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Water Injection Dredging- Application to the Dams Analytic and Experimental Approach

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Abstract

Algeria is located in the category of countries poor in water resources. The fast silting up, more than 65 millions m3/year, reduces considerably the storage capacity of many reservoirs. In order to overcome many of the dredging inconveniences used in Algeria, we propose a method similar to the Water Injection Dredging method (WID). It consists in injecting a flow of water that overtakes the material resistance provoking the appearance of failure areas. The underflow provoked by opening of the outlet gate acts like a flushing. It has been possible to evaluate the recovered volume of restraint thanks to a simplified theoretical formulation of injection and modelling hydro-mechanic behaviour of the injected soil massifs and in relation with the equation resolution obtained through the finite elements. This survey is completed by a scale model study. Some interesting indications on the efficiency of this method could be provided in showing the existence of critical values for pressure and speed injections. However, these values are open to several technological interpretations

Keywords: WID, Porous Media, Desilting, Dredging

Introduction

UN classifies Algeria among the ten African countries that will know serious problems by 2025. It is considered as one of the countries poor in water resources according to the shortage doorstep fixed by UNDP or that of the World Bank scarcity fixed to 1000 m3/inhab/year. The specific erosion rate reaches the most elevated values in North Africa (20 to 500 tons / km² / year), [*Kassoul and all,1997; UNPD 2005*]. This phenomenon entails the fast silting up of numerous water restraints that represents 0.86 Mm3s that is 13.15% of the total capacity of dams in exploitation in 2004. (6.54Mm3). On the basis of silting up rates resulting from bathymetric surveys carried out by the Dams National agency, 17 dams would have lost 50% of their capacity by 2050 [*Kassoul and All. 1997; ANRH, 2004 ; UNPD*, *2005*]. It is worth to mention that neither the preventive nor the curative means and methods have helped to solve the acute problem of silting up in Algeria, [*Cravero, 1989*]. However, some curative means like dredging, flushing and racking remain the most advisable.

The deposed material is composed substantially of three types of soil (clay mineral, sand and silts each has different mechanical behaviours and does not react in an identical way to the actions of the environment in which they are. The big particles, like sand, does not possess the plasticity and cohesion whatever its mineralogical nature, while the fine particles possess these properties to various degrees depending on their mineralogical character and the nature of their environment and of their consolidation state.

The non clayey thin minerals that are the main components of the inorganic silts and in spite of their small size don't possess any of these properties. In a solid state, mud presents a critical threshold over which it can be eroded. Actually, brewing of silt by out-flow creates shear stress and if it goes beyond this critical stress threshold, it provokes a digging out of particles of the deposit surface. Authors link this stress to the limits of ATTERBERG, what appear meaningless because these limits are not intrinsic mechanical features of the materials, but only of the parameters relating to limit of materials state. Mud properties are conditioned by several factors like the concentration, mineralogical composition, percentage of sand, consolidation state, interstitial water saltiness, pH of waters, and ionic composition of the middle. Rheological behaviour depends on the concentration and consolidation state of the silt which is very sensitive to the coagulation-flocculation phenomena and to settlement. The relationships between the various above cited parameters remain very uncertain and are often established only for some types of vases and other parameters, which is insufficient to model this material. Until now neither the preventive, nor curative means have permitted to solve the problem of silting up. The preventive methods remain difficult to see and impossible to master [AAHR, 2004]. The curative methods dredging, flushing and drawing off present disadvantages like the cost and the implementation.

In order to remedy many cited inconveniences, we propose a method that combines both the curative and preventive approaches, which are flushing and drawing off methods. This combination has many advantages among which we have:

- reduction of frequency of interventions;
- Operation in the secondary settlement phase, which allows the sediment to have a time; of stay longer than in the case of flushing;
- reduction of the water consumption;
- Action time shorter than in the other methods.

Phenomenological Approach:

Water injection is used to do some dredging to level ports, estuaries and channels as well as for the development and maintenance of waterways. It gave there in suspension, creation of current of density and which is transported by the current. It represents a very interesting alternative to the conventional methods

[*Borst and All, 1994; Sullivan, 1999; Murray and all, 1999*]. Several authors [*Sutherland, 1966; Mutlu, Sumer and Beynan, 1978; Perigaud 1983*] gave a very interesting formulation concerning the extraction of burst in channel submitted to a horizontal out-flow binding hydraulic parameters to breaking conditions. Constraints formulation led into layer sediments by small disruptions has lead to conditions for which Coulomb criteria can be verified with in lump ruptures [*Parsons, 1981; Moghadasi and All, 2004; Tigh and Byrne*, *2004*]. Other authors analyzed various parameters implied under hydrodynamics action [*Migniot, 1968; Sleath, 1976; Yamatomo, 1977; Madison, 1978; Perigaud 1984, Migniot, 1989*].

We intend to destabilize the deposit massif in order to put back the sediments in suspension that would be evacuated them through depth outlets. The process consists in injecting a water flow (Qi) under pressure (Pi) and speed (Vi) given by a diameter slant (Φi), driven in massif of sediments to depth (Hi) and distance (di). These efforts create a force that accompanies the released flow. The movement of injected water entails a modification of the interstitial pressure that affects the skeleton. Additional effective constraints are induced resulting in forces exceeding the material resistance. Rupture zones are formed that propagates till the massif surface. The horizontal current provoked by the opening of bottom floodgate acts then like a flushing. The soil state is in constant modification, it is dynamic, whereas the models are static. We stumble then on this contradiction: to evaluate the action of the throw, it is necessary to know the stress and pressures that can be calculated only according to a fixed geometry, whereas the geometry of the material is variable because of the internal erosion that modifies its porosity and permeability. We can deduce, then, that out-flow doesn't affect the material.

It is, also, worth to mention that the cohesion of thin materials depends on the attractions between its molecules which themselves depend on the distance separating them. Therefore, particles spacing is a major factor influencing silt properties. Generally, the void ratio expresses the spacing between the material particles lacking cohesion but in the case of silt different spatial particles orientations can correspond to the same void ratio. Thus, there is not a direct relation between void ratio and distance between particles. A priori, we don't have parameters of control to be able to determine accurately the moment to begin the process.

Methodological Approach

We suppose that media is porous, isotropic, elastic, saturated and possesses the Coulomb rupture criteria. The injected Water flow is governed by Darcy law. The liquid phase is considered solely on a quantitative plan. The chemical aspect is disregarded.

The numeric way supposes to have a device able to calculate the flow simulation of both factors of erosion and distortion which are themselves the result of the double action of injection and horizontal out-flow. Moreover, the uncertainty related to deposit and erosion laws [*Cormaut, 1971; Owen and Harrison, 1971; Bonnefille, 1973; Migniot, 1977; Lambermont, 1978; Ariathuriai and Arulanadan, 1978; Kelly and All ,1979*] and consolidation [*Partheniades,* *1965; Mignot, 1989*] makes the use of mathematical models very hazardous. We raised the difficulties of sediment deposit rheological behaviour and the consequences their modelling entails. Mathematical modelling sets in motion a multidisciplinary approach that involves a deep knowledge of treated "physical" phenomenon. Their changing states and laws are complicated by the variable differences between them. The situation requires the handling of conceptual tools able to express these laws by a "solid system" of relations. A particular effort on initial and boundary conditions must be also expanded in order to restore “physically admissible” models. So, the method we are about to adopt is an approach hybrid: the simplified injection formulation and the modelling of hydromechanics behaviour of injected massifs completed by an experimental study. The resulting equations are solved by finite elements. Effect of transverse flushing out-flow is disregarded and would be put in evidence by tests.

Analytical Approach

The movement provoked by the injection modifies the features of soil therefore the resistance. To explain this phenomenon, we analyze constraint state provoked by water movement in a saturated soil, with a given specific weight specific γs and of porosity *e*.

Solicitations due to the movement of water in soil:

Let's consider an element of soil volume dv. The volume of water will be *e* dv. The efforts acting on this volume of water are composed by:

- Self weight : $\vec{E}_{pr} = e\gamma_w \, dv \, grad \, z$

γ_w : waters unit weight

grad Z = (0, 0,1) (1)

- Pressure: it is about the effort resulting from the field from the pressures p and acting normally on the surface from equal pressure containing the point considered. Its direction is that of the decreasing pressures:

$$\vec{E}_p = -e \, dv \, grad \, P$$

$$\text{grad P} = \left(\frac{\partial P}{\partial x}, \frac{\partial P}{\partial y}, \frac{\partial P}{\partial z} \right) \quad (2)$$

- Friction: Resultant of the tangential stresses developed by the solid to be opposed to the movement water. This resultant is function the speed of the liquid.

$$\vec{E}_f = e\gamma_w \, dv \, K(v) \quad (3)$$

where K(V) is the resultant of tangential efforts per weight unit of liquid.

- Inertia:

$$\vec{E}_i = e.\frac{\gamma_\omega}{g} dv.D_t \vec{\mathrm{V}} \qquad D_t = (\frac{\partial}{\partial t} + V_x \frac{\partial}{\partial x} + V_y \frac{\partial}{\partial y} + V_z \frac{\partial}{\partial z})$$

$$\frac{1}{g} D_t \vec{v} = -grad\left(Z + \frac{P}{\gamma_\omega}\right) - \vec{K}(v) \tag{4}$$

Resultant $\vec{S}$ of these forces is:

$$\vec{S} = -\frac{e\lambda_\omega}{g} D_t.\vec{v} - grad(\gamma_m Z + P) \tag{5}$$

$$\gamma_m = -(1-e)\gamma_s + e\gamma_\omega$$

Equations (4) and (5) and a hypothesis on K (v) explicit form allow us to search for the problem unknowns. Knowing S, we can calculate the stress generated and can localize the rupture area in soil. Stress must verify the following equations:

$$\begin{aligned}
&\frac{\partial \sigma_x}{\partial x} + \frac{\partial \tau_{xy}}{\partial y} + \frac{\partial \tau_{xz}}{\partial z} = S_x && \sigma_x n_x + \tau_{xy} n_y + \tau_{xz} n_z = T_x \\
&\frac{\partial \tau_{xy}}{\partial x} + \frac{\partial \sigma_y}{\partial y} + \frac{\partial \tau_{yz}}{\partial z} = S_y && \tau_{xy} n_x + \sigma_y n_y + \tau_{yz} n_z = T_y \qquad (6) \\
&\frac{\partial \tau_{xz}}{\partial x} + \frac{\partial \tau_{xz}}{\partial y} + \frac{\partial \sigma_z}{\partial z} = S_z && \tau_{xz} n_x + \tau_{yz} n_z + \sigma_z n_z = T_z
\end{aligned}$$

For our problem: Tx = Ty = Tz =0

$$(1+v)\nabla^2 \sigma_x + \frac{\partial^2 j}{\partial x^2} + \frac{v}{v-1}(\frac{\partial S_x}{\partial x} + \frac{\partial S_y}{\partial y} + \frac{\partial S_z}{\partial z}) + \frac{\partial S_x}{\partial X} =$$

$$(1+v)\nabla^2 \tau_{yz} + \frac{\partial^2 j}{\partial y \partial z} + \frac{\partial S_z}{\partial y} + \frac{\partial S_y}{\partial z} = 0, \qquad \text{(x, y,z) = 0 ;} \qquad J = \sigma_x + \sigma_y + \sigma_z \tag{7}$$

$\vec{S}$ act like body force.

To describe the field of out-flow; we will make use of the polar coordinates of E3 space [SALENCON, 1966 ; DANDUIGNY,2005]. Taking into account the symmetry, speeds, pressures are independent of the longitude. It won't intervene therefore more that two variables of position: r and θ. considering homothety, the expressions of the speeds must keep the same form if one changes the unit of length. It results:

F(r). G (θ)

F (r) function of r (8)
G (θ) functions of.

For a steady movement equation (4) becomes

$$\frac{1}{g}(V_r\frac{\partial V_r}{\partial r}+\frac{V_\theta}{r}\frac{\partial V_r}{\partial \theta}-\frac{V_\theta^2}{r})=\cos\theta-\frac{1}{\gamma_w}\frac{\partial P}{\partial r}-K(v).\overrightarrow{e_r} \tag{9}$$

$$\frac{1}{g}(V_r\frac{\partial V_\theta}{\partial r}+\frac{V_\theta}{r}\frac{\partial V_\theta}{\partial \theta}+\frac{V_rV_\theta}{r})=-\sin\theta-\frac{1}{\gamma_w r}\frac{\partial P}{\partial \theta}-K(v).\overrightarrow{e_\theta}$$

The equations (8), (9), relations the local continuity condition mass conservation permit us to get the unknowns (The outgoing flow of a hemispherical surface of radius r and circle limiting this one must be equal to the flow injected q).

$$\frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2 v_r\right)+\frac{1}{r\sin\theta}\frac{\partial}{\partial\theta}\left(v_\theta\sin\theta\right)=0$$ Incompressible liquid (10)

$$\overline{q}=2\pi e\int_0^{\pi/2} r^2 v_r \sin\partial\theta+2\pi e\int_0^r \rho v_{\theta=\pi/2}d\rho \tag{11}$$

From equation (8) and (11) one obtains:

$$\begin{aligned} v_r &= f(r)g(\theta) \\ v_\theta &= k(r)h(\theta) \end{aligned} \tag{12}$$

$$\frac{q}{2\pi e}=r^2 f(r)\int_0^{\pi/2} g(\theta)\sin\theta\, d\theta+h(\pi/2)\int_0^r \rho.k(\rho).d\rho \tag{13}$$

The derivative of this relation gives

$$ak(r)=-\left(2f(r)+r\frac{d}{dr}f(r)\right) \quad \text{and} \quad a=\frac{h(\pi/2)}{\int_0^{\pi/2} g(\theta)\sin(\theta)d\theta} \tag{14}$$

From equations (10) and (14) we deduct:

$$-\frac{a}{r}k(r)g(\theta)+\frac{1}{r\sin\theta}k(r)\frac{d}{d\theta}\left(h(\theta)\sin\theta\right)=0 \tag{15}$$

We consider two cases:
k(r) # 0
From equation (15) we wrote:

$$ag(\theta)\sin\theta = \frac{d}{d\theta}\left(h(\theta)\sin\theta\right) \tag{16}$$

From where a physical solution is possible if:

$$\begin{aligned} h(\theta) &= \sin\theta \\ g(\theta) &= 2\cos\theta \end{aligned} \tag{17}$$

Relations (11) and (17) give:

$$\frac{q}{2\pi e} = r^2 f(r) - \left(\rho^2 f(\rho)\right)_0^r = \left(r^2 f(r)\right)_{r=0} \tag{18}$$

Is only possible if:

$$f(r) = \frac{1}{r^2} H(r) \quad \text{and} \quad H(o) = \frac{q}{2\pi\, e} \tag{19}$$

From relations (14), (17) and (19) one deducts:

$$\begin{aligned} v_r &= 2.\frac{H(r)}{r^2}\cos\theta \\ v_\theta &= -\frac{1}{r}\frac{d}{dr}H(r)\sin\theta \end{aligned} \tag{20}$$

From relations (9) and (20) one obtains

$$\frac{1}{g}.\frac{H(r)\cos^2\theta}{r^4}\left\{\frac{dH(r)}{dr}tg^2\theta\left(2 - \frac{r}{H(r)}\frac{dH}{dr} + 4\cot g^2\theta\right) - \frac{8H(r)}{r}\right\} = \cos\theta\,\frac{1}{\gamma_w}\frac{dp}{dr}k(v)$$

$$\frac{1}{g}\frac{H(r)}{r^3}\sin\theta\cos\theta\left\{\frac{1}{H(r)}\left(\frac{dH}{dr}\right)^2 - 2\frac{d^2H}{dr^2}\right\} = -\sin\theta - \frac{1}{\gamma_w r}\frac{dp}{d\theta} - k(v)\,e_\theta \tag{21}$$

These equations are only verified if:

$$H'(r) = H''(r) = 0 \tag{22}$$

That is:

$$H(r) = cte = H(o) = \frac{q}{2\pi\, e} \tag{23}$$

One deducts from equation (14): k (r) = 0 that we find the 2nd case (k (r) = 0) whose solution is:

$$\begin{aligned} v_r &= \frac{q}{2\pi\, e}\frac{g(\theta)}{r^2} \\ v_\theta &= 0 \end{aligned} \tag{24}$$

In this case relations (4) give:

$$\frac{\partial p}{\partial \theta} = -\gamma_w r \sin\theta - \gamma_w r \vec{k}(v)\ \vec{e}_\theta$$

$$\frac{\partial p}{\partial r} = 2\frac{\gamma_w}{g}\left(\frac{q}{2\pi n}\right)^2 \frac{1}{r^5} g^2(\theta) + \gamma_w \cos\theta - \gamma_w \vec{k}(v).\vec{e}_r \qquad (25)$$

Let's suppose that:

$$-\vec{k}(v) = \frac{1}{k} v^{m-1}.\vec{v} \qquad (26)$$

Where k is the coefficient of proportionality, "permeability»; we obtains then

$$\frac{\partial p}{\partial \theta} = -\gamma_w\ r \sin\theta$$

$$\frac{\partial p}{\partial r} = 2\frac{\gamma_w}{g}\left(\frac{q}{2\pi\ e}\right)^2 \frac{1}{r^5}\ g^2\ (\theta) + \gamma_w \cos\ \theta - \frac{\gamma_w}{k}\left(\frac{q}{2\pi\ e}\right)^m \frac{g^m(\theta)}{r^{2m}} \qquad (27)$$

First relation gives:

$$P(r,\theta) = \gamma_w r \cos\theta + G(r) \qquad (28)$$

Where, G(r) depends only of (r) Therefore G (θ) = constant = 1, from where

$$P\ (r,\theta) = -\frac{\gamma_w}{g}\ \frac{q^2}{8\pi^2 e^2}\ \frac{1}{r^4} + \gamma_w r \cos\ \theta + \frac{\gamma_w}{(2m-1)\,k}\left(\frac{q}{2\pi e}\right)^m \frac{1}{r^{2m-1}} \qquad (29)$$

For r > 1 (low speed), one can admit that m = 1 and Dtv is negligible, “Darcy”, that is:

$$P(r,\theta) = \gamma_w r \cos\theta - \frac{\gamma_w q}{2k\pi\ e}.\frac{1}{r}$$

$$v_r = -k grad\left(z + \frac{p}{\gamma_w}\right)\vec{e}_r = \frac{q}{2\pi e}\frac{1}{r^2}$$

$$v_\theta = 0 \qquad (30)$$

The body forces acting on soil are

$$s_r = (\gamma_m - \gamma_w)\cos\theta + \frac{\gamma_w q}{2k\ \pi\ e}\frac{1}{r^2}$$

$$s_\theta = -(\gamma_m - \gamma_w)\sin\theta \qquad (31)$$

Finite elements allows us to integrate the equations while adopting Darcy hypothesis (m=1). A FORTRAN program is finalized for a porous media. Boundary conditions admitted are combinations of the following conditions:

- Φ is given on a part of the domain
- speed is normal on a part of the domain surface
- debit is accumulated in a part of the media studied

Results are:

- Hydraulic potential (values of Φ to summits elements)
- Pressure gradient for the purpose of the elastic calculations

This program also contains an elastic calculation sequence. The used method is finite elements. Chosen element is the simple triangle of the 1st degree.

This sequence provides:

- displacements to triangles summits
- stress and the main stress with their directions, the accumulated elastic energy

Solicitations of the porous media:
- Body force due the pressure: dp/dr; $1/r\ dp/d\theta$
- Body force due to the self weight: $\gamma \cos\theta$, $-\gamma \sin\theta$

Field of pressure gradient is gotten by the integration of the equation of Darcy while using finite element method.

Field of stress due to:

$$\begin{array}{l} -\dfrac{dp}{dr}+\delta\cos\theta \\ -\dfrac{1}{r}\dfrac{dp}{d\theta}-\delta\sin\theta \end{array} \tag{32}$$

is also calculated while using the finite elements method.

Having stress field, one localizes the rupture area by traction or by shearing in soil.

Figure 1 gives examples of rupture zone. Form is symmetrical. We estimate the recovered volume. A comparison is made with the experimental values that we develop in the experimental part

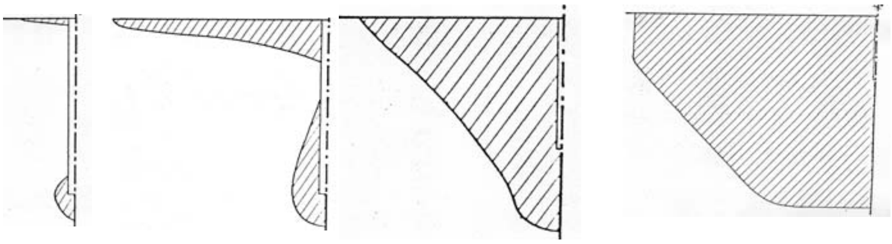


Fig. 1 Différents cas de simulation donnant les zones de rupture

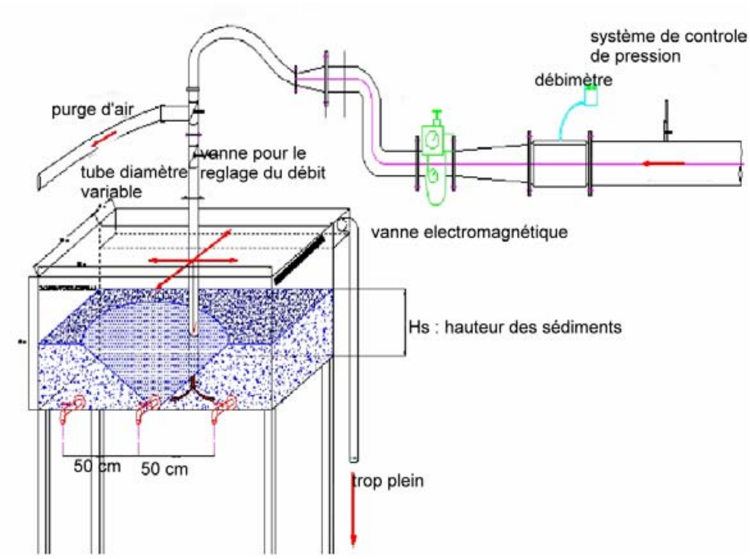
1. Experimental Equipments

Experiences were conducted in a special glass box of 2m70 long, 1m2à wide and 0.60 m deep, digital debimeter an electromechanical floodgate, injector and pump to variable flow (figure2). Injector is positioned to wanted point; depth (Hi): 1/3Hs10cm; 2/3 Hs20 and distance (di): 10cm, 20cm, 30cm, 40cm, 50cm. Hydraulics parameters pressure (Pi) and speed (Vi) are adjusted via device. The flow is, every time, established upstream by electronic measure debimeter and manual control. Losses in the system remain stationary; we can admit hypothesis that injected debit is constant. This hypothesis is verified by efficient exploratory tests.

2 Preliminary Experiments

Before adopting the basic experiments, it was necessary for us above all to check the reliability of the experimental device, from hydraulic and conceptual point of view.

Several tests were carried out for:



- To check the design of the model as well as the agreement of the values of the measured parameters "manually" and electronically.
- To visualize the phenomena concerned while seeking the comprehension of the mechanisms brought concerned to the level of the grains.
- To determine the various parameters in order to define the experimental protocol.

These preliminary experiments led us to consider that the material used is reliable with a good approximation of the measured parameters and data by the equipment.

In addition we drew some noted and precautions of uses by defining limits of the parameters:

- Depth (Hi): 1/3, 1/2 and 2/3 the height of the sediments (Hs)
- Outdistances injection (di) varying of 10 with "half of the vat" by step of 10 cm.
- Pressures at entry Pi: 2.2m, 3.5 m and 5.7m.
- Speed (Vi) are adjusted via the device. The interval speeds of injection vary between 0.10 m/s and 2.5 m/s.

Apart from these intervals either the systems becomes unstable, or the test does not have any physical sense.

Analysis of the Results

The grains of sediments are subjected to forces of volume acting in the direction opposed to gravity. During the tests carried out in laboratory, one noted the formation of a cone and circular lines of rupture around the injector. It occurs in material one or more phenomena (deformation, fracturing.) leading to a change in form. (Fig.n° 2.).

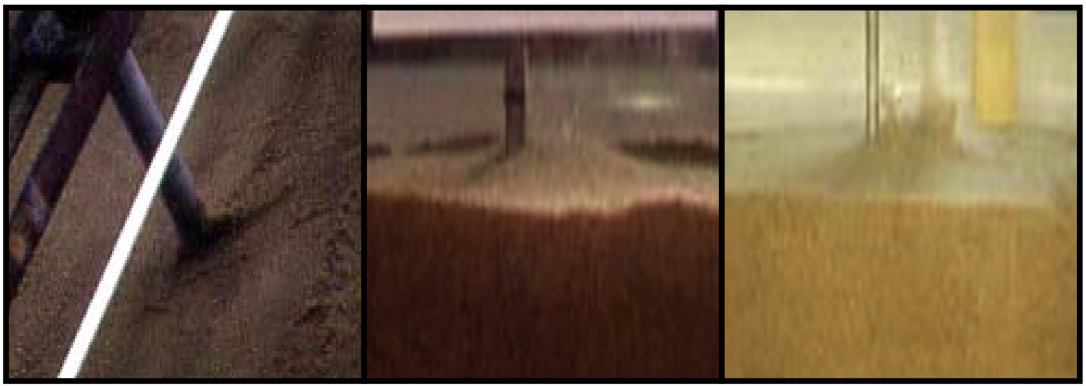


Fig.3. Action before rupture

1 Geometrical Parameter's Influence

1.1 Distance Injection Effect

The curves of the evolution of the volume recovered according to the distance from injection were obtained for several speeds. They take a general form represented by a fast rise with a parabolic growth of all the curves where the peaks do not seem prevalent. A maximum is reached between the distances 30 and 40 cm followed by a decrease to reach minimal values at semi distance. (50cm) (Fig.3, Fig4, Fig.5 Fig.6 Fig.7 and Fig.8).

The analysis is made compared to the volumetric ratio recovered Vs for the test given and pilot volume Vo obtained without action of the injection. The curves are plotted compared to Vs/Vo.

Fig.5- Volume récupéré en fonction de la distance
vitesse constante. Pi=2.2; Hi=20

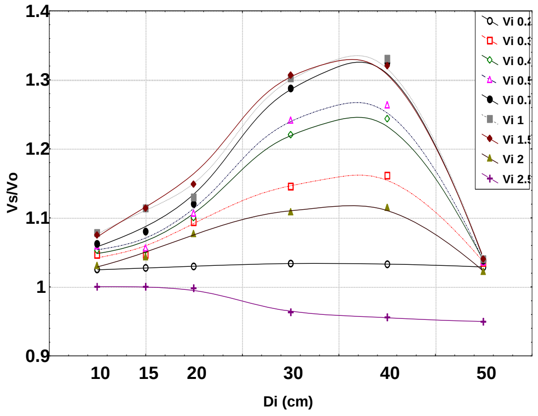


Fig.4- volume récupéré en fonction de la distance
vitesse constante. Pi=2.2; Hi=10

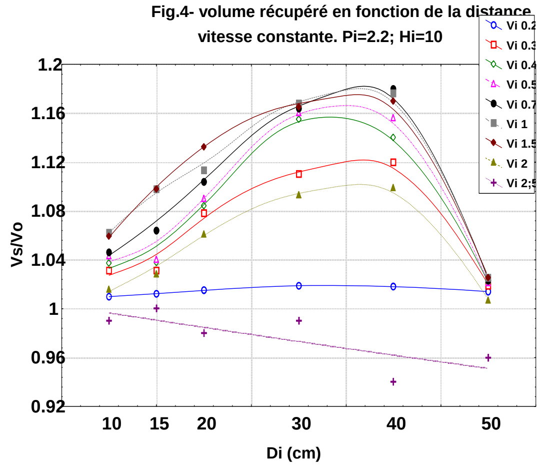


Fig.7- Volume récupéré en fonction de la distance
vitesse constante. Pi=3.5 ; Hi=20

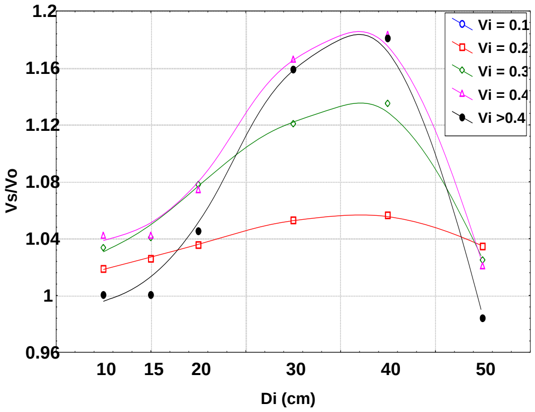


Fig.6- Volume récupéré en fonction de la distance
Vitesse constante. Pi=3.5 ; Hi=10

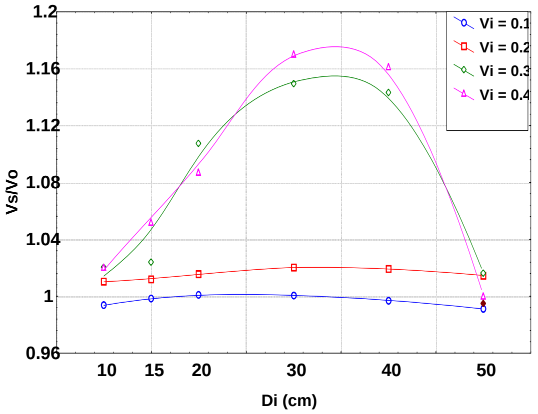


Fig.8- Volume récupéré en fonction de la distance
Vi=cte; Pi=5,7; Hi=10

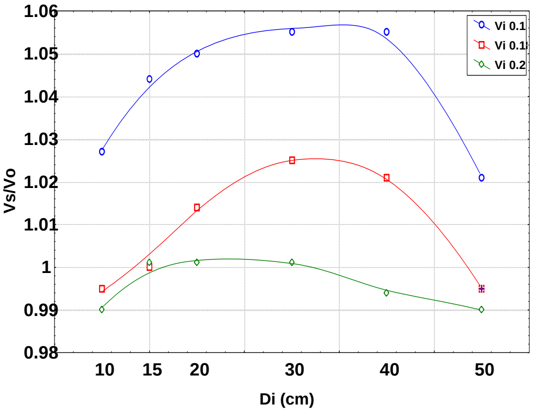
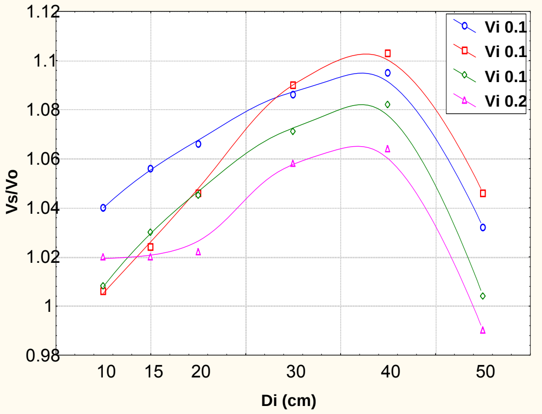


Fig.9- Volume récupéré en focntion de la distance
Vi=cte; Pi=5,7; Hi=20



1.2 Depth effect:

In the same way for the depth of injection the tests showed as the optimal value of Hi is at the 2/3 the height of the Hs sediments. Beyond this value the threads of current would cut the surface of the bottom. The field of influence of the flow is decreased from where reduction of the zone of rupture. It is valid for all the test parameters; it has there only the percentage of profit which changes. Table 1 summarizes the characteristic values:

Table 1 - Volume maximum recovered

Pressure	Max (Vs/Vo)		Vr20/Vr10
	Hi20	Hi10	
2.2	1.33	1.18	1.13
3.5	1.193	1.100	1.085
5.7	1.103	1.0554	1.045

2- Hydraulic Parameter’s Influence

2.1 Injection speed effect

We present recovered volume according injection speed. (fig.10, 11, 12 and 13)

The maximum is obtained for the speeds included between 0,5 and 1,5 m/s.

Fig.10- Volume recovered according to speed
Di=cte; Pi= 2,2; Hi=10

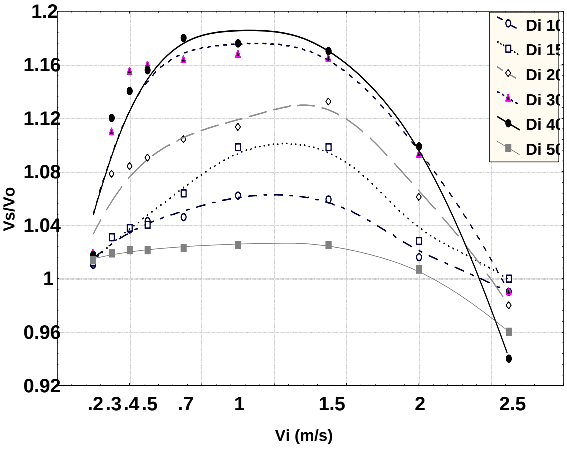


Fig.11- Volume recovered according to speed
Di=cte; Pi=2,2; Hi=20

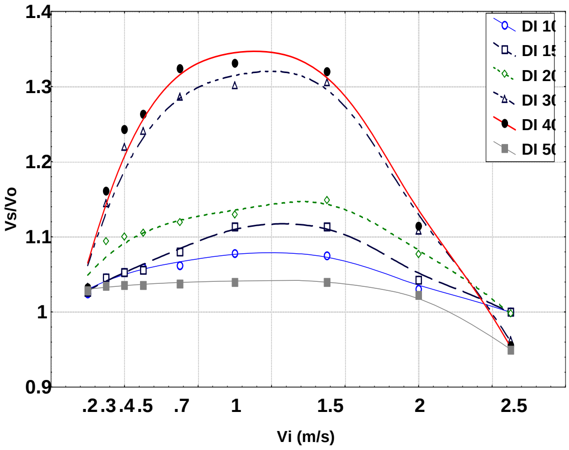


Fig.12- Volume recovered according to speed
Di=cte; Pi=3.5 ; Hi=10

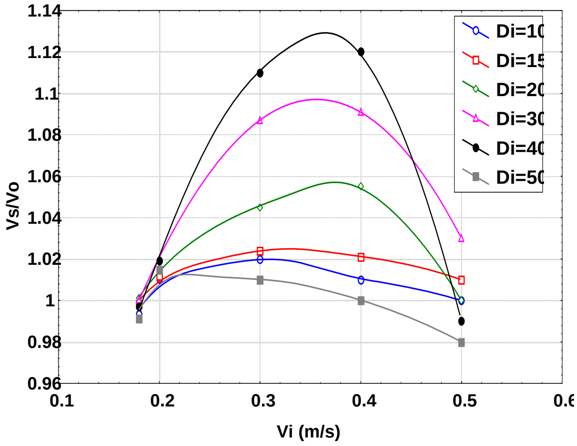


Fig.13- Volume recovered according to speed
Pi=3.5; Hi=20

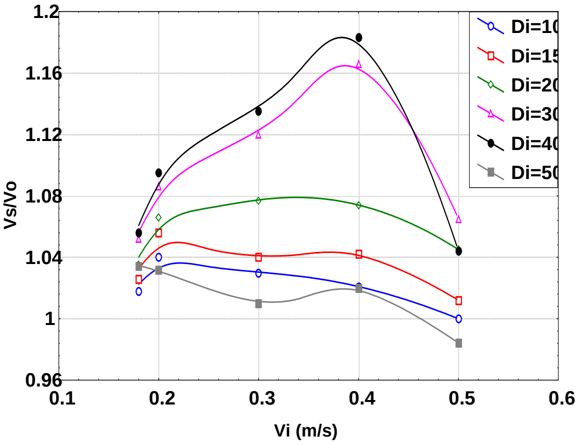


Fig.14. Volume recovered according to speed
Di=Cte; Pi=5.7; Hi=10

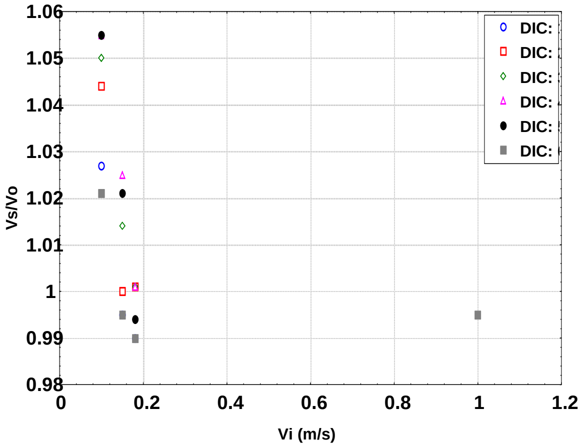
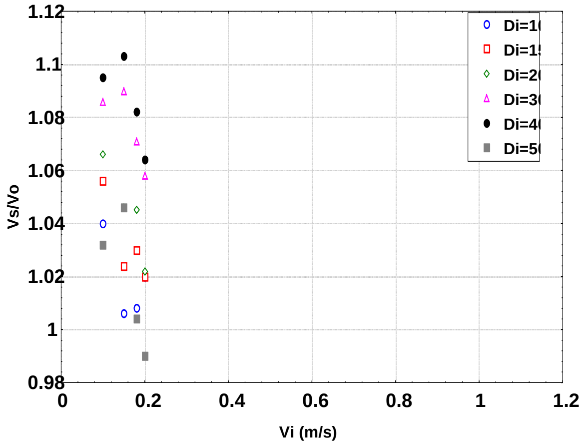


Fig.15. Volume recovered according to speed
Di=Cte. Pi=5.7; Hi=20



2.2 Pressure injection effect

It influences the phenomenon considerably, with equal parameters; the time of rupture varies from a ratio of 2/3. For the lowest speed the beach of action is larger some is the depth of injection. The figures (16, 17) represent the volumes recovered according to speed with a double categorization, the distance and the pressure from injection to show the intervals of action.

Fig.16- Pressure effect according distance

Vi= Cte. Hi=10

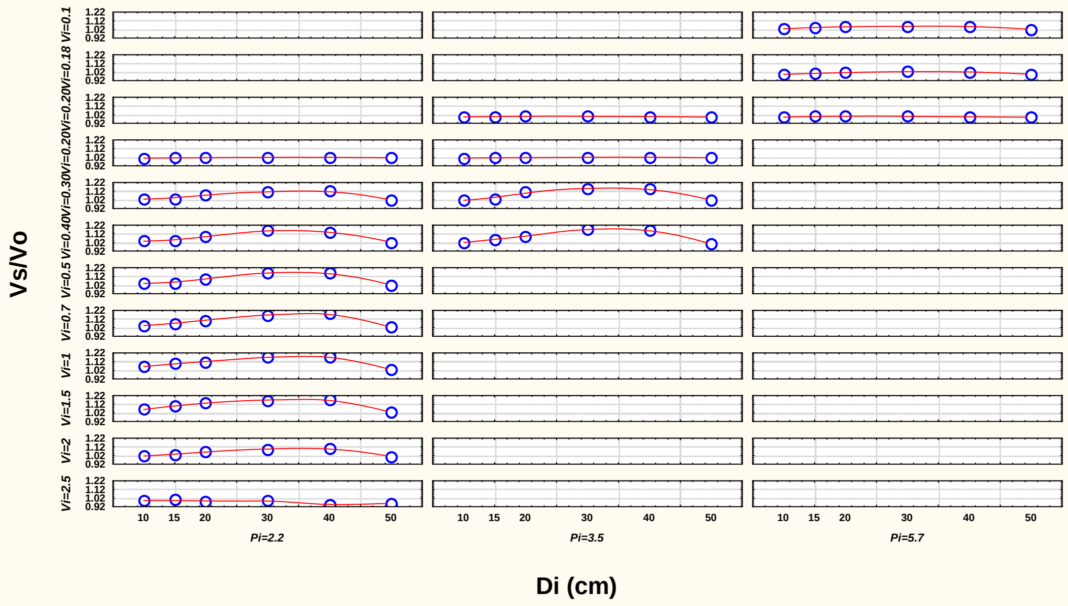
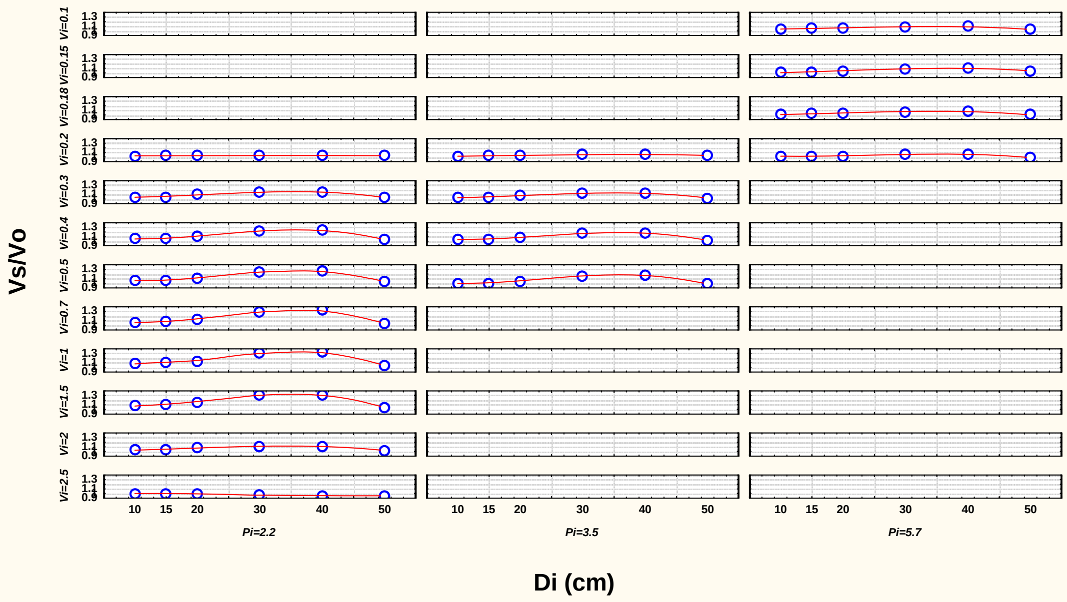


Fig17-Pressure effect according distance

Vi = Cte; Hi=20



2.3 « Pressure - speed » effect

We deduct that it is couple (Pi, Vi) is predominant. An optimal surface exists according to two parameters. The figures (18,19) show that there exists an optimal zone being located at the centre: speed ranging between 0,5 and 1,5 m/s and a distance ranging between 25 and 40 cm for the conditions of injection of low pressure and a depth 2 /3. The same conclusions are observed for the remainder of the tests. There are only the maximum ones which changes. Below a certain pressure and beyond one a certain speed the jet does not act: the limiting values are known as criticisms; We have the same form for all curves for the other parameters. The values change.

3 Comparison of the experimental and theoretical results:

The table 2 gives the comparative maximum values obtained by the tests (Vexp) and those estimated (Vtheo) by the approach numerical for the optimal conditions and represented by the figure (22).

Fig.18 Volume recovred according distance and injection speed - Pi = 2.2 ; Hi = 10

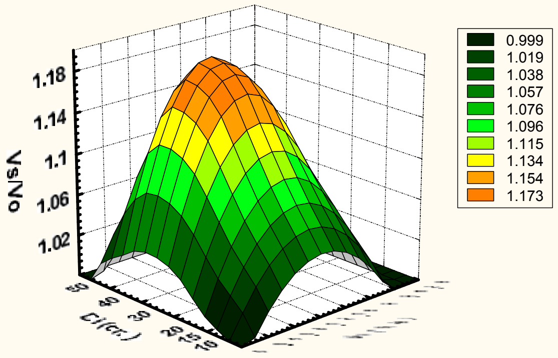


Fig19.Volume recovred according distance and injection speed Pi=3.5; Hi=10

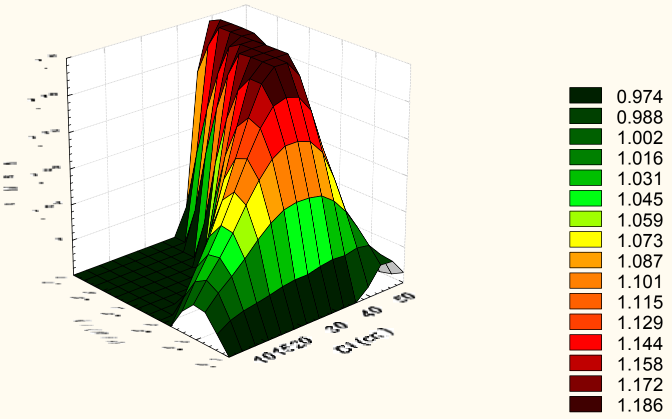


Table 2 Values comparatives Vexp -Vtheo

Vi	0.4		0.5		0.7		1		1.5	
Di Vol.	30	40	30	40	30	40	30	40	30	40
Vol.exp.	1.22	1.243	1.241	1.263	1.287	1.324	1.302	1.331	1.306	1.32
Vol.theor	1.017	1.03	1.035	1.05	1.064	1.1	1.09	1.12	1.08	1.13
Vexp /Vtheo	1.20	1.21	1.20	1.20	1.21	1.20	1.19	1.19	1.21	1.17

The difference is due to the action of the horizontal current at the time of the opening of draining. The effect of hunting was not taken into account in the numerical equations. The report/ratio is practically stable. The difference is of 20%.

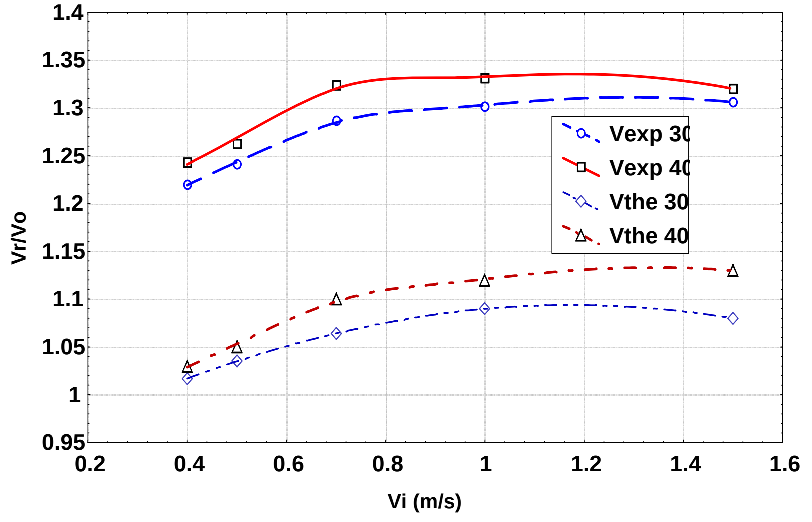


Fig.22- Comparison volume recovred volumes: exprimental and theoretical

Conclusions

We are provide some indications technologically interesting on the efficiency of desilting by injection while putting in evidence the preponderance of the couple “pressure – speed” as well as the existence of critical values for these parameters. Recuperation performances of volume reservoir depend on essential manner of this couple. While adopting like criteria of efficiency the energy, it is advantageous to operate to low pressure and speed. It allows us to consider inside a propertied setting a certain consistency and by there of to understand mechanisms. First practical forecasting is the one of the efficiency size order of a method used. Such a model rather appears like a physical reflection tool on the basis of minimal hypothesis and providing the approached value. It permits to classify the phenomena and to causes some questions to which one would not wonder necessarily.

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