increase in tire crumb mixture is higher, molecular diffusion coefficient of compounds of series 1 is 10^{-10} m^2/s and series 2 is 10^{-8} - 10^{-10} m^2/s, this value approximately is about the molecular diffusion coefficient in compacted clay liners. Grain size of the compound (DIF 5) contains 17% same size clay soil (<0.002 mm). It is in the recommended range for clay soils used for landfill liners. Due to the fact that pure rock flour has compaction problems and lack of clay minerals for the absorption of a contaminant, and on the other hand have a suitable molecular diffusion coefficients, can be understood singly cannot be used to make liners. However, the compound DIF 5, due to having 50% clay in its composition and 17% same size clay (plus 50% RF), have suitable compaction and suitable absorbtion. In the next stage, to control the amount of permeability, triaxial permeability tests were conducted on the compounds.

The permeability's pure rock flour and all mixtures are consistent with typical low-permeability clayey soils. In clay-RF and clay-TC mixtures, permeability decreases with the increase of normal pressure and clay soil. Therefore, these materials cannot be used alone to create landfill liner, but in combination with clay can have a useful role in reducing leachate migration. The results show that the compounds containing maximum 50% RF in the first series (C-RF) mixture and up to 40% of the tire crumb in the second series (C-TC) mixture due to the molecular diffusion coefficient and its permeability coefficient in the recommended range for liner and considering compressibility, and ion absorption can be used as alternative material in construction clay liners in a landfill.

References

1. ROWE R.K. Performance of GCLs in liners for landfill and mining applications. Environmental Geotechnics, **1** (1), 3, **2014**.
2. DE CAMILLIS M., DI EMIDIO G., BEZUIJEN A. VERÁSTEGUI-FLORES RD. Hydraulic conductivity and swelling ability of a polymer modified bentonite subjected to wet-dry cycles in seawater. Geotextiles and Geomembranes, **44** (5), 739, **2016**.
3. LIU Y., GATES W.P., BOUAZZA A., ROWE R.K. Fluid loss as a quick method to evaluate hydraulic conductivity of geosynthetic clay liners under acidic conditions. Canadian Geotechnical Journal, **51** (2), 158, **2013**.
4. DI EMIDIO G., MAZZIERI F., VERASTEGUI-FLORES R.D., VAN IMPE W., BEZUIJEN A. Polymer-treated bentonite clay for chemical-resistant geosynthetic clay liners. Geosynthetics International, **22** (1), 125, **2015**.
5. SHACKELFORD C.D, MEIER A., SAMPLE-LORD K. Limiting membrane and diffusion behavior of a geosynthetic clay liner. Geotextiles and Geomembranes, **44** (5), 707, **2016**.
6. SABAT A.K., NAYAK R. Evaluation of fly ash-calcium carbide residue stabilized expansive soil as a liner material in engineered landfill. Electronic Journal of Geotechnical Engineering, **20** (15), 6703, **2015**.
7. PRASHANTH J., SIVAPULLAIAH P., SRIDHARAN A. Pozzolanic fly ash as a hydraulic barrier in land fills. Engineering Geology, **60** (1), 245, **2001**.
8. KALKAN E., AKBULUT S. The positive effects of silica fume on the permeability, swelling pressure and compressive strength of natural clay liners. Engineering Geology, **73** (1), 145, **2004**.
9. KAYABALI K. Engineering aspects of a novel landfill liner material: bentonite-amended natural zeolite. Engineering Geology, **46** (2), 105, **1997**.
10. VARADARAJAN R., VENKATESAN G., SWAMINATHAN G. Removal of Copper Using Clay Admixed with Quarry Fines as Landfill Liners. Polish Journal of Environmental Studies, **25** (1), **2016**.
11. KATSUMI T., BENSON C., FOOSE G., KAMON M. Performance-based design of landfill liners. Engineering Geology, **60** (1), 139, **2001**.
12. SHACKELFORD C.D., BENSON C.H., KATSUMI T., EDIL T.B., LIN L. Evaluating the hydraulic conductivity of GCLs permeated with non-standard liquids .Geotextiles and Geomembranes, **18** (2), 133, **2000**.
13. KING K., QUIGLEY R., FERNANDEZ F., READES D., BACOPOULOS A. Hydraulic conductivity and diffusion monitoring of the Keele Valley Landfill liner, Maple, Ontario. Canadian Geotechnical Journal, **30** (1), 124.34, **1993**.
14. ROWE R., BOOKER J. Clayey barrier systems for waste disposal facilities: E & FN Spon (Chapman & Hall), London., **1995**.
15. AHMED A., UGAI K., KAMEI T. Investigation of recycled gypsum in conjunction with waste plastic trays for ground improvement. Construction and Building Materials, **25** (1), 208, **2011**.
16. AHMED A., UGAI K. Environmental effects on durability of soil stabilized with recycled gypsum. Cold regions science and technology, **66** (2), 84, **2011**.
17. GUNEY Y., KOPARAL S., AYDILEK A.H. Sepiolite as an alternative liner material in municipal solid waste landfills. Journal of geotechnical and geoenvironmental engineering, **134** (8), 1166, **2008**.
18. LAKHANI R., KUMAR R., TOMAR P. Utilization of Stone Waste in the Development of Value Added Products: A State of the Art Review. Journal of Engineering Science & Technology Review, **7** (3), **2014**.
19. SUTCU M., ALPTEKIN H., ERDOGMUS E., ER Y., GENCEL O. Characteristics of fired clay bricks with waste marble powder addition as building materials. Construction and Building Materials, **82**, 1, **2015**.
20. CHEN Y., ZHANG Y., CHEN T., ZHAO Y., BAO S. Preparation of eco-friendly construction bricks from hematite tailings. Construction and Building Materials. **25** (4), 2107, **2011**.
21. VELASCO P.M., ORTÍZ M.M., GIRÓ M.M., VELASCO L.M. Fired clay bricks manufactured by adding wastes as sustainable construction material – A review. Construction and Building materials, **63**, 97, **2014**.
22. ZHANG L. Production of bricks from waste materials – A review. Construction and building materials, **47**, 643, **2013**.
23. BORIES C., BORREDON M-E., VEDRENNE E., VILAREM G. Development of eco-friendly porous fired clay bricks using pore-forming agents: A review. Journal of environmental management, **143**, 186, **2014**.
24. LATIFI N., MARTO A., RASHID A., YII J. Strength and Physico-chemical Characteristics of Fly Ash-Bottom Ash Mixture. Arabian Journal for Science & Engineering (Springer Science & Business Media BV), **40** (9), **2015**.
25. BILGIN N., YEPREM H., ARSLAN S., BILGIN A., GÜNAY E., MARŞOGLU M. Use of waste marble powder in brick industry. Construction and Building Materials, **29**, 449, **2012**.
26. NEAZ SHEIKH M., MASHIRI M., VINOD J., TSANG H-H. Shear and compressibility behavior of sand – tire crumb mixtures. Journal of Materials in Civil Engineering, **25** (10), 1366, **2012**.

27. RAVICHANDRAN N., HUGGINS L. Applicability of shredded tire chips as a lightweight retaining wall backfill in seismic regions. Geo-Congress: Geo-characterization and Modeling for Sustainability, 3496, **2014**.
28. RAMAJI A.E. A Review on Analysis of Stabilization of Soil using Scrap Tire Rubber. Caspian Journal of Applied Sciences Research, **4** (6), **2015**.
29. ANBAZHAGAN P., MANOHAR D. Small-to Large-Strain Shear Modulus and Damping Ratio of Sand-Tyre Crumb Mixtures. Geo-Chicago, 305, **2016**.
30. THOMAS B.S., GUPTA R.C. Mechanical properties and durability characteristics of concrete containing solid waste materials. Journal of Cleaner Production, 48, 1, **2013**.
31. ROWE R.K., QUIGLEY R.M., BRACHMAN R.W., BOOKER J.R. Barrier systems for waste disposal facilities, Spon Press, **2004**.
32. Inc EI. Operating instructions for Tri-Flex 2 permeability test system. ELE Inc UK **1994**.
33. ASTM. Standard test method for measurement of hydraulic conductivity of saturated porous materials using a Flexible Wall Permeameter. American Society for Testing and Materials, Philadelphia, USA. **1997**.
34. ROWE R.K. Liner Systems. Chapter 25 of Geotechnical and Geoenvironmental Engineering Handbook;Kluwer Academic Publishing, Norwell, U.S.A, 739, **2001**.