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A Peridical Inclinometry Follow-Up of a Landslide of Quaternary Terrain in an Urban Zone (Constantine City, Algeria)

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Abstract: Since more than thirty years, the town of Constantine, witch is the third largest town in the north-eastern of Algeria has known serious damages to the dwellings due to the landslides. Its unstable urban perimeter presents some sites covering a total area of approximately 195 hectares that represent 3.9%of its urban space. The total population is about 15.38% which is equivalent to more than 100,000 inhabitants. This instability was clearly shown from 1970 to 1980. According to investigations, the lithology, the microtectonics, the water, the slope of the relief and the entropic actions are the main causes. To have a dimension on the extent of the situation and an idea on the progression of the damage caused to constructions some inclinometer field surveys have been carried out. Geological and geotechnical studies of the sites in question have been given a close attention.

Key words: Landslide, quaternary, miopliocene, geotechnical, clay, inclinometer, constantine

INTRODUCTION

About thirty years ago, the town of Constantine (North-eastern of Algeria) (Fig. 1), located on unstable, broken and neotectonic grounds, has known serious damage with the dwellings due to the landslides. The urban zone of Constantine of a surface of 5001 ha presents a set of unstable zones of a total surface of approximately 171 ha witch is 3.9% of this agglomeration. Such zone contains more than 100 000 habitants of approximately 650000. The evolution of the PDAU (Master line of Installation and Town planning) (Fig. 2) of the city has never taken into the first signs of sliding into consideration which appeared only in 1966.The geological research made after some significant sites descriptions, the Algerian industry expansion, programs of urban habitats and development of the road network have begun before 1970 and have given worrying results.

MATERIALS AND METHODS

Climate: The climate was alone responsible for the quantity of water that the soil receives during one season. The soil is not sliding during the dried season, but the

Fig 1: Chart of situation of the town of constantine

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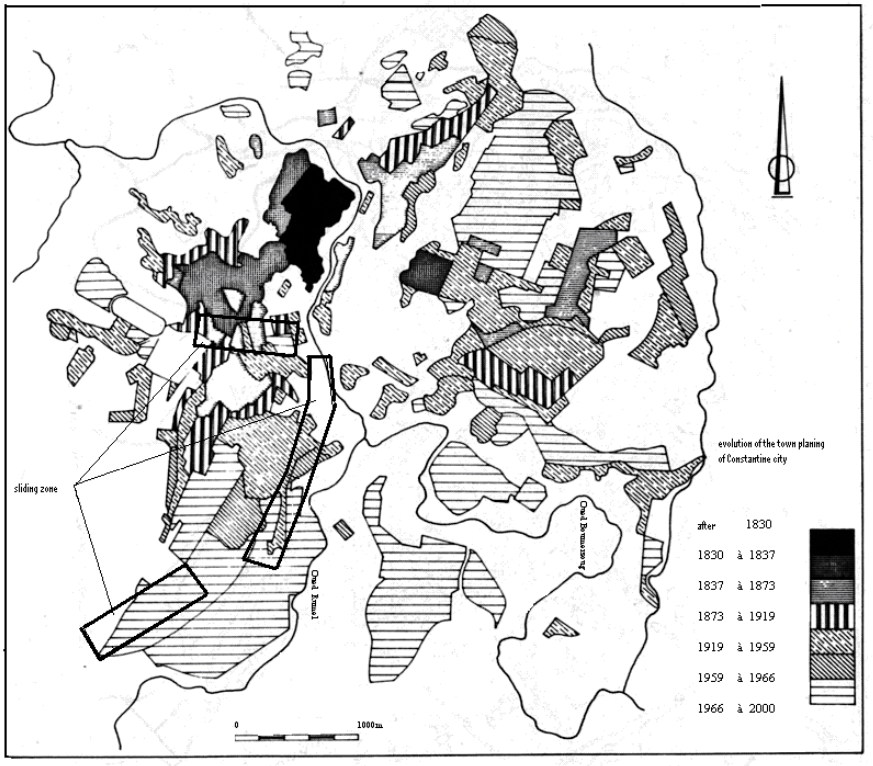

Fig 2: Evolution of the urban perimeter of the town of constantine and location of the sites of sliding (According to the services of town planning of constantine city 2004)

Table 1: Climatic data 1970 to 2004

Mont.	Sep.	Oct.	Nov.	Dec.	Jan.	Fev.	Mar.	Avr.	May.	Jun.	Jul.	Aou.
mm	33.13	39.41	58.63	83.65	69.9	58.4	55.3	50.42	40.07	18.66	6.94	10.12
Seasons			Winter	Spring	Summer	Autumn						
Pluviometry mm		211.95	149.79	35.72	131.17							
Mont.	Sep.	Oct.	Nov.	Dec.	Jan.	Fev.	Mar.	Avr.	May.	Jun.	Jul.	Aou.
t°	24.19	19.84	14.98	10.10	8.96	11.51	14.17	16.06	19.76	26.56	30.88	29.41
Seasons			Winter	Spring	Summer	Autumn						
Average température t°		10.19	16.66	28.95	19.67							

Average temperature on Constantine department from 1970 to 2003 (ANRH Constantine)

cycle is activated once the climate is wet, this lads to deduce that the water infiltration is the principal cause of sliding. The region is imposed to a semi-dry climate witch two main seasons. The first season is cold and humid and begins from December up to April; the second season is hot and dry and begins from May up to November. Annual average pluviometry is 530 mm for the last 35 years, after a long period of dryness which lasts for 10 years (from 1983-1993) (Table 1), those last year, the pluviometry is more important and the meteorological conditions are particular, giving an annual average pluviometry of 733 mm which is higher than the one given before.

These movements are more perceptible after this bad period. These sites are situated on the 25 to 45% sloping grounds, we conclude that the ground topography has contributed to this instability. The rock alteration has modified the crystalline structure and consequently the cohesion angle and the repose angle are deformed (Benaissa, 1998).

Average pluviometric intensity on Constantine department 1970 to 2004 (ANRH Constantine, Arranges National Hydrous Resources) (Table 1).

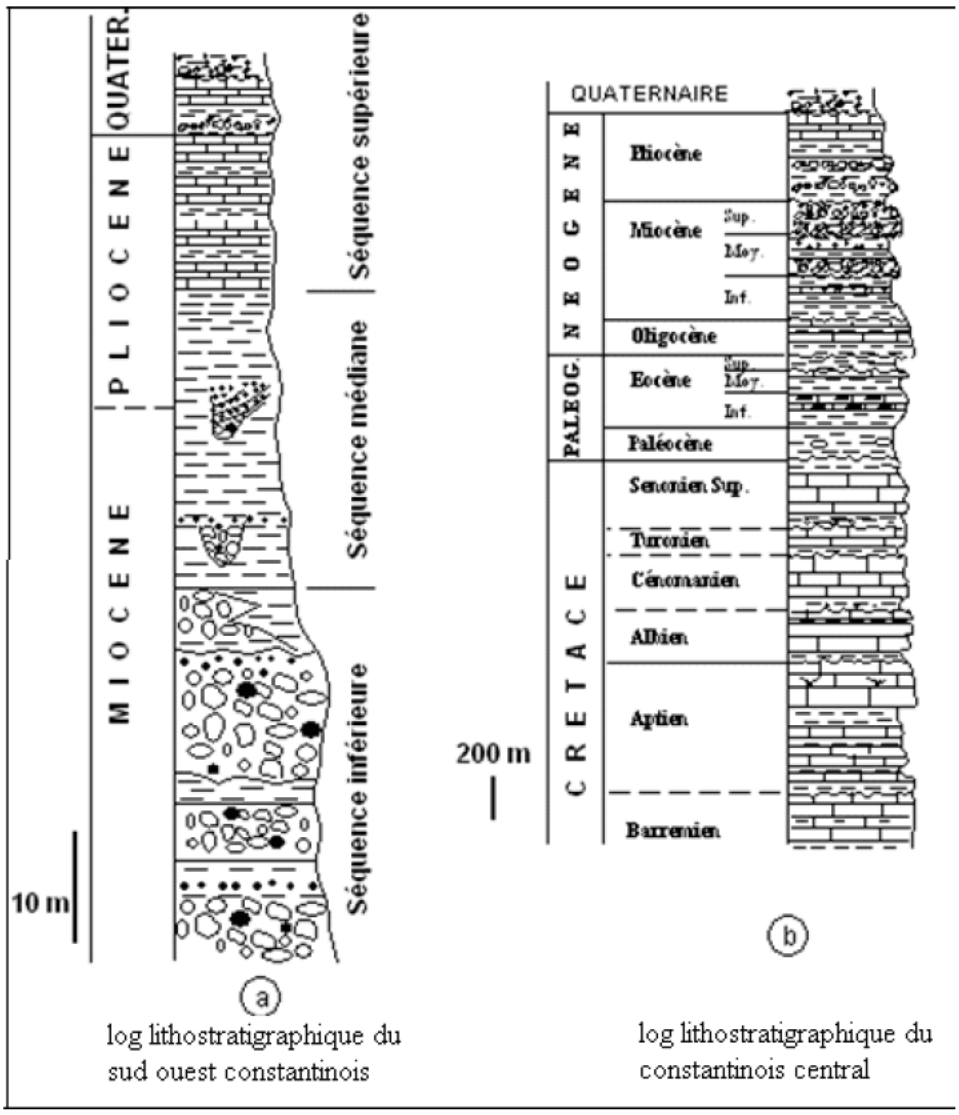

Fig. 3: Simplified geological map of central constantinois (According by Coiffait P.E 1992), 1-Trias, 2 Cretaceous, 3 Oligocene,4 Eocene, 5 Mio-Pliocène, 6 Plio-Quaternary

Geological cartography of the unstable sites: The geological series starts with massive limestones of the Rock of Constantine Cénomanien in Turonien on which the old districts of the city were built. A series of the black marls with schistous pace of Campanien age exists above the linestones. It is in these marls that the landslide developed. Later, after the alpine orogenetic movements, a powerful series of continental layers was deposited; they are an alternation of the conglomerates and red sandy clays Mio-Pliocene (Fig. 3). It is well recognized that it is this formation which is most sensitive to instabilities the slopes and the landslides (Coiffait, 1992).

According to the synthesis of the information collected by library research and on site, the study will deal particularly with the faciologic cartography of Neocene in the area of Constantine in order to see the space distribution of the deposits.

The Neocene one of the surroundings of Constantine is composed of continental deposits with dominant detrital in its lower part and carbonated in its higher part. This continental sedimentation covers in angular unconformity the frame representing neritic Constantine's. By places the Neocene series appears by a side change of facies and by discontinuities in relation to a microtectonic activity. Sometimes it is put in direct contact with limestone neritic because of neotectonic accidents.

The Neocene deposits are subdivided into three distinct cycles on the ground of sedimentological criterion (Fig. 4).

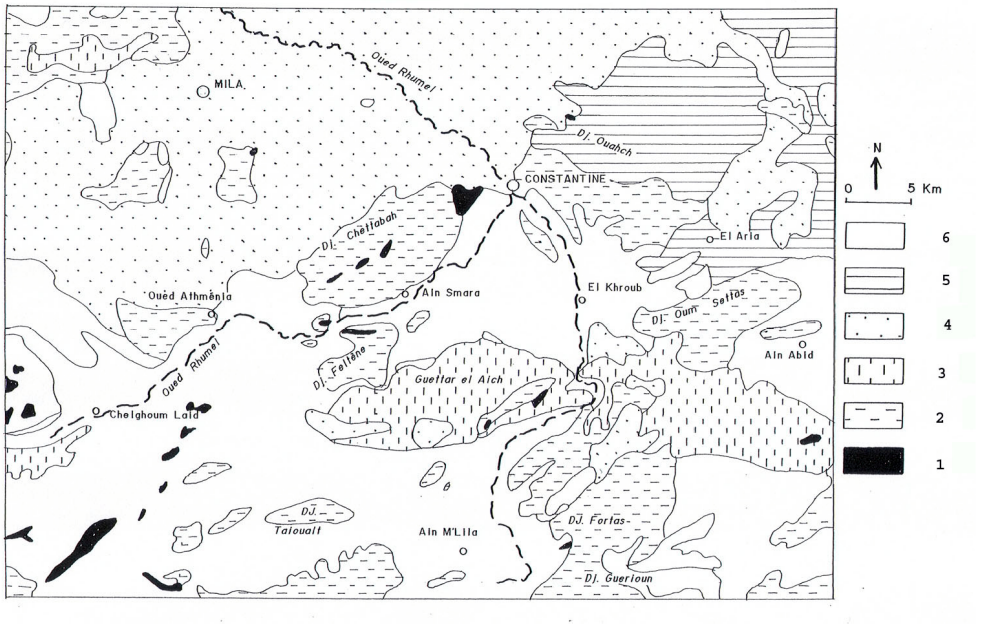

Fig. 4: lithostratigraphic Columns, (According by Coffait P.E 1992), 1 Central of Constantine, 2 Face of overlapping, 3 Faults, setbacks, 4 Faults opposite, 5 Arches, 6 Folds synclinal

A basic cycle, made up primarily of reddish conglomerates, with polygenic and heterometric elements whose dimensions can reach more than 50 cm and whose facieses are carbonated, sandy or siliceous. On the surface, large benches of poudings are observed being able to reach several meters thickness. This set often includes, in alternation, of the silteuses clay or sandy marl levels always in the same nuance.

A median cycle, with dominant marly with muddy, contains gastéropodes, thin discontinuous levels of gypsum and coarse deposits of channels. The gypsum often fills of fine cracks appearing in clays without preferential orientation.

A higher cycle, represented by lake limestones gray, includes layers of dyed of the same marls. Certain benches are rich in gastéropods and the vegetable remainders. The latter are observed on the western plate (Exit of Constantine towards Sétif) and in Dj.Hadj Baba, dated Pliocène inferior-means (Coiffait 1992).

The series is crowned by a quaternary term generally beginning with detrital levels and overcome by limestone benches.

Geological cut: To visualize the profile of the ground, two lithostatigraphic columns will reveal following results

The mio-pliocène: This cut is raised on the slope of the western South Constantine, cite 5 Juillet. Two successive lithological sets are distinguished:

A marly lower set exceeding the 50m thickness which, in its turn, can be subdivided in two terms.

A basal term composed of gray marls, on very thin gypsum levels (millimeter and centimeter). In these marls one finds Gastéropods similar to those found in the marls, often filled with gypsum we sometimes observe only the gypseous mould. In these marls appears, by places, of the deposits of channels made up of conglomerates with well rolled elements, with variable granulometry (centimetric with decimetre). In their higher part sedimentary structures represented by oblique litages in the coarse sandy sediments appear particularly. These deposits of channels end in fine sandy levels covered by a silteux facies.

A second term, always made up of marls, slightly beige colored (60 to 70 m) contains also deposits of channels with coarse elements. In the fine levels one distinguishes an intersected stratification, sometimes slightly curve.

A higher sit, less thick, compared to that subjacent (~40 m). It is composed of reddish silteuses marls, layers of argillaceous limestones to travertineux, always of the same color and of the marno-sandy levels very little consolidated. At the top some decimetre water limestone benches gray-rosâtres with small vacuums (vacuolar) papered fine calcite crystals, comprising a fracturing with calcic filling. Often these limestones contain fossil traces of plants and gastéropodes (Hélicidés) brought back to Quaternary old.

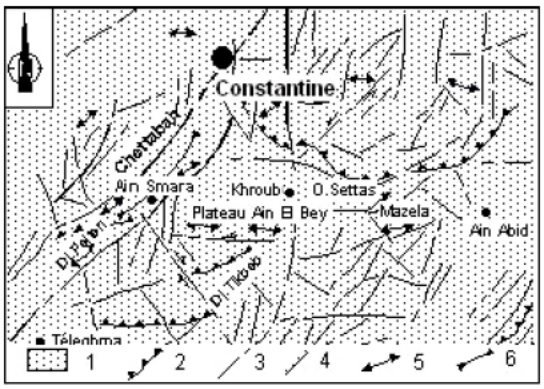

Fig. 5: Structural element of the area of Constantine. (According by VILA J.M. 1980)

Quaternary recent deposits: They are made up especially of old colluviums in edge of the reliefs and of the crusts and tufas, the deposits of slopes and the polygenic glacis.

The alluvial terraces are laid out on banks of Rhumel River with the top of the current bed. They are consisted muddy materials, rolled gravels and rollers which one finds throughout the valley of Rhumel and Boumerzoug. They are located at various altitudes and are observed locally in edge of the plains. Travertines are deposited by the great sources on more raised levels and appear on the level of Békira, of the plates of Mansourah and Aïn El Bey. They correspond to limestone of sintered aspect, more or less vacuolar of gray color to yellow.

For more details on the consequences of the slidings, microtectonic has also its effect on dynamics of the ground (Fig. 5) then by this phenomenon; it has also to be announced the presence of faults to flat contact, inducing overlapping with southern vagrancy and more particularly those injected by Trials by (Vila, 1980).

Geotechnical study: The soil surveys relate mainly to clays and the marls because in fact metamorphic rocks absorb water enormously, they are very porous, their grains are microscopic, therefore a very significant coefficient of liquidity and plasticity. TERZAGHI thoroughly studied the complexity and the characteristic of clays (L.N.T.P).

In the curve of Talbot clays reach a porosity of 0.84 for which the vacuums occupy more than 5 times equal to that of the grains. The voluminal clays have an index of the vacuums which exceed 13 times the volume of the grains (Costet and Sanglerat, 1981). If we considers the shapes of the grains, he notices the more the grain is small the more the presence of the vacuum and that as the the ground inflates water, its fine composition in particles increases. It is the case of clays whose their diameter varies from 0.05 à5µ. The property of the fine particles explains the characteristic and of the diversity of the behavior of clays by their complex composition and their shape of grains called in spangle or layers from where the phenomenon of absorption of water. The complexity of absorption water has an essenttial role in their behavior and consequently the behavior of the ground on the surface and in-depth.

Variation of the mechanics rock properties: In a ground containing of fine materials (clay and silts), the variations of the water content have effects on its mechanical properties:

Absorption involves a reduction in the shear strength; the desiccation involves on the contrary an improvement of these properties on a small scale and on a large scale of the cracks and cracks more or less profound appear (polygonal ground). Although the demonstrations are very slow and not very spectacular compared to erosion by running waters, they lead to a deterioration of the general stability of the ground sometimes on great surfaces. In particular, after one dry period, the first rains penetrating in the open cracks are frequently responsible for the reactivation of ground masses on the slopes.

Samples were taken from various zones; from our test sites; argillaceous formations of Mio Pliocene which characterize only from a geotechnical point of view. These sites are: Bellevue, 5juillet district and the bardo (district of the slaughter-house). Certain grounds were the subject of several tests concerning it's repetitively. The tests carried out on these formations were realized from natural samples. For the whole of the studied sites, several cored surveys were carried out.

Agranulometric analysis was applied with in each test and for each site in order to compare the curves, making sure that these last have about the same paces we took the average curve of each the mineralogical nature was determined by the diffraction of x-rays on the samples of the three sites. Spectra of diffraction obtained for the three sites in question show the presence of technical Kaolinite (Mongéreau *et al*., 1985). La of diffraction of x-rays allowed us to identify the nature of clay. The principal minerals are the Kaolinite (which are the only phyllosilicaté mineral), quartz, Lutecite, Zeolite, Schistovite and Tredimite.

While basing oneself on the index of plasticity and the argillaceous fraction, one can have various behaviors of clay. According to Skempton, the value of ac, which by definition is the report/ratio of the Index of Plasticity IP (%) with the content of clay (particle of dimension lower than 2µm), directly reflects the mineralogical character of

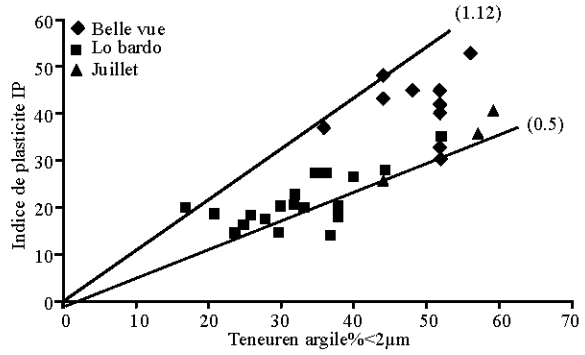

Fig. 6: Ratio between index of plasticity and argillaceous fraction, (According by L.N.T.P)

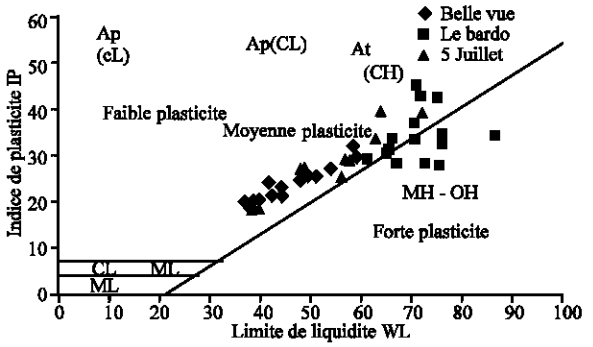

Fig. 7: Plasticity of clays of constantine. (According by L.N.T.P)

clay. Thus, we will have: Ac<0,75 inactive clay; 0.75<Ac<1.25 normal clay; Ac>1,25 active clay.

In spite of the importance of the argillaceous fraction, the whole of the values of the activity (ac) of the studied sites is located between the lines of slopes ranging between 0,5 and 1,12. These grounds can be regarded as inactive or having a normal, elsewhere, there are relations between the various properties which are validated for the majority of clays. Thus the property characterizing the consistency of clays is represented by the relation between the index of liquidity and the shear strength not drained (Fig. 6) a correlation was carried out, between the angle of repose and argillaceous fraction. This correlation shows well the influence of the argillaceous fraction on the physical properties and mechanical of the studied clays.

Limits of atterberg: In a traditional way, the Index of Plasticity IP represents the beach of water content for which the ground acts like a plastic material, the plasticity and liquid limits (Fig. 7) being the high delimiters and lower plastic behavior.

The limits of Atterberg test results the granulometric analysis shows that carried out on samples sites position on the abacus of Standard in a well defined zone, parallel with line " A " and just above this one, of equation: IP = 0,73 (Wl-21).

More share of the studied samples, corresponding to clays of the various sites, are of average with strong plasticity (Fig. 8) with values of IP ranging between 15 and 45%.

In spite of the great diversity of the clay soils, the great principles controlling their mechanical behaviors are always identical, which makes it possible to develop general approaches for the various practical problems. Clays are cohesive materials consisted of fine elements and are characterized by a very low permeability compared to granular materials (pulverulent) and in particular sands. Their mechanical behavior is very influenced by the history of the constraints of consolidation, in particular the water content which is a fundamental parameter. When they are saturated this parameter can be replaced by the index of the vacuums

Indices of sliding: The study of the theological characteristics of the ground for this phase relates in a general way to the determination of the geotechnical parameters, physics and mechanics starting from the natural samples under the conditions of nondrainage.

The required objective is of being able, initially; to appreciate the short term ground behavior. Each taken ground was the subject of a visual identification.

Site of belle vue: The ground is covered by a formation of fill of which the thickness varies between 1 and 2 m the below, with the compact argillaceous formations which present sandy lenses.

Site of the bardo: The ground is covered by a formation with fill with brown clay of which the thickness varies between 1 and 2 m below, one observes gypseous and muddy argillaceous formations.

Site of 5 juillet: This ground is made up mainly of clay with sand alternations, gravels, or with muddy matrix clay.

The analysis of the values of the various parameters shows that all the samples of the various sites have the same rheological entities. the granulometric analysis shows that the formation of mio-pliocene presents a granularity of sometimes sandy muddy clay type, of muddy argillaceous fraction (%> 1µm) varying from 35 to 80%, one notices that the shape of the curves reveals that this clay has a uniform granulometry with fine

One notices that the indices of plasticity are slightly homogeneous, except for the site of Belle Vue, where the indices of plasticity are definitely higher, which explains the tendency to the swelling of the site. The clay of Mio-pliocène has a coefficients compressibility varying from 0,188 to 0,287 and an average not drained cohesion varying between 0,25 to 0,6 bars. It is noted that the first depths indicate coefficients of compressibility and cohesions relatively low. These values correspond for the majority of the surveys to the formations of fill; beyond these formations, these values become average

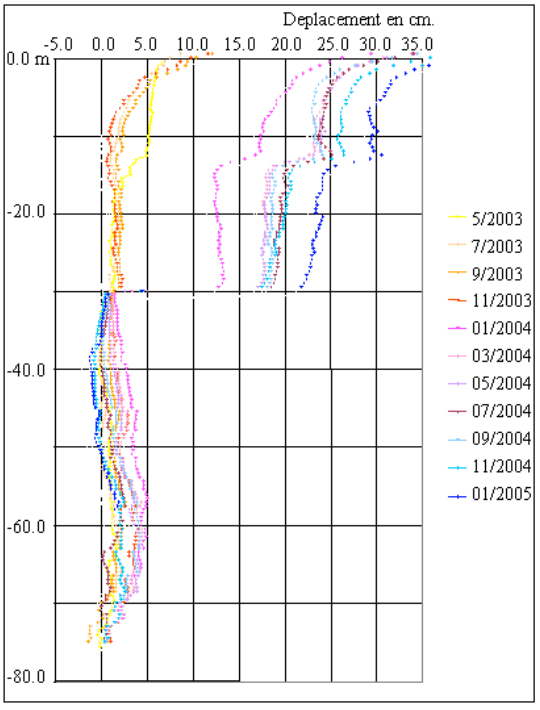

Fig. 8: Test in 5 juillet city 05/2003 to 01/2005 (According by L.N.T.P)grains. The state in question shows that it is about dense clay. The dry density varies from 1.5- 2.02 t m^{-3} the corresponding water contents are very homogeneous-W varies (14.4-22%) and definitely lower than WP. These clays are partially saturated to saturate

Inclinometric test: The geological data clearly do not show the depth of the slips as well as the layer in question which makes rupture, the inclinometric intervention of the test proves to be essential if one wants to really study the problem and to have results which will give an outline on a recommendation of solutions.

In the three cases, Bellevue, Bardo and 5 juillet the installation of a device of monitoring is essential (Fig. 8).

It must make it possible to determine the position of the rough surface, to determine contours of volume moving, to follow the evolution and to consider possible risk of aggravation of the situation. The monitoring system constitutes a fundamental and essential element for the follow-up of the movements of grounds and the definition of the confrontments. It is for this reason that the inclinometry was selected in priority for the follow-up and the measurement of the landslides of the town of Constantine.

RESULTS

Periodic estimate: Having studied the geological aspects, mineralogical geotechnics and physico-mecanique of the various sites, an inclinometric test will give information on the unstable layer of ground and its thickness, to follow the evolution and to consider possible risk of aggravation of the situation of the site for one given duration, this instrument loses its reliability if the dynamics of the ground arrives at the limits of its use.

This instrument was installed the 03.05.03 in the 5 juillet city because it is close to the Belle Vue and because it is a site of a considerable importance (the institute of Islamic sciences).

The results recorded for 18 months duration gave (Table 2):

- 36 cm of displacement on a level of-2 m compared to the surface of the ground
- 32 cm of displacement on a level of -14 m compared to the surface of the ground
- 27 cm of displacement on a level of -31m compared to the surface of the ground

Table 2: Displacement of the ground in time and the depth

Period	Depth (m)			Displacement (cm)			Natural of time	Géology
May2003								
to nov 2003	-2	-14	-31	10	4	3	dryness	Pliocène
Nov2003								
to jan 2004	-2	-14	-31	17	15	10	wet	Miocène
Jan2004								
to mar 2004	-2	-14	-31	4	6	6	wet	Miocène
Mar2004								
to nov 2004	-2	-14	-31	5	3	3	dryness	Miocène
Nov2004								
to jan 2005	-2	-14	-31		4	5	wet	Miocène
Displacement (cm)				36	32	27		

CONCLUSION

The most significant displacement were recorded during the wettest seasons mainly during winter 2003-2004, water with a slope of more than 25% are the principal causes of the landslides. We concluded from it that the water of the rains exceeding a high threshold becomes the principal factor of the movements of ground and consequently damage causes with old and recent constructions.

REFERENCES

Benaissa, A., 1998. Propriétés géotechniques de quelques formations géologiques propices aux glissements de terrains dans l'agglomération de Constantine», Rummel, Constantine, pp: 111 -120.

Coiffait, P.E., 1992. Un bassin post-nappe dans son cadre structural: L'exemple du bassin de Constantine. Thèse de doctorat d'état., Université Henri Poincaré, Nancy I, France, pp: 502.

Costet J. et G. Sanglérat, 1981. Cours pratiques de mécanique des sols T1. Dunod Paris, pp: 6-45.

LNTP. Est Laboratoire National des Travaux Publiques de l'Est Constantine. Résultats des travaux dans la région 1970-1990, travaux dans la ville 2000-2005.

Mongéreau N. et G. Sanglerat, L. David et H. Millers, 1985. *Mouvements de terrain en zone urbaine*: Exemple la ville de Lyon. Bulletin de l'AIGI N° 31, pp: 93-103.

Vila, J.M., 1980. La chaîne alpine d'Algérie orientale et des confins algéro-tunisiens. Thèse, Université Pierre et Marie Curie, Paris VI, 2: 665.