The Erosion of expansive soils through a zoning of Taza (Morocco)

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Abstract. Like other cities in the region of Fez-Meknes, Taza undergoes the phenomena of erosion of soils facing the builder in general and the town planner in particular. This type of aggression of the land is sometimes amplified by the swelling-withdrawal of soils. In effect the marl clay layers are considered as unstable soils because of their volumetric changes depending on the duration and intensity of extreme climate changes (weather, droughts, ventilation.). This phenomenon, which is part directly or indirectly so-called natural disasters, can lead to significant costly damage and particularly intense (soil erosion, landslides, obstruction of the course of the water, hydraulic works and sanitation networks, cracks of the constructions and their annexes’, deformations of pavements, etc.). The knowledge and mastery of this phenomenon are essential to prevent, limit or remedy the consequences and damage related to their impacts. We focus as well our contribution on the geotechnical characteristics of the soils of the city of Taza with highlighting of the hazards in susceptibility to erosion of soils in particular through their potential of swelling-removing and this for the benefit geotechnical zoning of Taza.

1. Introduction

The Moroccan area of Fez-Meknes and for numerous cities as it is the case of Taza, the urban development coped with multiple challenges, because of the extensions in mass for the realization of the infrastructures, works, buildings and other installations. The new constraints of safeguard of the environment and the climate changes sharpen the intensity and the degree of the risks of the natural disasters type. The geological and geotechnical factors are determining on this subject and can generate catastrophic effects if they are badly taken into account or if the projects lack of adaptation to the sites. On the level of Taza, the parameters of swelling and withdrawal of the grounds predispose on the whole with these phenomena. Direct and indirect methods make it possible to consider as well risk of erosion as that related to swelling. Among the indirect methods, we have empirical procedures, which make it possible to exploit physical or chemical results carried out on representative selected samples. The direct methods are in several procedures of mechanical tests and are carried out on undisturbed samples. The œdometric test is that which is commonly used to measure the expansibility and the pressure of swelling. Other methods consider the loss due to erosion or the percentage of swelling starting from the chemical characteristics and mineralogical analyses. In this article we referred to the geotechnical current tests (Atterberg limits, swelling stress, value of Blue) [1], on the one hand and the cohesion of the ground on the other hand. Our objective is consequently to show that more the grounds are likely with the swelling-withdrawal more they are potentially erodible. After presentation of the site of the city of Taza, we recall various types of soil erosion that may affect the structures or lands concerned and various correlations proposed by different researchers. From the site we have selected marly samples to test them in the laboratory. We have then considered correlations between the Atterberg limits, the swelling pressure, the cohesion and the loss due to erosion.
2. Urban site

2.1. Taza city context
Taza city is located north-east of Morocco and east of Fez- Meknes area. It fits between Prerif lies to north and of the Middle Atlas to the south like structural fields. The pre-Riffian zone [2,3] constitutes the southernmost part of the external furrow of the chain of Rif. It is made of grounds of Tertiary age represented by a series of marl blue, very powerful, relatively homogeneous of higher Miocene (Figure 1) and the olistolithes with varied ages and natures. The deposits of the Middle Atlas contrast completely with those of the Riffian pre-zone. They are composed of Liasic limestones and marl-limestones resting on argillaceous deposits of permoo-triasic age, intersected with outpourings doleritic [5].

2.2. Climate of Taza
Taza province climate is semi continental type with Mediterranean influence. It is marked by a temperate and humid winter season (October to May), and hot and dry summer one (June to September). Temperatures vary between -8º and 38º, while rainfall ranges between 100 and 700 mm / year [6]. These conditions put the grounds at severely tested of alternate of water content and consequently volumetric variations. It is what will be clarified in the continuation of our matter.

3. Types of erosion
Often types of erosion are rather undesirable that we consider individually.

3.1. Undermining of the hydraulic works
3.1.1. Channels. One of the estimates of the constraint of training of blocks of protection in a single channel with ripraples is given by [7]:

$$\tau = \left( \frac{\tan(\phi)}{0.03} \right) Y_w \tan(i)$$

(1)

With $\phi$: angle of friction of the ripraples. $Y_w$: voluminal weight of water. $h$: height of water. $i$: slope of the flow.

3.1.2. Structure on waterway
The depth $h$ of undermining is estimated by LPEE [7]:

$$h = 0.217 \left( d_{50} \right)^{2/7} \left( Q/L \right)^{6/7}$$

(2)

With $Q$=flow of the wadi. $h$= height undermining compared to the coast of high waters. $L$=width of the bed of wadi. $d_{50}$=average diameter (sieve letting pass to sifting 50% of material).

3.1.3. Dam. For estimation, the speed of silting of the stoppings as result of erosion of the basins slopes in their upstream one can resort to the formula of Baker [7]:

$$D = 6.14C - 49.78 \left( t/km^2/an \right)$$

(3)

Where $C$ is the coefficient aggressiveness climatic: $C = P^2/Pm$. $P$: precipitation of the wettest month. $Pm$: annual precipitation averages.
We note that the hydromechanical effect of erosion is important as soon as the angle of friction of the soils or their mean diameter of the grains is low and the monthly rainfall is momentarily intense. This is verified for the marly soils of Taza and its region and their climate.

4. Correlation between characteristics

4.1. Correlations between parameters of identification and erosion

We initially refer on the correlations of Mr. Goutte-Lima [8]. In reference to this experimentation we can advance that under the effect of the action of erosion the loss of the water-logged soil is inversely proportional to cohesion.

Just as the variation of loss of ground is in quasi proportionality with the variation of the loss of cohesion. Besides the digraph of Mc Graw-Hill [7] makes it possible to envisage fields speeds leading to sedimentation, or on the contrary transport until the erosion of the ground following its granulometry highlighting the aggressive dynamic action of the flow on the haulage of the grounds.

According to Dos Santos and E. Decastro [7] they consider criteria based on the granulometry and the swelling of ground. Philipponat proposes the quantification of the impact of erosion by [7]:

\[ E_r = H + P \]  

H (in cm): represents the depth of the drain dug in a test tube of ground subjected to thin fountain constant speed and flow during a given time. P (in g): weight of the moved ground. A. Merzouk [9] indicates that the role of the mineralogical characteristics on erosion of nine Moroccan soil types could be approximated by the index of loss of ground (Sl) for a slope of 9% and under a shower of simulation of rain of 10 cm/hour of intensity:

\[ Sl = 311.83 - 4.48(Sm + S) + 6.45C + 613.40Ec \]  

With Sl=index of loss of the ground; Sm=matrix of the ground<2mm; S=%sand; Ec= electric conductivity of the ground. C=% of active CaCO3.

Considering erosion at the level of the fields the quantification is obtained thanks to the formula [7]:

\[ A = K R L S Cp \]  

With A= erosion per unit of area ;K=coefficient erodibility of the ground ;R=coefficient influence of the rain; LS=coefficient of geometry of the watershed (length-slope) ; Cp = coefficient of vegetation and protective works.

It follows from this research that fine soils of the Taza marl type will be more sensitive to water erosion if their cohesion is low because they are less compact due to volumetric shrinkage, for example. In all cases, the steep slopes of this city and its region contribute to the predisposition to thrusting.

4.2. Correlations between parameters of identification and swelling

Komornik and David [10] propose a relation between the pressure swelling \( \sigma_g \) in kPa, the dry density \( \gamma_d \), the water content W and the liquid limit WL:

\[ lg(\sigma_g) = 0.0208WL + 0.000665\gamma_d - 0.0269W + 2.132 \]  

The model of Brackley [11] proposed a general relation between the pressure swelling in kPa, the index of the vacuums \( e \) and the index of plasticity IP of the ground:

\[ lg(\sigma_g) = 5.3 - (147 \frac{e}{IP}) \]  

When M. Chrétien[12] drew up a relation between the index of plasticity IP and the specific value of blue VBS of a clay inflating according to a correlation of about 0.979:

\[ IP = 10.51 VBS + 6.948 \]  

Of the same Chen [13], being based on work of Kassif and Baker [14], concluded that the pressure of swelling is not affected by the water content in the event of prevention of the variation of the dry voluminal weight.

In addition, work of M. Goutte-Lima and al. [8], arises a susceptibility of the wet argillaceous-muddy grounds saturated to erosion is all the more notable as cohesion is notable on the one hand, or that the loss of cohesion, by withdrawal for example, is also important. The correlation in these cases is very good that we improve by proposing a linear function (Figures 2,3). Thus, the increase in the water content of the marl reduces its swelling pressure in favor of the increase of its void index, a reduction of its compactness and its cohesion which prelude to a weakness of resistance to erosion. as we show by our following experiments and correlations.
5. Fields of investigation and experimentation
In reference to the geology brought closer to the topography of Taza we carried out a set of samplings to marl predominance established and selected according to the transfer on the following map. Our samples cover thus mainly fields of slopes between 5 and 15% places of the most urbanized or potentially urbanizable, close to the road infrastructures, works and waterways, and thus threatened by the slips, the erosion of surface or undermining under effects of water streaming (Figure 4)

6. Results and discussion
6.1. Geotechnical characteristics of the tested marls
Table 1 summarizes the minimum, maximum and medium values of the geotechnical characteristics of the one hundred marl samples tested: Atterberg limits WL and IP, mechanical characteristics not drained by shear cohesion (Cu), angle of friction (\(\phi_u\)), as well as swelling pressure \(\sigma_g\).

| Parameters | Blue marl | Green marl |
|------------|-----------|------------|
| WL (%)     | MAX 69.00 | MIN 15.47  | MED 47.22  |
|            | MAX 70.00 | MIN 29.00  | MED 49.93  |
| IP (%)     | MAX 44.00 | MIN 17.00  | MED 28.02  |
|            | MAX 48.00 | MIN 13.00  | MED 28.87  |
| Cu (kpa)   | MAX 430.00| MIN 8.00   | MED 250.00 |
|            | MAX 370.00| MIN 80.00  | MED 182.75 |
| \(\phi_u\) (°) | MAX 34.00 | MIN 10.00  | MED 20.86  |
|            | MAX 33.00 | MIN 8.00   | MED 19.13  |
| \(\sigma_g\) (kpa) | MAX 350.00| MIN 0.00   | MED 48.69  |
|            | MAX 500.00| MIN 6.30   | MED 124.07 |
6.2. Comparison between plasticity and the value of Methylene blue

By referring to figure 5 graph, the results of marl and muddy samples of Taza related to the index of plasticity IP of Atterberg on one hand and the values obtained with the methylene blue VB on the other hand we end to the following linear correlation. This shows that the clay activity of the tested soils increases with its plasticity. This confirms the tendency of the literature but with a specific correlation with the formations in Taza urban area (Figure 5).

![Figure 5: IP and VB Correlation of the marl-clay soils of Taza](image)

6.3. Comparison between plasticity (IP-WL) and swelling potential

The carry forward of the plasticity index values IP according to the liquidity limits on the Casagrande diagram (Figure 6) by beach of the swelling pressure of our primarily marl and clay samples within the meaning of geotechnical classification, enable us to note that:

The evolution of the results take place in a way quasi parallel with the right-hand side of line limitation, such as \( IP = 0.73 \times ( WL - 20 ) \) between the frankly argillaceous grounds and those muddy.

The cloud of the whole of couples (WL, IP) representative of the grounds fairly to strongly inflating are located in the field of index of plasticity IP higher than 20% and liquid limit WL ranging between 40% and 60%.

The swelling and shrinkage of the marl results in a loss of cohesion and consequently a high susceptibility to erosion according to Goutte-Lima et al.

6.4. Exploitation of the experiments

The marl grounds which constitute major urbanized surface or candidate to the extension of the occupation of the regional planning are often very plastic, which is in strong correlation with the Blue values reflecting their activity as an argillaceous ground classified according to the diagram (Fig. 5). Then the majority of our samples relatively dispersed on the town of Taza for a good representativeness are of swelling fairly to strongly powerful.

This predisposition and always in reference to our experimental tests and those of the literature results in considering that the marl object of our investigations are easily candidates with erosion under the action of the water streaming as soon as their cohesion has suddenly lost its value or that this one is weak right now.

The climatic conditions which lead to the marl saturation and particularly after their prolonged drying out or loss of its dried density by withdrawal, and the time as of bad weather offers this context of its cohesion loss.
7. Conclusions

Through the facet of our experiments and investigations by taking into account the got results we could draw up an erosion prediction methodology. Then soil loss is reported to cohesion loss with a correlation rate $R^2$ of 0.91 in one hand, or reported to cohesion value with a correlation rate $R^2$ of 0.95 in the other hand. This leads to a time saving of at least half. Which makes it possible to anticipate the risks related to the exhibitions of the marl grounds such as those of Taza with the phenomena of streaming of water. Which is possible by having recourse to the mechanical tests instead of oedometric test which needs longer time. That is all the more alarming as the marls are potentially inflating and that they are of low cohesion or that they are threatened of decoherence.

This kind of grounds, suitable for volumetric variations of expansion-withdrawal following the fluctuation of their water behavior, is reported on the cards of zoning geotechnics of the town of Taza. It will help the town planners in the construction to act in an active way against the damage by erosion of surface or mass in the form of slip.

Among the damage of erosion, we recall the obstruction of the networks of cleansing, the undermining and washing away of the foundations of buildings, works, roads and others as well as the raising of levels of high waters of believed in the wadis.

The results of the geotechnical tests of identification, swelling and mechanical parameters on the one hand, as well as those of the erosion on the other hand, reinforce our proposed method for a rigorous indirect and practical approach. It may be easily applied to other cities in the Fez-Meknes region like Taounate and My Yaacoub where marl constitutes the main bedrock.

8. References

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