DEVELOPMENT OF A NEW CLASSIFICATION BASE FOR CONCRETIONARY SOILS OF TROPICAL REGIONS

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Abstract: The necessity of the Brazilian government to develop the Amazon region in a sustainable way motivated the carrying out of several tecnological studies. Projects have been encouraged for the development of urban centres at the country boundaries and other strategic locations. In the places where there is no access by river, it is fundamental that airfields are constructioned because the road access among the urban centers is impossible due to distance, environment impact and cost.

Being a tropical region, generally there is no granular material obtained from rocks in the surrounding areas. However, there are lateritic soils in abundance, particularly the concretionary ones. This material is largely used in pavements structure of airports and highway and unpaved vicinal roads. Due to its quality this soil can be used in all structural layers.

The conventional classification methods of soils, HRB and USCS do not include this type of soil. The classification methodology MCT-Miniature-Compaction-Tropical developed in Brazil for soils in tropical region was restricted to fine soils.

In order to extend the MCT methodology to concretionary soils compaction equipment MCV-ITA-pneumatic was developed which experimental procedures was adapted. Studies were carried out on about 20 different samples of fine soils and four concretionary lateritic soils and then, the scale effect, structural junction and compacting energy were evaluated.

The new classification methodology developed allows the genesis and the mechanical and hydraulic behavior of the concretionary soils to be evaluated in the laboratory.

The application of this methodology will allow the rational choice of materials in borrow areas. In construction, the aim is avoid problems such as sinking pavements, disintegration and erosion on slope faces of cut and fill, among others, with more rational studies. The implement of procedures will decrease the future environment impacts and it will ensure the durability of the work.

Résumé: La nécessité du gouvernement brésilien pour développer la région d'Amazon d'une manière supportable a motivé l'élaboration de plusieurs études tecnological. Des projets ont été encouragés pour le développement des centres urbains aux frontières de pays et aux endroits stratégiques. Dans les endroits où il n'y a aucun accès par le fleuve il est fondamental la construction de terrains d'aviation parce que l'accès de route parmi les centres urbains est dû impossible à la distance, à l'impact d'environnement et à ses coûts.

Être une région tropicale, généralement là n'est aucun matériel granulaire obtenu à partir des roches dans les abords. Cependant, il y a les sols lateritic dans l'abondance, en particulier les concrétionnés. Ce matériel est en grand partie employé en structure de trottoirs des aéroports et de la route et unpaved des routes de rural. En raison de sa qualité ce sol peut être employé dans toutes les couches structurales.

Les méthodes conventionnelles de classification de sols, de HRB et d'cUscs n'incluent pas ce type de sol. La méthodologie MCT-Miniature-Compaction-Tropical de classification s'est développée au Brésil pour des sols dans la région tropicale a été limitée aux sols fins.

Afin de sortir la méthodologie de MCT aux sols concrétionnés que c'a été développé un équipement MCV-ITA-pneumatic que des procédures expérimentales ont été adapté, il de tassement était des études réalisées dans environ 20 échantillons différents de sols fins et 4 sols lateritic concrétionnés et puis, c'a été évalué l'effet de balance, la jonction strutucturel et l'énergie de compactage.

La nouvelle méthodologie de classification développée permet à a évalué la genèse et le comportement mécanique et hydraulique des sols concrétionnés dans le laboratoire.

L'application de cette méthodologie permettra le choix raisonnable des matériaux dans des secteurs de prêt. Dans la construction, le but est évitent des problèmes tels que les trottoirs de descente, la désintégration et l'érosion sur des visages de pente de coupe et de suffisance, entre d'autres, avec des études plus raisonnables. L'instrument des procédures diminuera les impacts d'environnement à terme et il assurera la longévité du travail.

Keywords: aggregate, classification, earthworks, infrastructure, laboratory tests, soils

INTRODUCTION

The biggest forest reserve of the world is in the Amazônia andpresents 61% of the Brazilian territory. To develop the region, the construction of aerodromes in the Amazon region has become more important in the last decade, as the means of transport that, in a comparison with the other ways (river, road and railroad) demonstrates better results in a cost-benefit analysis. River transport, the way most used currently, does not give access to all the places, therefore it depends on the existence of the rivers. In dry periods, passage may be impossible, due to the low level of water in the rivers. Roads and railroads, need the construction of long linear stretches of platforms at high cost and cause incalculable environmental impact, through deforestation and movement of soil in cuts and earth embankments.

DIRENG (Direction of Engineering of the Aeronautics) and COMARA (Commission of Airports in the Amazon region), agencies of the Command of the Aeronautics, are respectively, responsible for the project and construction of aerodromes in the Amazon region. The ITA (Technological Institute of Aeronautics), also an agency of the Command of the Aeronautics gives scientific and technological support to DIRENG and COMARA, in the improvement and development of proper technology for Amazônia.

One of the main problems for construction of the tracks is the absence of granular material of rock in nearby locations, to be used in the sub-base and base of the structure. This fact motivated the carrying out of this research, whose main objective was to evaluate the hydraulical and mechanical characteristics of concretionary lateritic soils. These soils, abundant superficially in all the region, can be used as an alternative to the aggregate material of rock. However, in post-construction evaluations of construction work, it can be observed that the expected performance was not always achieved. For exemple, in some instances rapid and intense degradation of the base of the structure occurred.

Initially, this was attributed to the severe climatic conditions. Studies for the ITA by Vertamatti (1988) had shown that despite the results of laboratory showing how a satisfactory performance for the material could be achieved, this was not always used. On the basis of this evidence it was concluded that different types of lateritic concretions existed and that the traditional laboratory methods were not capable of correctly predicitng the behaviour of the concretionary lateritic soils.

The development of this research sought to extend classification procedure MCT (Miniature, Compact, Tropical) to concretionary lateritic soils, thus that the methodology MCT comes to demonstrate its potentiality in the forecasting of the mechanical behaviour of fine soils of regions of tropical climate.

TRADITIONAL AND NOT-TRADITIONAL CLASSIFICATIONS

Traditional classifications

Traditional classifications are those cited by the reports of the Comittee on Tropical Soils (1985).

Classification MCT

Nogami & Villibor (1980) presented a new classification, specially developed for the best tropical soil use in pavement at low cost. This simplification involved an adaptation of the procedures of the English test Moisture Condition Value (MCV), introduced by Parsons (1976) and the equipment of compacting that was an adaptation of that developed by Lafleur et al. (1960) in order to use bodies of test of reduced dimensions, which led to the development of the Mini-MCV test.

The proposal of Nogami & Villibor (1981, 1985) allowed the separation of the soil's lateritic character in accordance with or not, evaluating them in the possible condition next to its use in the field or compacted.

Classification MCT is composed for two basic tests: Compacting Mini-MCV and Loss of Mass for Immersion.

The most recent proposals of modifications to the Mini-MCV have been made by Marson (2004), described below.

Mini-MCV Compacting test

- execution of the test soon after the homogenization of the water in the sample of soil;
- compaction of only 3 test samples to get the c ' and for definition of the attribute of the curve Pi x Mini-MCV;
- manipulation of a smaller number of values and curves to get the result;
- reduction in the time of test, the volume of work and also of the number of expended blows to get the Classification MCT.

Loss of Mass for Immersion test

- the upper face (directly hit) of the test sample or the lower face can be used, without significant alteration in the results;
- the test samples can be immersed in water for only 4 hours;

- necessity of attainment of the attribute of the curve Pi x Mini-MCV, which expresses the behaviour of the soil due to the immersion in water. For this, the curve must be launched in the abacus of attributes (Figure 1). The attribute varies of 1 the 3, as the area where if it locates the curve.

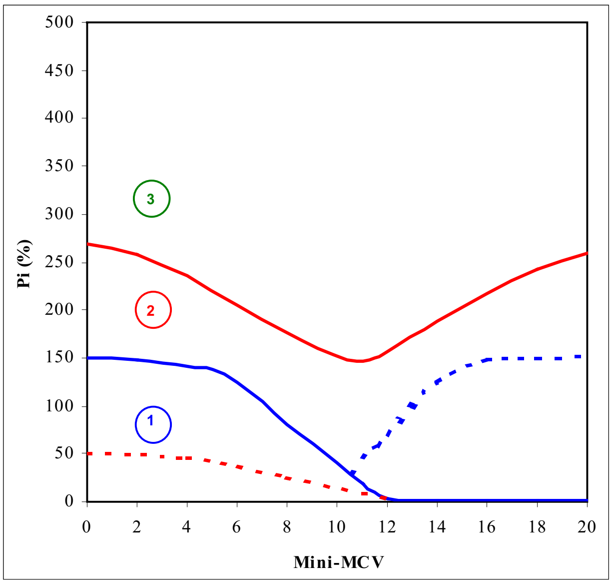

Figure 1. Abacus of attributes of the curves Pi x Mini-MCV.

Attainment of group MCT

With the values of Pi and of the attribute e' can be calculated. Launching coordinate point (c'; e') in the classification abacus gets it Classification MCT of the soil.

$$e' = \sqrt{\frac{Pi}{100}} \cdot At$$

The new MCT-M abacus

With the modification of the formula of calculation of e' it was necessary to make some adjustments in the classification abacus (Figure 2).

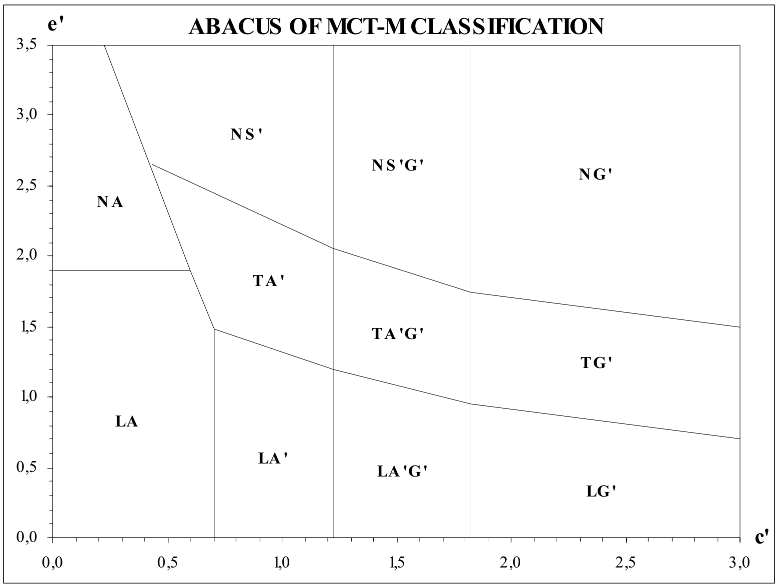

Figure 2. MCT-M abacus for tropical soil classification.

CONCRETIONARY LATERITIC SOILS

According to the Brazilian Soils Classification (EMBRAPA 1999), the concretionary lateritic soils are defined as Plintosols, which are constituted by mineral material, with plintic or lithoplintic horizons starting at less than 400 mm depth, or less than 2000 mm when immediately below of the horizons A or E. They have a variegated pale coloration, or with stains in abundant amount (> 20% for volume) and satisfying one of the following colours: shades 2,5Y or 5Y, 10YR or 7,5YR, stains in abundant amount with coloration since red until yellowish or still, horizons of pale coloration (grey colours, white or yellowish-clear).

In the studies of classification developed by Vertamatti (1988), the cycle of grain sized evolution of lateritic soils of the Amazônia, a first attempt was identified to classify concretionary lateritic soils on the basis of the granulation. This divided lateritic soils into three main groups: zone of becoming plintite, zone of hydromorphic lateritics or low concretion and zone of accented concretion (mature soil).

The field investigations had shown that the plintite and the hydromorphic laterite should not be used in the structure of the roadway, as they provided insufficient structural performance.

Figure 3 illustrates a mature concretionary lateritic soils deposit (Oiapoque/AP) and Figures 4 and 5 illustrate the magnifying of the track of the aerodrome of Oiapoque/AP where the lateritic concretion was used as sub-base and base.

Figure 3. Mature concretionary lateritic soils deposit (Oiapoque/AP).

Figure 4. Track of the aerodrome of Oiapoque/AP.

Figure 5. Lateritic concretion used as sub-base and base of track of the aerodrome.

METHODOLOGY

The MCV-ITA equipment and its test procedure

In view of using the Mini-MCV equipment, methodology MCT was restricted to fine ground, that is, fractions with average diameter of particles less than 2mm. Thus, for concretionary lateritic soils treatment it was necessary to adopt equipment where the materials were compact to pass through the 1" seive. First, the use of equipment MCV was developed by Parsons (1976). However, the weight of the falling weight of 7kg, and the difficulty of manual operation of that equipment had led to the development of a new device. To facilitate the reproduction and national application of the procedure, the diameter of falling weight, height of fall and weight of falling weight of the Marshall equipment had been adopted. From a project of research with support of the CNPq and the FAPESP, the archetype of the equipment MCV-ITA was developed. In this, was incorporated a pneumatic system for application and counting of blows, controlled through an electromechanical panel. Rezende (1998), during the development of his thesis of Master, tested and became accomplished the equipment

First, a sample of fine soil was tested to calibrate the tests. Operational problems with the prototype were identified and corected, such as: the axle-guide of the falling weight and the extrusion of soil from the bipartite cylinder. Figure 6 illustrates the pneumatic MCV-ITA equipment in its final version. To verify the repeatability of tests and to adjust the procedure of the Mini-MCV test to the MCV-ITA, three different kinds of fine soil were chosen: a clayey one, sand-clayey and a sandy one. After the test of procedures, such soils were tested again and the results compared.

Some adjustments were necessary for example: the wet mass of 1.5 kg of soil and the setting of Δan=5 for determination of parameter c ' such as in the original procedure MCV of Parsons (1976), and the extension of the axis of in the graph of Δan x the number of blows. The alterations had been necessary, mainly in terms of the scaling effect between the Mini-MCV equipment and the MCV-ITA.

Figure 6. Pneumatic MCV-ITA Equipment.

After to have been adjusted the procedure of the assay, was being increased the number of samples of fine soils, looking itself to enclose the groups of the classification abacus MCT-M adapted for Vertamatti (1988). The distribution of the samples in this abacus can be observed in Figure 7.

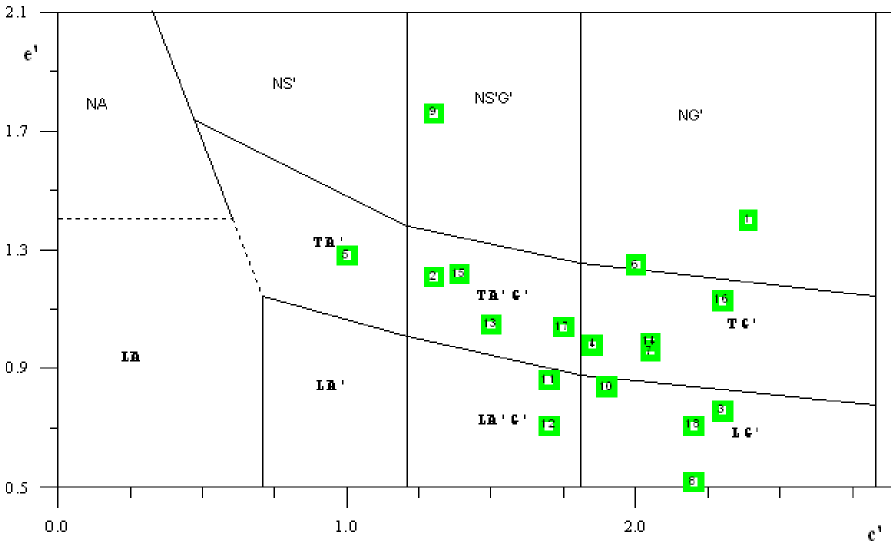

Figure 7. MCT-M abacus showing the distribution of fine soil samples the assayed in the Mini-MCV equipment.

To calculate the parameters c', d', Pi and e' the procedures of methodology MCT with the Mini-MCVequipment were adopted. In Figure 8 the results in the MCT-M abacus can be seen for fine soils tested in the MCV-ITA equipment. It was observed that the results of the MCV-ITA equipment had been displaced horizontally to the right as a result of the scale effect. The vertical displacement of the points, a function of the parameter e' associated with the genetic characteristics of the soil, was small. It was decided, then, to converge the results of parameter c' from the MCV-ITA equipment to the ones for the Mini-MCV to have an equivalence factor between the two sets of results. For this, the region was identified where the structural break in the curves of number of blows versus reduction of height of the test body occurred. It was tested, then, the Mini-MCV=10 value for MCV-ITA = 14, 15 and 16. For the MCV-ITA value = 14 the best approach was achieved and this was adopted as the result equivalent next to the classification for the MCT-M abacus, considered thus to compensate for the scale effect. This was followed so that the same classification base MCT was used in the expanded abacus, so that the same sample of soil would be classified similarly by both sets of equipment.

Additionally, to evaluate the specific energy of compaction the process of absorption of the energy applied through the two sets of equipment was studied, by reducing of the height of the of the test as a function of the applied energy. The sample of Red Latosol (number18 - LG') was used and using for the curves of total compaction for a moisture content of 10.8%. Figures 9 and 10, show the development of these curves. It can be seeen that the specific energy applied by the equipment is practically equivalent and that above 70 blows more significant reduction of thickness of the sample in the two tests does not occur. It can be observed, also, that the test was appropriate for lateritic soils, since the structural break continues occurring, which favours the introduction of a new classification extended to include concretionary lateritic soils.

It must be clarified that it was not the objective of the research to substitute the Mini-MCV equipment for soils with fine texture with the MCV-ITA. Therefore, for this kind of soil this has advantages as a smaller amount of soil is needed and the test is easier to carry out with a smaller falling weight, among others.

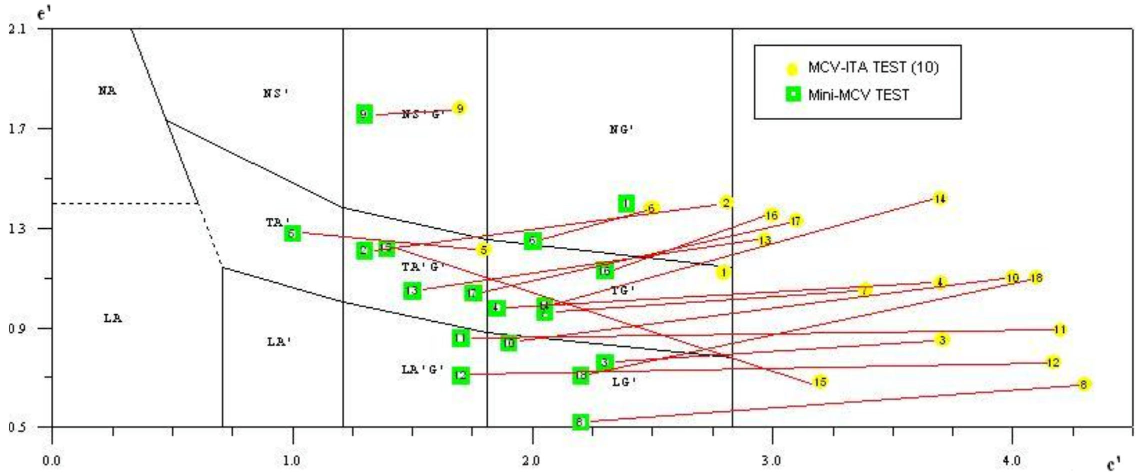

Figure 8. Expanded abacus MCT to indicate resulted equivalents to the MCT-M when the sample in the MCV-ITA is assayed.

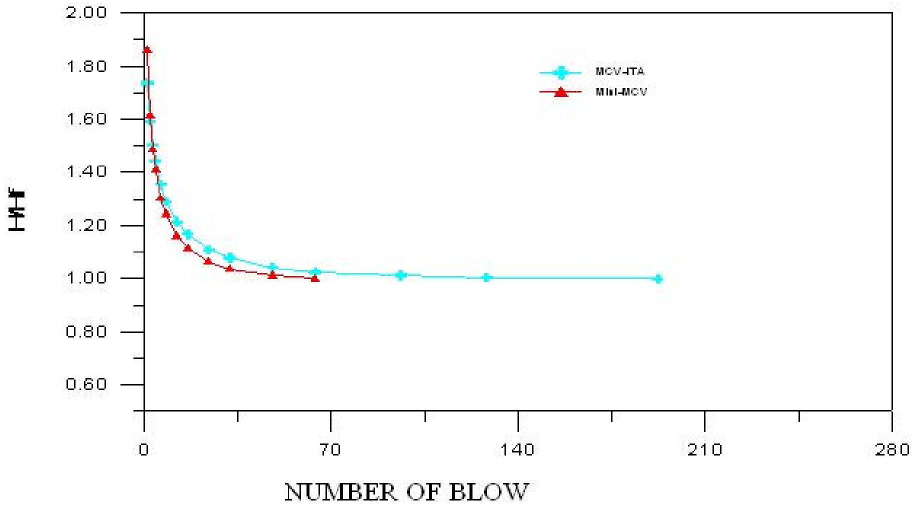

Figure 9. Verification of the applied specific energy in the body of test for the sample of Red Latosol in function of the number of blows.

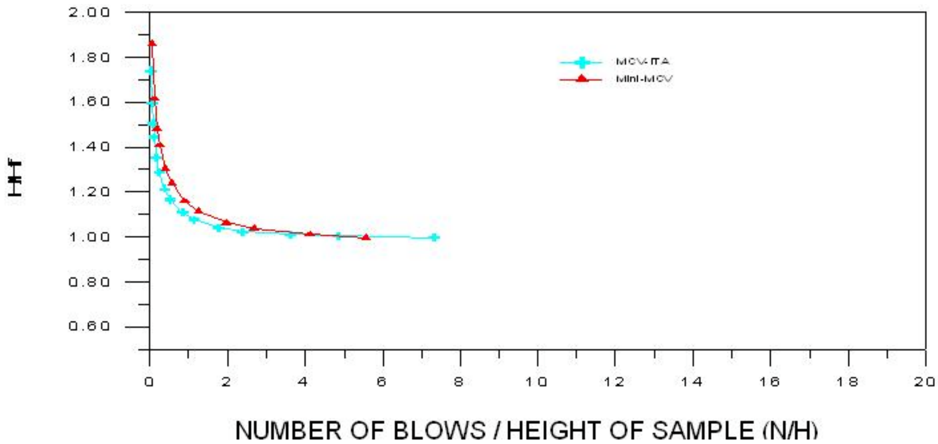

Figure 10. Verification of the applied specific energy in the body of test for the sample of Red Latosol in function of reason N/H.

TEST WITH CONCRETIONARY LATERITIC SOILS

To evaluate the applicability of suitable methodology MCT to the MCV-ITA equipment for classification of concretionary lateritic soils four different samples representative of these soils were selected. These were identified and collected as follows:

- sample 2-B - High Forest - TM,
- sample 11-B - Tiriós - Pará,
- sample 13-B - Breves – Pará
- sample - 14-B - Surucucu - RO.

After that, a reference test was made. The results of the test of Mini-MCV for the fine part of the selected samples had been extracted from the thesis of Vertamatti (1988).

Such samples had been, then, plotted in the abacus of grain size evolution (Figure 11), developed by Vertamatti (1988), from which were identified the groups into which the samples fit.

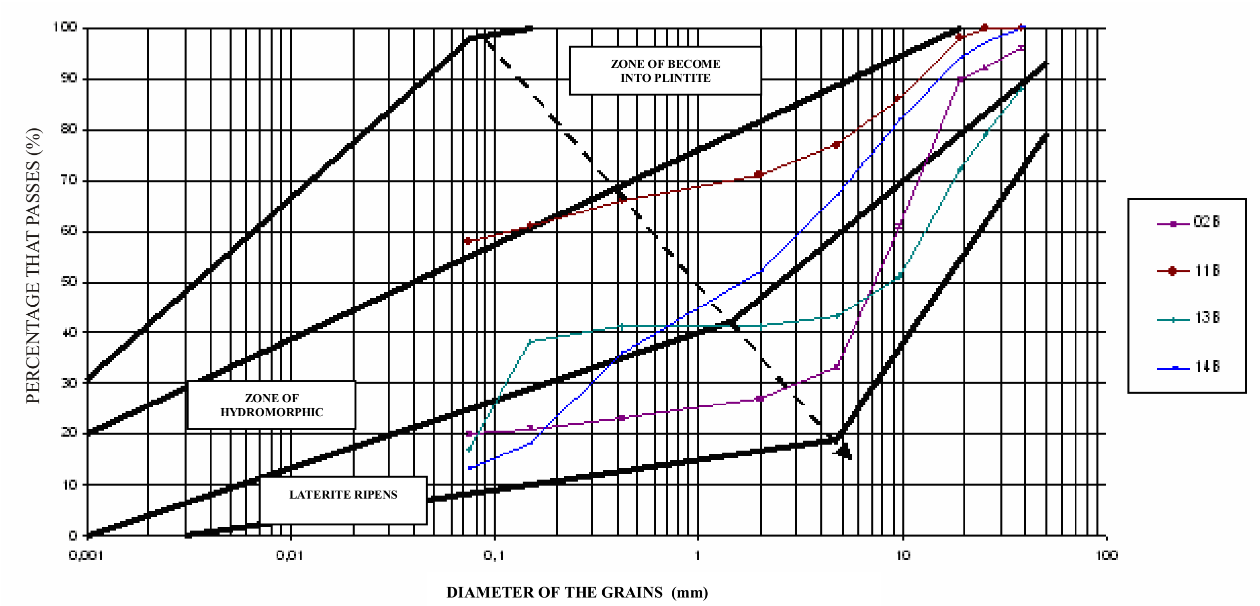

Figure 11. Cycle of grain sized evolution.

The samples had been passed through the 1" sieve and tested according to the new established procedure. The results can be seen in the MCT-M abacus of Figure 12. These confirm the areas of the graph that dictate the behaviour of the soil. The behaviour of the soil is dictated by predominance of the fine or coarse fraction grain size of the soil.

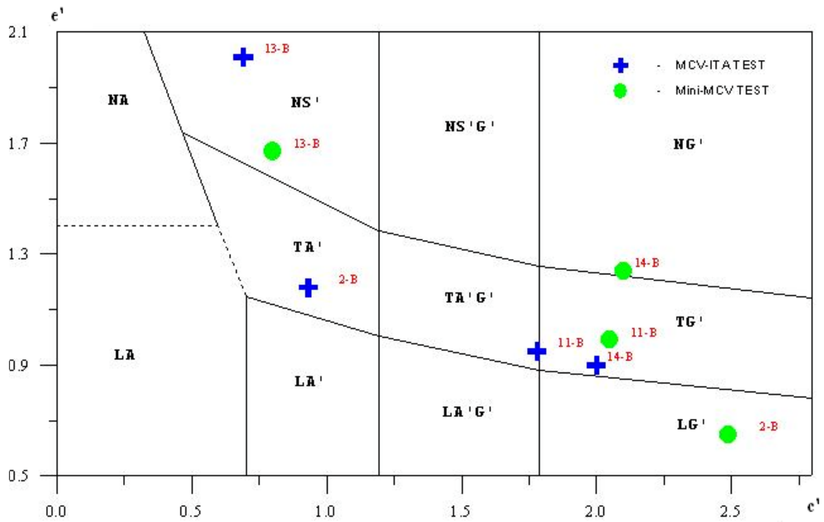

Figure 12. MCT-M abacus with the result of concretionary lateritic soils (where it is taken MCV-ITA = 14 for equivalence effect).

A first sketch of the new MCT-M abacus was prepared for application to concretionary soils, as indicated in Figure 13. To establish classification zones, the phase of genetic evolution was taken into account and the grain size fraction that the behaviour of the soil commands.

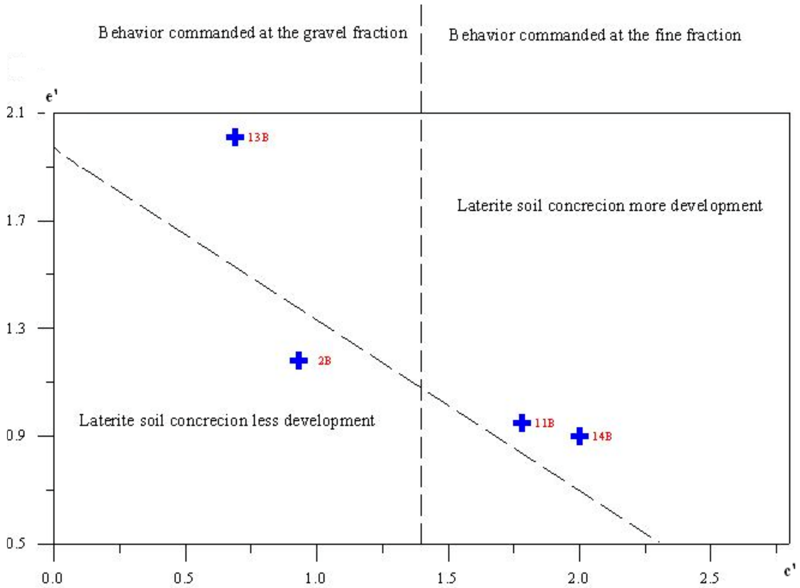

Figure 13. Sketch of classification abacus for the lateritic concretions

CONCLUSIONS

It is concluded that the proposed alterations to the classification MCT must simplify the laboratory test and decrease the necessary time for its accomplishment.

The MCV-ITA equipment for compaction proved to be functional and can be reproduced from the prototype.

The procedures developed for the concretionary soils classification are promising; therefore they allow the identification and classification of the types of existing concretionary soils in the Amazon region, taking into consideration thier mechanical characteristics.

In this way, such materials can be applied as bases and sub-bases of foundations in a rational way, being able itself to predict the performance and to guarantee the durability of the structure of the foundation.

The Amazon region is an important area and all the actions aim to generate sustainable development must be studied and be implemented.

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