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CORRELATION OF COEFFICIENT OF FILTRATION AND POROSITY OF CLAYS

CORRELATION DU COEFFICIENT-DE PERMEABILITE ET DE LA POROSITE DE L'ARGILE

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ABSTRACT

In engineering geological practice, very often there is a need for intermediate determination of coefficient of filtration value in clays(k) on the basis of others phisical and mechanical characteristic of clays. Correlation with sieve analysis is very frequently applied. Meanwhile, clays can be differently compacted in the same sieve analysis. When the clay is differently compacted a coefficient of filtration changes. And because of that this coefficient is determined more precisely on the basis of correlation with porosity (n).

To determine the porosity of clays in laboratory, the patterns are dried on the temperature of 1o5 degrees C. The patterns become free from free water and loosely bounded water. So determined values of porosity are greater than porosity that enables the currency of free water in natural conditions, under the activity of gravitation force. In order to present the exact situation, there is a need to show the porosity which can be filled up with free water (nfw). This porosity may be determined out of the difference between the porosity derived in laboratory process (n) and the plastic limit (W_p) because the plastic limit is the amount of loosely bounded water ($n_{fw} = n - Wp$).

In his extentive researches M. Vlahović has determined the correlation between the coefficient of filtration in clays(k) and the coefficient of porosity which corresponds to free water (e_{fw}).

The coefficient of porosity which corresponds to free water(e_{fw}) served to M. Vlahović at the same time as the basis criterion in valueing the process 8f filtration in clays which is not in accordance with Darcys law.

ABSTRAIT

Dans la pratique inge´nieur-géologique il est souvent necessaire de de´terminer indirectement le valuer du coefficient de perme´abilite´ de l´argile(k) a la base des autres caracte´riques physiques et me´caniques de l´argile. On applique souvent la corre´lation avec le fuseau granulome´trique. Cependant, pendant le meme fuseau granulome´trique la compation de l´argile peut etre diffe´rente. Pendant la compation diffe´rente de la meme argile le coefficient de perme´abilite´ se change. A cause de cela ce coefficient peut etre determine plus exactement a la base de la correlation avec la porosite (n).

Pendant la détermination de la porosité de l´argile dans les laboratories les e´chantillons sont se´ches a la tempereture de 1o5°C. D l´echa-

ntillon e´vaporent alons l´ eau libre et l´ eau osmotique.Les valeurs de la porosite´ ainsi de´terminees sont plus grandes de la porosite´ par laquelle peut couler l´eau libre dans les conditions naturelles,sous l´influence de la force de la gravitation. Dans le but de la pre´sentation plus exacte il est ne´cessaire de pre´senter la porosite qui peut etre remplie par l´eau libre (nfw).Cete porosite peut etre definie de la difference entre la porosite´ obtenue par le proce´de´ dans les laboratoires(n) et la limite de plasticite´(Wp), car la limite de plasticite´ repre´sente la quantite´ de l´ eau osmotique (nfw) = n - Wp).

A la base des investigations volumineuses, M.Vlahović a de´termine´ la correlation qui existe entre le coefficient de permeabilite´ de l´ argile (k) et l´ indice des vides qui peut etre remplie par l´eau libre (e_{fw}).

L´ indice des vides qui se rapporte a l´eau libre du (efw) a servia M. Vlahović en meme temps comme une base du criterium pour l´evaluation quand le processus de la filtration dans les argiles ne se développe pas surement conforme´ment a´ la loi de Darcy.

INTRODUCTION

In engineering geological practice, very often there is a need for intermediate determination of coefficient of filtration values in clays(k) on the basis of others physical and mechanical characteristics of clays. In that case the correlations of coefficient of filtration (k) are most frequently used with sieve analysis or with void ratio (e). In the meantime, clays can be differently compacted in the some sieve analysis. The coefficient of filtration (k) is also different when the degree of condense varies in the same clay. Because of that the correlation of this indicator and coefficient of filtration(k)offer more precise results.Knowing that K. Terzaghi (8) has restored the empiric correlation defined with the equation:

$$k = f(e-0,15)^3(1+e) \qquad (1)$$

f = 1o-8 = const.

e = void ratio.

Kozeny (1927) has theoretically derived the equation of correlation between the coefficient of filtration (k) and porosity (n):

$$k = F\,\frac{n^3}{(1-n^2)Sa^2}$$

in which:

F = o,5 = const. ↖ $(1-n)^2$

n = porosity and

Sa- specific area of porosity

Carman(1938) has announceed that the equation (2) can be inserted inthe best way with the results of experiments he has tried on the patternsof clays if F=0,2-isknown as Kozeny - Carman´s equation, if the value of F is 0,2.

Considering the results of experiments on the patterns of clays Nishida and Nakagawa (5) have determined the equation by which the coefficient of filtration(k) is ruled by the value of void ratio(e) and plasticity index (Ip):

$$\log k_{10} = \left[\frac{e}{0,01 I_p + 0,05}\right] - 10 \qquad (3)$$

The equation of correlation of coefficient of filtration(k)and void ratio (e) by Šuklje (7) is:

$$k = \mathrm{Exp}\,(0,60206\,e_v - 7,9633) \qquad (4)$$ 2

The equations (1), (3)and(4) are very simple and convenient for use.

POROSITY WHICH CAN BE FILLED UP WITH FREE WATER (n_{fw})

The precision of correlations defined by the equations (1),(3) and (4) was tested on the value of coefficient of filtration (k) and void ratio (e) that were taken for experiment. For this purpose M. Vlahović has shown on the graphic the equations (1), (3) and (4) as wel as the results of 120 tests on the diagram, Fig. 1. Clays and silts of different characteristic of plasticity were considered by comparison (CI; CH; ML;MI; and MH). It can be seen on the diagram (Fig. 1.) that a part of the results

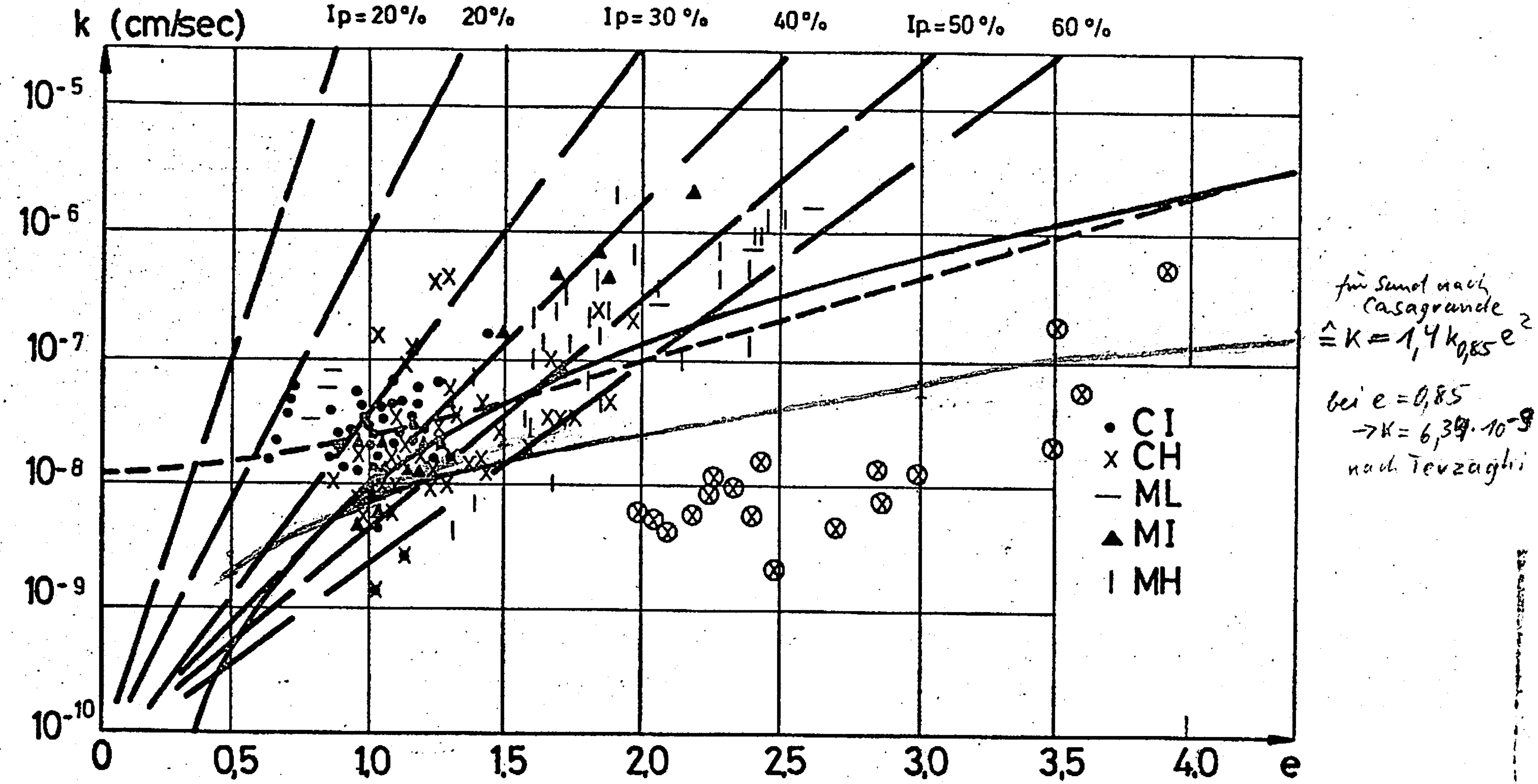

Fig. 1. Correlation e–k

——— Terzaghi ; —— —— Nishida and Nakagava ; – – – – – Šuklje

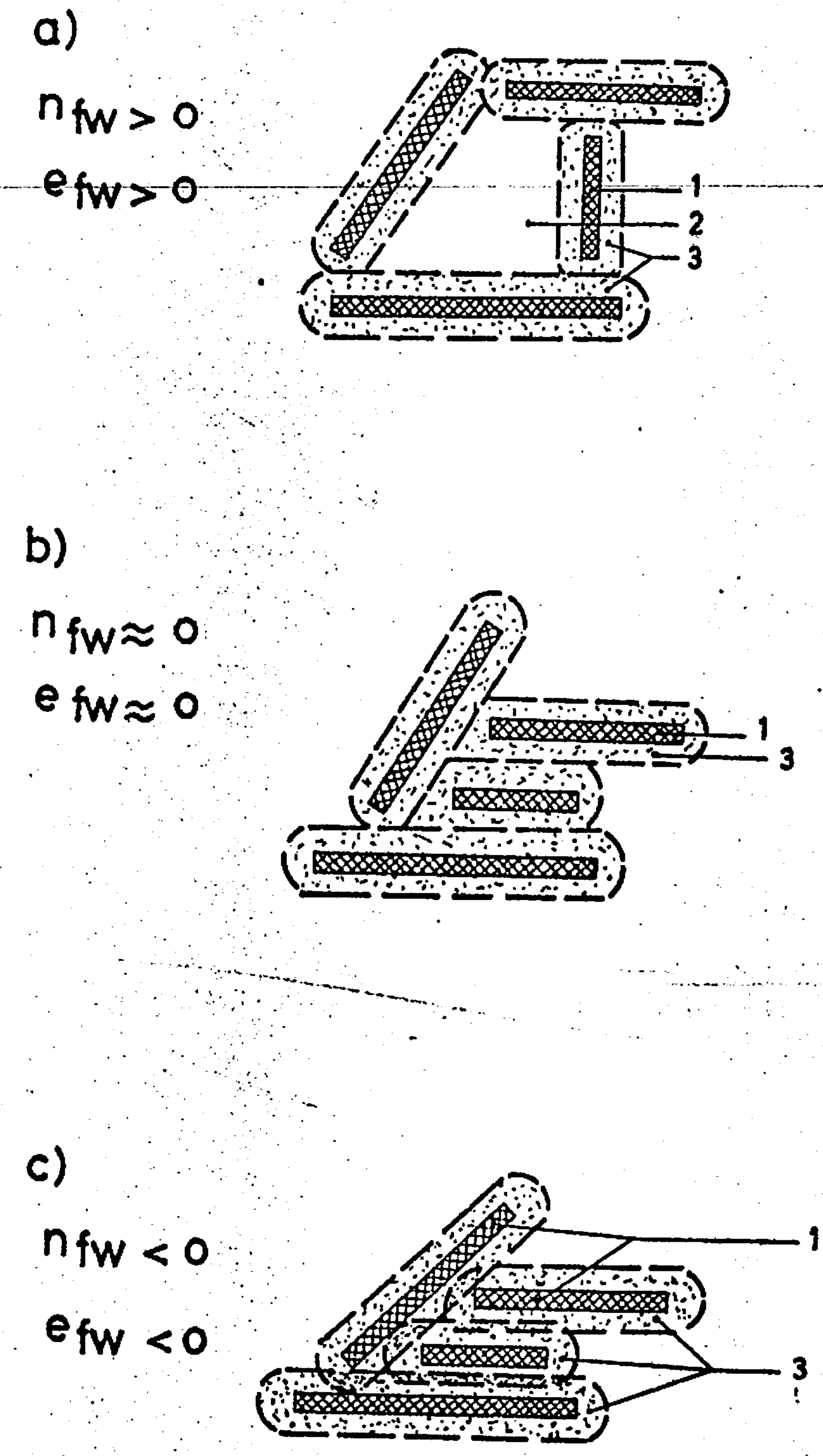

Fig. 2. Arrangements of the free water and loosely bonded (osmotic) water.
1 – clay ; 2 – free water ; 3 – osmotic water

withdraws considerably from the area in which there are the majority of data. Those results are encircled so as to be better seen.
The noticed withdrawals can be explained by possible"mistakes" of machines or the operators during the experiment. Nevertheless,detailed studies show that the withdrawals appear, as a rule with the patterns whose plastic limits (Wp)are considerably greater than with the others samples. That means that those withrowals can be influenced by plastic limit (Wp) or the quality that powers the plastic limit (Wp). It was also observed that the void ratio of those samples is e=2,0 - 3,9.

The values of void ratio are determined in laboratory by experiments when the patterns are dried on the temperature of lo5 degrees C.In this way free water and loosely bounded water evaporate from the patterns. In fact the values of coefficient of filtration are determined on water saturated samples with temperature about 20 degrees C. On this temperature loosely bounded water and mineral particles are parts of a whole. In that case porosity that canbe filled up with free water is smaller than that determined by driyng of samples on the temperature of lo5 degrees C. It seenes that mistakes are inevitable if the porosity determined by standard treatment in a laboratory is applied. Those mistakes are seen either in theoretical studies and solving practical problems of filtration and consolidation. To avoid this it is necesary to introduce a term porosity which can be filled up with free water (n_{fw}).

Accepting the fact that the plasticity limit (Wp) with its value approximatiely responds to the value of loosely bounded water (4) and (6) the equation can be written as:

$$n_{fw} = n - W_p \qquad (5)$$

In equation (5) the simbols are:
nfw - porosity which can be filled up with free water,
n - porosity determined by drying of patterns on the temperature of lo5 degrees C,
Wp - plastic limit.

According to the equation (5) the coefficient of porosity of free water (e_{fw}) can be defined by the equation:

$$e_{fw} = \frac{n - Wp}{1 - (n - Wp)} \qquad (6)$$

By introducing the term porosity which can be filled up with free water it is possible to understand more clearly the nature of process of filtration and consolidation in water saturated clays.

When $n_{fw} > W_p$, respectively $n_{fw} > 0$ and $e_{fw} > 0$, there is porosity which can be filled up with free water in clays (Fig. 2.a.). Free water is then included in the process of filtration and filtration is performing according Darcys law.

When nfw is equal $W_p$or $n_{fw}=0$ respectively $e_{fw} = 0$, the layers of loosely bounded water founded about all mineral particals come into contact with one another by their outer parts (Fig. 2.b.).

When $n_{fw} < W_p$, respectively, $n_{fw} < 0$ and $e_{fw} < 0$, from the pores of clay all subterranean water is banished as well as part of loosely bounded water (Fig. 2. c.).

In the last two cases (Fig.2. b. and c.) in the process of filtration only loosely bounded water cantake part. Filtration and consolidation in clays surely do not perform in accordance with Darcys law.

CORRELATION BETWEEN THE COEFFICIENT OF FILTRATION (k) AND THE VOID RATIO WHICH CAN BE FILLED UP WITH FREE WATER (e_{fw})

To establish the correlation betwen the coefficient of filtration (k) and void ratio which can be filled up with free water (e_{fw})there were used the data of the experiments shown on the diagram Fig.1. The values of void ratio which can be filled up with free water (efw) are determined according to porosity (n) and plastic limit (Wp) and applying the equation (6). The values of coefficient of filtration (k) are determined immediately by experimenting with the patterns built into the instruments with the corresponding level of water. The values of these two indicators are drifted on the diagram of correlation e_{fw}- k. Fig. 3. The data that withdrew from the correlation e- k shown on Fig. 1, are also encircled on this diagram.On this diagram

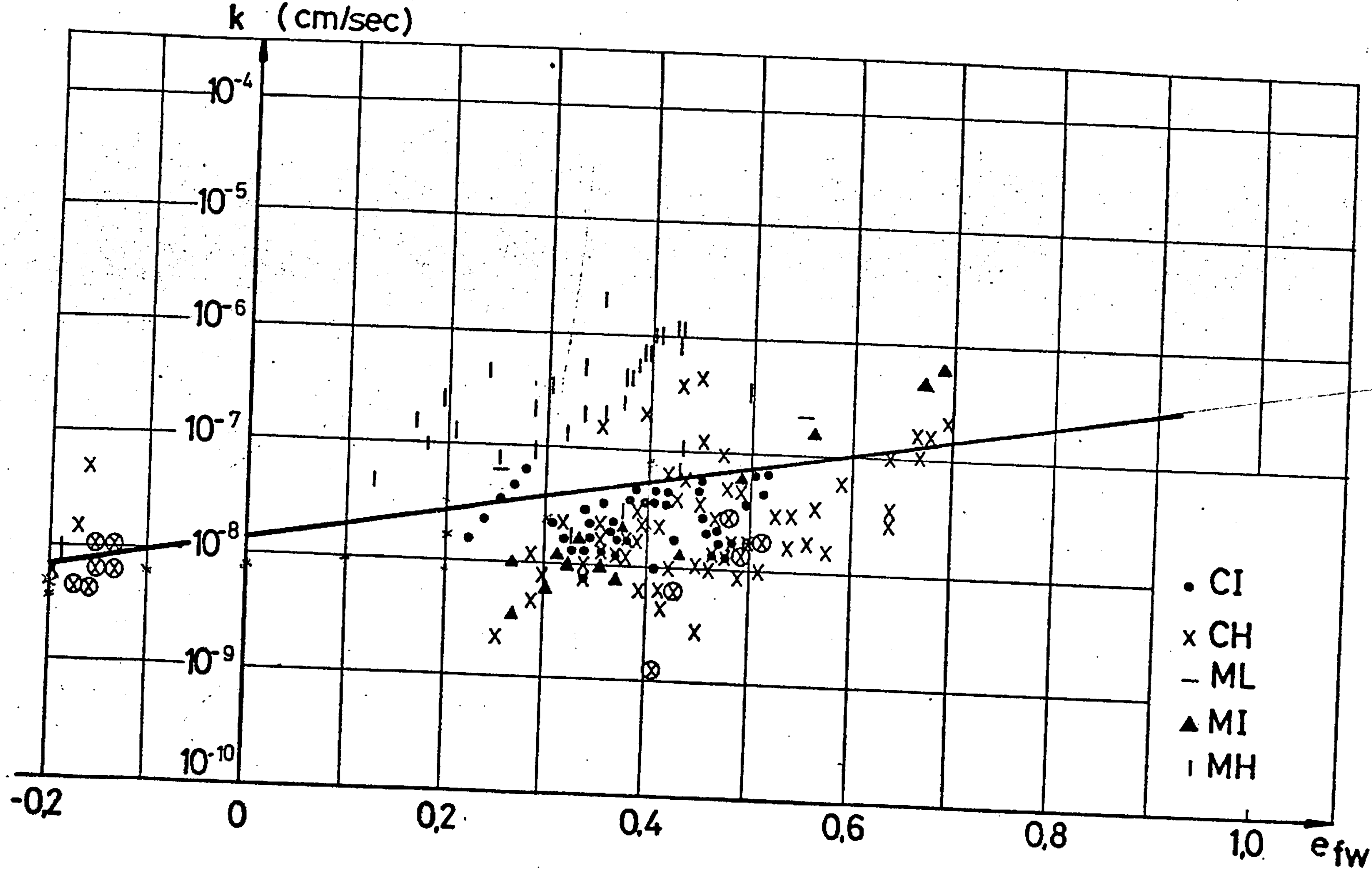

Fig. 3. Correlation $e_{fw} - k$

(Fig. 3). it is clearly seen that the data are now inserted in tee correlation e_{fw} -k. They are either in the area with others data or on the part of the diagram with negative values e_{fw}($e_{fw}<0$).

By the method of statistic mathematics a equation is derived which approximatively shows the data on the seen diagram Fig.3. It runs:

2

$$k = Exp(1,6\ e_{fw} + 2,1) - 1o \quad (7)$$

Correlation e_{fw}- k defined by the equation (7) is graphically represented on the diagram Fig.3, as well as the others data. The correlations of the defined equations(1) (3) and (4) are not based on the values of void ratio which can be filled up with free wather (ef_w). Because of that they can not be directly compared with the data shown on the diagram Fig.3.

According, to analyses based on the statistic mathematics principles, it was stated that the withdrawals of the equation graphic (7) from the experimental data shown on Fig. 3, smaller than the withdrawals of the equation graphic (1), (3) and (4) and naturaly having in mind the data from the Fig.1. Besides that the prolongation of the equation graphic (7) represented with discontinuous dashes on the diagram Fig. 3 approximate quite well the data with the negative values e_{fw}.

CONCLUDING REMARKS

In engineering geological practice for intermediate determination of coefficient of filtration (k)the most frequently used are the correlation of the indicator with sieve alalysis or with void ratio (e),

When the degree of compactnes in the same clay is different the coefficient of filtration(k) is diferent too.

Consequently, the coefficient of filtration can be determined more precisely upon the void ratio.

Correlation e - k can be simply defined by using any equation (1), (3) and (4).

Comparing the correlation e-k defined by the equations (1), (3) and (4) with the experimental results upon 12o samples of clays and silts of different characteristics of plasticity (CI; CH; ML; MI; and MH) a considerable withdrawals were stated. The source of those withdrawals is in neglect the presence of loosely bounded water in clays and silts in natural conditions but during the experiments, that loosely bounded water removes from the samples.

The neglect of loosely bounded water is eliminated by the introduction of the term porosity (n_{fw})or void ratio which can be filled up with free water (e_{fw}). Both indicaters help to understand more clearly the character of filtration proces and consolidation in water saturated clays and silts.

When the $n_{fw} \leq 0$, respectively $e_{fw} \leq 0$ the proceses of filtration and consolidation are not performed in accordance with Darcys law.

Applying correlation between the coefficient of filtration (k) and void ratio which can be filled up with free water (e_{fw}) represented by the equation (7) the values of coefficient of filtration are determined more precisely than by the equations (1), (3) and (4).

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