GEOTECHNICAL AND SOIL MATERIAL CONDITIONS

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Abstract: This topic of discussion is about the related criteria on the soil behavior under pressure due to the plasticity and elasticity of clay material during construction. this topic relates to an Environmental Sanitation of Hazardous waste within our surroundings. It is about soil structure which creates some changes in Electrical Clay Particles with an overview of coverage.

Keywords: Soil Material, Soil Formation, Geotech Method.

1. INTRODUCTION

1. SCOPE. Methods of determining earth pressure with chemical elements acting on walls and retaining structures are summarized in this chapter. Types of walls considered include concrete retaining walls and gravity walls that move rigidly as a unit, braced or tied bulkheads of t h i n sheeting that deflect according to the bracing arrangement, and double-wall cofferdams of thin sheeting to confine earth or rock fill.

2. RELATED CRITERIA. Additional criteria relating to the design and utilization of clay liner for Leachate towards the controlling Manhole appear in the following sources: Subject Sources are as follows.

1.0 METHODOLOGY: EXPERIMENTAL STEPS ON METHODOLOGY.

1) **Definition:**
    Soil Structure = Interparticle Forces + Fabric
    Types & negative   Orientation & distribution
   Magnitude of particles

2) Interparticle Forces: want to describe how shear structures (τ) and normal stress are transmitted between soil particles. Start with normal stress.

- From <u>effective stress principle</u>   (L & N Sect. 16.2)
   Effective normal stress ($\sigma^1 = \overline{\sigma}$) = total normal stress (σ) minus
                        Pure water pressure (u = uw)

- The effective stress is transmitted by force acting between the soil particle (here was previously termed "intergranular" stress)
- In general for cohesive soils, this transmission occurs at two stress tackle (it has two components a la system
   σ^1 = net short range (contact) stress x content ave. ratio
   + net long range stress due to surface (double large) forces
- We will use later that shear stresses (τ) are primarily carried by contact stresses.

3) Fabric: We will distinguish between fabric at the macro-level (can observe visually) vs. that at the micro-level.
4) In theory, soil structure completely defines soil behavior. But in reality, only can use in a qualitative fashion to help product/explain some aspect of soil behavior (e.g, what causes "quite clay").
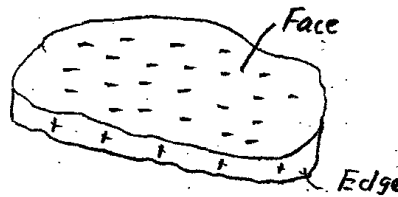
Fig. 1.1a. Clay Particle Illustration

a) The edges of clay particles usually have a positive charge at low to moderate PH*. But increasingly PH may change this to a negative charge. Das.(2004)

b) The NET charge of clay particles is always negative. Hence the application of an electrical fluid to a suspension of clay particles will cause the particular to move to the anode. Called electrophoresis. Das. (2008)
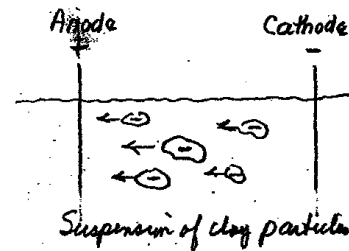
Fig.1.1b: Section of net charge of clay

1.2 EXCHANGEABLE ION MATERIAL

Since the soil must be electrically neutral, the following results appears.

The negative faces attract underline exchangeable cation (Na^{+1}, Ca^{+2}, Mg^{+2}, ch)

Positive edge attracts exchangeable anion on cation if negatively charged Edge repair of clay Particle + pure water often oven drying
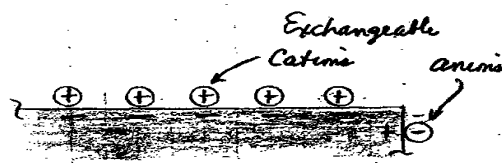
Fig. 1.2: Element of Cation

TABLE 1.1   TABLE OF CATION AND ANIONS

*PH = - Log$_{10}$ Cone	(H$^+$ cone)	PH < 7 = acidic (high H$^+$)	PH > 7 = basic (low H$^+$, high OH$^-$)

2   Surface Charge Density (σ_0)

$\underline{\sigma_0 = \text{No. of charges}}$ =   Cation Exchange Capacity   =   CEC

Unit area   Specific surface area   SSA

$\dfrac{\text{CEC in milli- Quovalants}}{100g}$ = $\dfrac{(10^{-3})(A_N)(e_c)}{100}$ =   0.965 C/g

($A_N = 6.02 \times 10^{23}$ molecules/mol; ec = electrical change = 1.6×10^{-19} coulomb)

From Shang, Lo & Quiglay [1994, CGJ, 31(5)]

TABLE 1.2: CLAY MINERAL VS AVE. SPACINGS

| Clay Mineral	CEC (Meg/100g)	SSA (M²/g)	σ0 (C/m²)	Ave. Spacing (A) Between Charges
Kaolinite	5	15	0.32	7.1
Ulite	25	84	0.29	7.5
Na. Mont	100	800	0.12	11.5

Overview of Coverage

1)   Clay-water forces
- Water vapor absorption ~ nature of "absorbed water" ($t < 10\text{-}15\ \text{A}^0$)
- Interaction between clay particle
  Long-range double layer) force}   Physics-chemical effective
  Short range (contact) force}   stress equation
- Strength generation in soils
2)   Soil structure: effects of mineral correspondent and environmental factors .

2.0   CLAY WATER FORCES; FOR WATER ABSORPTION PROCEDURE

2.1   Absorbed Water
1)   Water Vapor Absorption

a)   Start with oven-dried clay; increase Relative Humidity (RH) and measure water content (w)
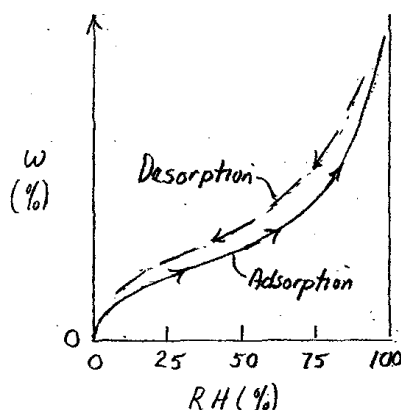
$$RH(\%) = \underline{Pw} \times 100$$

Pw = Vapor Pressure of water

Ps = Saturation Vapor Pressure at same Temperature

(Barshad 1955)

Fig. 2.1; Absorption Vs. Adsorption. Braja. (2007).

Table 2,1. Water Content (%)

Mineral	RH = 50%	90%	95%
Na Kaol.	0.8	2.0	2.5
Na. mon+.	14	28	37

b)   Absorption vs. RH (from 1.322)

- At RH = 50%,   w(%) = (0.05) (SSA m²/g), is avg. $t = 5\ _\text{A}^0$
- At RH = 99%,   H2Ot = 10 – 15 A^0 (3 – 5 Molecular thicknesses)
c)   From thermodynamics, can compute equivalent pressure of attraction (tensile pressure required to remove absorbed water) as expressed in terms of capillary pressure (uc) = soil suction (S)

Soil Suction (S) = $\dfrac{P_w R_g T}{M}$ in $\left(\dfrac{100}{RH}\right)$ P_w = density of H_2O (998 kg/m³)

R_g = gas content (8.314 J/m+e.K⁰)

S(bar) = $\dfrac{1350}{RH}$ in $\left(\dfrac{100}{RH}\right)$ at 20⁰c   T = absolute temp. (213 + temp. ⁰C)

M = molecular mass of H_2O

1 bar = 100 kpa   (18.0 g/mol)

2.)

RH(%)	S(bar)	S(atm)	
50	936	924}	very strong attraction
90	142	140}	very strong attraction
2	13.6	13.4}	very strong attraction

Table 2.3; <u>Mechanisms of water vapor absorption</u>   (CCL 1.322; Chap. 6 of Mitchel (l993)

			Cation	Hydrated ion (A)
a)	H-bonding}	partially most	K⁺¹	9 + 2.5
b)	Cation hydration}	important	Na⁺¹	13.5 + 2
c)	Omitation of H_2O dipole		Ca⁺²	19
	In- elastic fluid (quatinatle)		mg⁺²	21.5
d)	Vander Waals forces			

(JKM, 1993 P122)

3) Physical Properties of "Absorbed Water" Layer.

(Note: Discussion applies to fust 10-15 A⁰ of water adjacent to the mineral surface for charge in contact with the water, i.e with the double layer)

All agree that the structure of this water layer is diffused from that of ordinary water. However, two structures of thought are;

1ˢᵗ – is "us-like" with a high viscosity ~ generation of a cohesive strength that is responsible for cup effects

2ⁿᵈ – is a man-like a 2-D liquid similar to ball bearings on a magnetic surface (R.T. Maintain of MlT)

Therefore, does not constitute to strength of soil conditioning.

Both: layers inhibit material-to-material contacts

<u>2.3</u>   <u>Diffuse Double Layer (DL)</u>

1)   Clay particles in pure water   (+ = exchangeable cation)

Bulk (free) water

2)   Effect of Pore Fluid Chemistry on Double Layer Thickness

a)   Thickness <u>decreases</u> with:

- Increasing cation valence (v): $\propto 1/v$
- Increasing salt core. In bulk water (Co): $\propto 1/\sqrt{c_o}$
- Decreasing deductive constant (D): $\propto \sqrt{o}$

b)   Example calculation (See page 7a for the definition of Debye length)

T = 20⁰C

Table 2.4

Pore Fluid	Dielectric Constant (D)	Cation Valence & Bulk Conc. (Co, M)		Debye Length (t_0, A^0)	
Water	80	Nacl	10^{-4}	305	
		"	10^{-3}	96	
		"	10^{-2}	30	
		"	10^{-1}	10	
		CaSo4	10^{-3}	48	
Alcohol	20	Nacl	10^{-4}	152	x ½ vs H$_2$O
		"	10^{-2}	15	
	CCL4	2	Nacl	10^{-4}	48
			"	10^{-2}	5

3)   Debye Length and Related Phenomena
(From J.K. Mitchell (1993 book) & Shang et.al, (1994, CGJ 31(S)]

a)   Equation for Debye Length, to (measured <u>from</u> Stem Layer)

$$t_D = \left(\frac{E_o \, D \, R \, T}{2 \, n_o \, e_c^2 \, v^2}\right)^{as} \text{ where}$$

E_o = permeability of vacuum (8.854 x 10^{-12} C^2/J.m)

D = deductive constant (see below)

K = Boltzmann constant (1.38 x 10^{-23} J/oK)

T = temperature (oK = 273 + °C)$tP(A) = \underline{0.020} \sqrt{\frac{D.T}{C_o}}$ n_o = bulk cation cone

(numta/ms) V e_c = electric charge (1.60 x 10^{-19}C)

V = cation valence

Where C_o = cation concentration in the bulk
Water in lead/lita (M = mol on)

b)   The Debye Length is commonly used as a measure of the DL thickness and is the distance between a parallel plate condenses having the same surface charge density (σ0) and electric potential (V = volta)
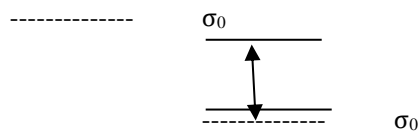

Fig. 2.2; Surface Change Density

c)   Di elective Constant, D

•   Force (F) between two electric charges (Q, Q') separated by a distance d
For Vacuum.

$$F = \frac{Q \, Q^1}{E d^2}$$

where   E = permittivity = E_o.D
= lose with which molecular can be polouigid
and qualitative is an electric fluid.

•   Polar molecular like H$_2$O (high D) ~ less force of attraction between DL cation & and the negative surface charge ~ expanded DL

Fluid	D (At Room Temp)
Water (H_2O)	80
Ethyl Alcohol ($C_2 H_6O$)	24

2.4 Double Layer Repulsion   (for infinite parallel particular)

1)   Consider two parallel clay particles in pure water repulsion between 2 particles is caused by fact that H_2O molecules want to enter the double layer minute to reduce the chemistry of cation.

2)   Is exactly analogous to development of an Osmotic Pressure (P_o) From Ideal gas Law ($PV = nR_gT$) $P_o = R_gT$ (Δ ion concentration; cation + anion) $R_g = 8.314$ J/mol-^oK = 0.08205 let an-atom/mol- ^oK For
T = 293^oK = 20^oC

$$\therefore P_o(atm) = 24\ (\Delta\ Cma, M = mol/L)\ cation + anion)$$

Salt core. (M) =	10^{-3}	10^{-2}	10^{-1}	1
P_o (atm) =	0.024	0.24	2.4	24

3)   Value of DL repulsion (P_r) from Govy- Chapman theory with connection for stem layer: see Fig ;2-3a - b for detailed plot.
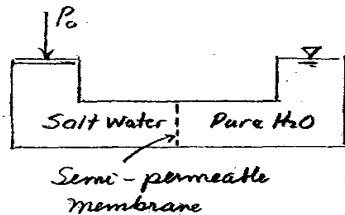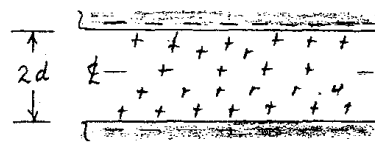

Fig. 2.3a; Profile view

Fig. 2.3b. Plan View of Stem Layer

For $C_o = 10^{-3}$ molar

P_r(atm)	2d(A^0)		Valence	
1	90	+1}	x	½ spacing
4	45	+"}	x	½ spacing
10	30	+"}	x	½ spacing
1	45	+2}	x	½ spacing

Very low Pr Fn sea water
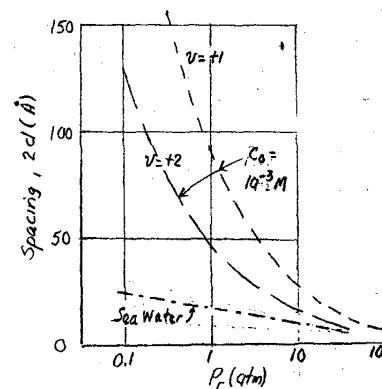(35 g/L salt = 1.1 M, Co = 0.6 M)

Fig.2.4; Spacing Vs Sea Water

2.5 Supplement on Double Layer Repulsion

  Single Double Layer   Ion conc vs distance   Na & Ca Montmorillonite
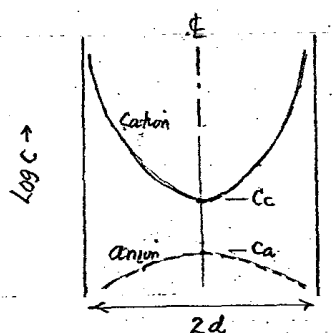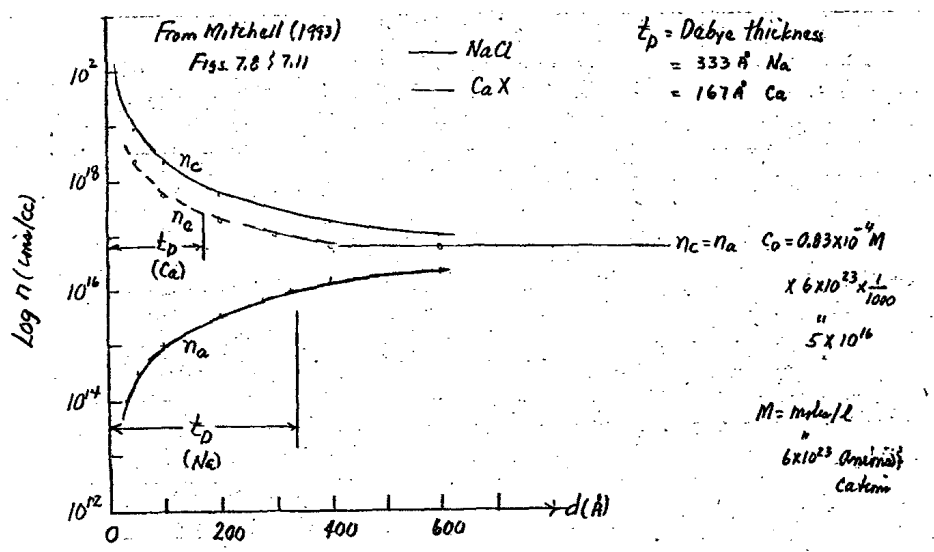

Fig 2.6; Graph of Log C

Interacting Double Layer

(valence $V = V_c = V_a$; C_o = bulk concentration, M-Moles/e)

$P_r = R_g T (C_c + C_a - 2C_o)$ $T = 273 + oC$
Mid -   Bulk $Rg = 8.314$ J/mol.oK
Plane   C.M, moles/e

$P_r(bar) = 24.37 (C_c + C_a - 2C_o)$ at 20^0C, $D = 80$ F_nH_2o

$$\left\{ \begin{array}{llll} C_o(m) & V & 2d\,(A) & Pr(bar = atm) \\ \hline 10^{-3} & 1 & 200 & 0.2 \\ & & 100 & 0.8 \\ & & 50 & 3.3 \\ & & 25 & 12 \\ 10^{-3} & 2 & 100 & 0.2 \end{array} \right\} \; C_o = 0.06\frac{g}{e}\,Nacl$$

$$= \tfrac{1}{2}\,\text{spacing}$$

0.13

$$\left\{ \begin{array}{llll} C_o(m) & V & 2d\,(A) & Pr(bar = atm) \\ \hline 10^{-3} & 1 & 200 & 0.2 \\ & & 100 & 0.8 \\ & & 50 & 3.3 \\ & & 25 & 12 \\ 10^{-3} & 2 & 100 & 0.2 \end{array} \right\} \; C_o = 0.06\frac{g}{e}\,Nacl$$

$$= \tfrac{1}{2}\,\text{spacing}$$

2.6. Other Clay-Water Forces

1)   Vander Waals Attraction   (short to long range)

a)   For parallel particles $P_a = \underline{A''}\,[\;\underline{1} + \underline{\;248\pi}\;\; d^3\;\; (d+s)^3\;\; (d+s/2)^3]$

A''= Hamaker Constant = 2.5 x 10^{-20}J (Norch & Ring1984)
P = Particle thickness   see Fig. 2.4 for 2 – 1to plat fn S = $100A^0$ (Ulite)

b)   Compared to double layer repulsion fn clay. Water vapor

- Fn very low salt corre. , $P_r > P_a$ ~ particle repel each other during sedimentation

- For sea water, $P_r < P_a$ ~ <u>Flocculation</u> of Sediment Flore

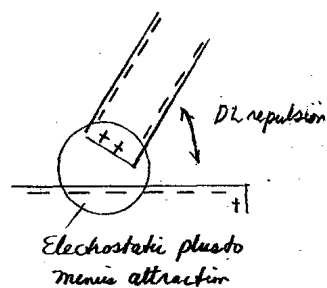2)   Edge – to – face electrical attraction (short to medium range)

Sketch Fn 2 particle in water with PH $\leq$ 7

Fig. 2.7; Electrolyte material

- Can provide very substantial attraction between particular (esp. Kerlonite)
- Add dispersant (large anion: TSPP) to clays to neutralize positive edge change to pursuant attraction during hydrometer tests
- Increasing PH ~ less positive edge change (on even goes negative) ~ reduced attraction (negetive repulsion)
3)   For mineral to minerial contact between particles
a)   Attraction due t primary value bonding (covalent & cones)
b)   Born repulsion which presents interpenetrating method

2.5 Physico-Chemical Effective Stress Equation   (Ladd 1961

1)   Physical model

•   Look at how effective normal stress
is transmitted between two particles
per unit area.

•   Assume intraparticle <u>contacts</u> at spacing
$2d \leq 20A^0$ (Amerihat arbitrary)

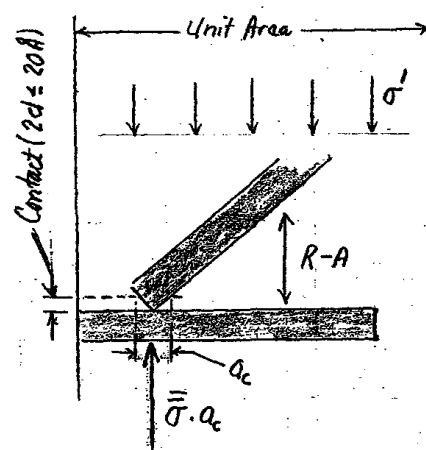•   ac = contact area nets = contact
            area per unit area

Fig. 2.8. Pressure From Chemical Effect

2) Equation for components of Effective (normal) stress, $\sigma^1 = \sigma - u$

   $\sigma1$ = Net contact Stress + Net long range shear $= \sigma.a_c + (R - A) = (=\sigma r - = \sigma_a)a_c + (R - A)$

•   R = double layer (osmotic) repulsion = $F(P_r)$
•   A = long large Vander Waals attraction = $F(P_r)$
$=\sigma$ = contact repulsion stresses $(=\sigma)$ – contact attraction stresses $(=\sigma_a)$
• $=\sigma$ = resistance due to displacement of "assorted water"
+ Born repulsion (if mineral to mineral contact)
• $=\sigma_a$ = short range Vander Waals attraction = $F(P_a)$
+ edge-to-fall electrostatic attraction
+ punning valence bonding (if mineral to mineral contact)

3.0   <u>STRENGHT GENERATION IN SOIL</u>

3.1   <u>Frictional Resistance</u>

1)   Tazaghi – Bowdon – Talon <u>Adhesive</u> theory (developed for metals)
                                                (1940s)

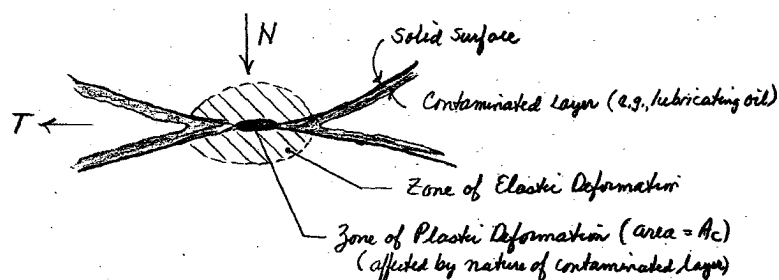   all surfaces are rough at microscopic scale. Therefore, get contacts at asperities

Fig;3.1. Section of microscopic Scale

Normal force = $N = A_c . = \sigma_y$, where $=\sigma_y$ = yield stress
- Shear force = $T = A_c . = \tau$, where $=\tau$ = shear strength due to punning valence bonding

Increasing $N \sim$ increasing $A_c \sim$ increasing T } constant coef. of
Decreasing $N \sim$ decreasing A_c due to elastic } friction = $T/N = =\tau/=\sigma_y$
Rebound $\sim$ decreasing T}= $\tan \varnothing^1_N$

- Testa on Quality by Bowell (1966)

Ultrasmooth surface, $\varnothing^1_N = 10 - 35^0$ is function of surface contamination
Regular, rough surface, $\varnothing^1_N = 25 + 5^0$ independent & contamination

2) Tazaghi - Granular Soils

$\sigma1 = =\sigma.a_c$, where $=\sigma = 10,000$ atm at typical stem level

(Fn σ^1 = atm, $a_c = 0.01\%$)

3) Cohesive Soils
a) Are there mineral to mineral contacts in change at typical $\sigma1$ levels (say $\sigma^1 \geq 1$ atm)?

. Ladd (1961) bach calculated likely value of contact shear stresses $\sim =\tau = 100^1$s of atom. $\therefore$ must have punning valence bonding at min-min contacts
. Metchell (1993 bach), but based on metchell in 1960's using rate percent theory $\sim$ activation energy of bonding

Material	activation Energy (Kcal/Mol)	Calorie x 4.2 = J = N.m
Water	4 – 5	
Ice	10 – 15	
Metals/Contacts	≥ 50	
Soil	30 + 5	sands & clays, both wet & dry

b) Conclusion: change develop a functional resistance ($\varnothing_1$) due to punning valance bonding at contacts. <u>However, get wide variation in $\varnothing_1$ due to wide variation in</u>

CONCLUSION AND RECOMMENDATION

Based on the QA/QC reports on the laboratory preparation of clay soil material for the construction of liner and berm wall, the item specifications were applied wherever necessary (see page 10 for these specifications). The attached borrow test results shown on pages 23 and 4 are the MDP relationships for the material that were used during the construction for the liner area and was also used for hate berm walls.

The recommended moisture contents were based on these MDP'S and were provided. For sample P-2, 14.2% is actually wet of optimum, even though it was approximately 2% below optimum for sample P-3. Therefore, 14.2% minimum was recommended for the line area soils, because it has being demonstrated to be sufficient in achieving the required permeability test results.

The actual in place test results as the date the construction started are attached (see the attached laboratory permeability test result on page 4) and it show that the in palace permeability was achieved at 3×10^{-8} cm/sec or below using the MDP evaluations as was proposed.

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