# Application of the MCV to the construction of Barbate dam

## Application du MCV à la construction du barrage de Barbate

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SYNOPSIS: The MCV test (Moisture Condition Value) is being used for compaction control of clays in Barbate dam. The heterogeneity in the quality of the material used for construction made it necessary to use a quick and precise method for the daily compaction control. Its usefulness was decided after a preliminary study in experimental earthfills. After the necessary initial correlations in a certain soil formation have been established, the test has demostrated being quite adequate to know both the soil natural moisture content deviation with respect to the optimun value for compactation and the soil classification.

## SITE DESCRIPTION

The Barbate dam is being constructed in the province of Cádiz, south of Spain.

The valley of the Barbate river is extensive and has a variable elevation from 12 to 18 m above the sea level at the dam site. In order to obtain the required water level it is necessary to construct a dam 1.500 m long to reach elevation + 42.00 m. The alluvial flat land is formed by a thick soil deposit located over a terciary marl formation which appears approximately at elevation 0.00 at the center of the valley and at the surface of both valley slopes, as shown in Figure 1. The alluvial deposit is quite heterogeneus. It is a formation of gravels and sands which appear with a certain continuity over the marly botton and a mixture of sands, silts and clays distributed in a non uniform pattern.

To give an idea of the type of soil formation of the Barbate valley Figure 2 shows a typical soil profile where soil identification, consistency and shear resistance data are included.

The presence of smectites is one of the peculiarities in the clays of this valley. Consequently, they have expansive characteristics. The climate in this area is extremely dry during summer and quite wet during the rainy season. The superficial clays are subjected to a tough cyclic process of expansion and retraction.

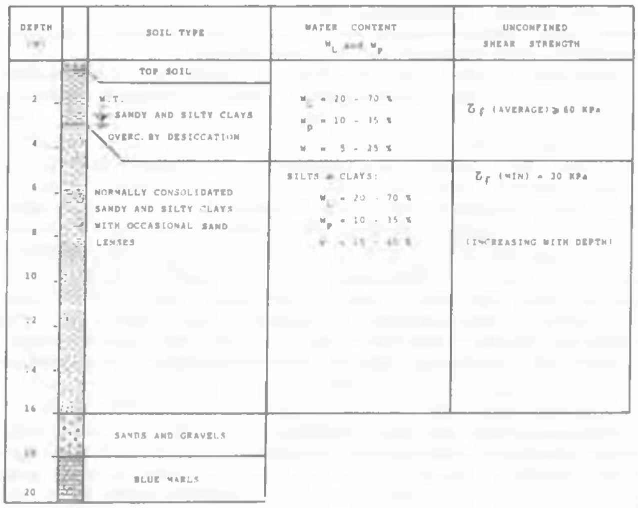


Figure 2. Typical soil profile

The waterlevel in this zone has a seasonal oscillation and it is located in between 2 and 5 m deep below the natural soil surface, higher in the valley slopes than in the center of the valley.

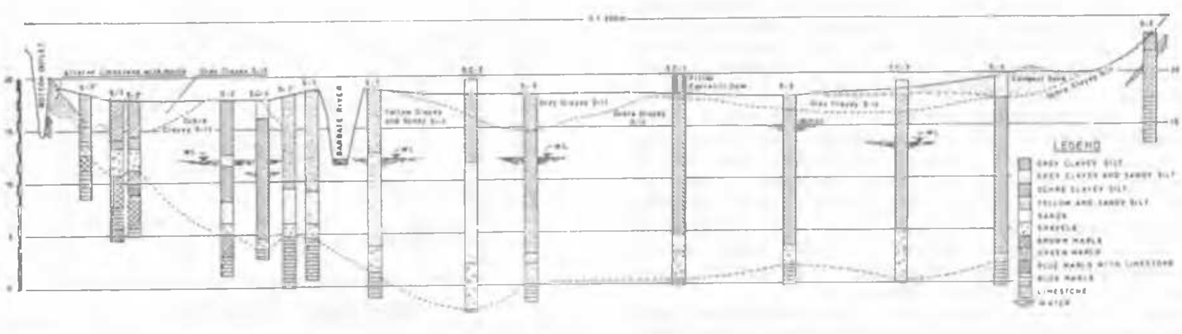


Figure 1. Cross section of the Barbate valley

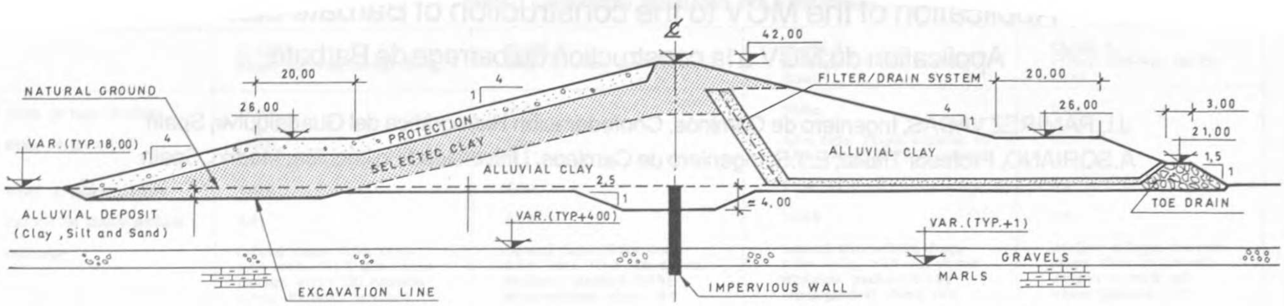


Figure 3. Typical dam cross section

## DAN SOLUTION PLANNING

The selection process which conducted to the adopted type of dam is beyond the purpose of this paper. But, it is important to quote that a basically homogeneous dam was decided after considering the conditions of materials of the zone and the foundation quality. Figure 3 shows a typical cross-section of the dam.

Appart from the filters, drains and protections, only two materials are distinguished in this dam. One of them, the nearest to the upstream slope, is specified to have low expansiviness so that it experiences small swellings during pond filling for pressure levels similar to the weight of the granular protection that covers it. The other material forms the rest of the earthfill dam and has a less strict limitation in the allowable expansiviness. Both materials should be selected from the same alluvial dam site located upstream of the earthfill dam and at the valley shallowest layer after eliminating the organic top soil and before reaching the water level.

A good number of lab tests were done with the clayey soils of the valley in order to establish the future execution control. It was concluded that those clays with a liquid limit lower than 45% could be used in the construction of the first earthfill dam zone while those soils with $W_L$ up to 65% could be used in the second zone far away from the upstream slope.

## DAM EXECUTION PROBLEMS

A wide pit recognition was done with several hundreds of soil identification tests and the quality of the different explotable zones was mapped quite accurately. But, after construction began, it was concluded to be practically imposible to know with sufficient precedence and precision the characteristics of the soil being placed in a certain moment to require the corresponding degree of compactation and placing moisture content. On the other hand, the soils water content during the dry season (May to November) which is the only one that allows construction work in this zone, is extremely variable because their drying is very fast since they are extracted fresh from the pit until they are placed in the earthfill dam.

To solve this problem an investigation was conducted about the possibility of using the MCV test to classify the soils of the alluvial flat land in a suficiently quick and precise manner.

## MCV TEST DESCRIPTION

This test was principally developed by Parsons (1976-1978).

In the MCV test a 7.0 kg rammer is dropped from a height of 0.25 m onto the soil specimen, with its natural moisture content, contained in a mold 100 mm internal diameter. A light weight disc is placed between rammer and soil to avoid its extrusion during rammering.

The compaction equipment has a ruler for settlement measurement of the upper soil part while the number of blows increases.

The main idea of the test is the well known fact that the soils, with higher moisture content than the optimum moisture content for compaction, can not be compacted even though the number of blows increases while the very dry soils can continue being compacted with the rammering process (See Figure 4). Basically, it is posible to deduce, from the relationship between the number of blows and the soil settlement, if the moisture content is high or low for its later field compaction.

Parson (1976) defined the MVC index as the number of blows N after which compaction was not practically posible.That point was arbitrarily chosen when by increasing N by 3N, the sample settlement was exactly 5 mm. Therefore the test

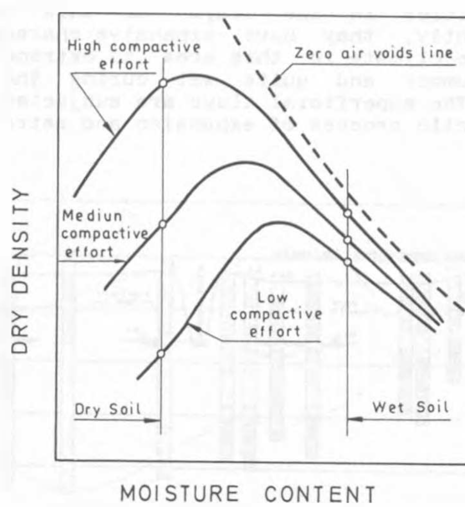


Figure 4. Escheme of MCV test principle

is done by measuring the sample settlement as a function of the number of blows, using increasing series of the total number of blows such as: 1, 2, 3, 4, 6, 8, 12, 16, 24, 32 ...

The upper soil settlement is computed later as the difference in the number of blows 1 and 4, 2 and 8, 3 and 12, etc. The relationship between the initial number of blows (1,2,3,...) and the settlement due to four times this number (4,8, 12,...) can be ploted and used to calculate the initial number of blows N that fulfills the above referred condition.

The number of blows N found in this tests varies from low values (2 or 3 blows) up to very high values (several hundreds). Therefore, instead of using N as a test result, the M.C.V. index is defined by

$$MCV=10 \log_{10} N \qquad (1)$$

## THE MCV AS A MOISTURE CONTENT DEVIATION INDEX

In the first place it was expected that the MCV test were able to predict if the soil sample were above or below the optimum moisture content and to quantify the difference. In order to establish this relationship, the MCV index and natural moisture content were determined on samples of known standard Proctor test results.

It is practically imposible to conduct Proctor and MCV tests on identical samples so the comparisson of the sample moisture content in the MCV test with the correspondent in the Proctor test will have a certain dispersion.

An experimental area with four zones at the clays deposit was done to establish the MCV moisture content deviation correlation. Two Proctor standard compaction tests were done with each layer of each zone of the pit (with a total of 1.000 $m^3$ per layer) in order to adopt as the optimun moisture content the mean of the two determinations. The same volume was tested with five MCV tests and five moisture content determinations. The mean of the five results was adopted as the reference value. The result obtained when the twenty reference values (four zones with five layers each) were compared is shown in Figure 5.

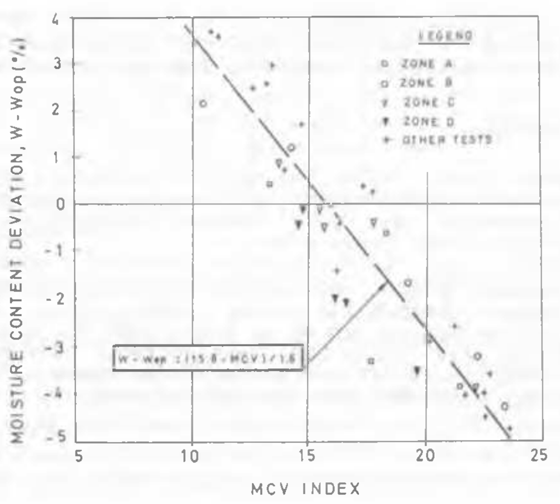


Figure 5. Correlation between MCV and moisture content

Within the logic caution due to the limited number of tests (40 Proctor and 100 MCV tests) and considering that the error in the moisture content determination of this soil and that in the Barbate area where sample drying can be significant during transportation from pit to lab, it can be pointed that there is a certain correlation between the MCV test and the difference of the natural moisture content to its optimum value in the Proctor standard compaction test. The correlation is

$$W - W_{op} = (15.8 - MCV)/1.6 \qquad (2)$$

The standard deviation of this correlation in the optimum moisture content proximity is around 1%.

Construction began after these tests while research on this correlation was continued. Today, with the experience gained in placing half a million cubic meters, it was observed that although the correlation is sensible to the soil quality, when the soil has the optimum moisture content of compaction its MCV is near to 15 (the actual mean value is 15.8 after considering all the available results). Furthermore, for each unit of deviation of the moisture content from the optimum value, the MCV deviates two units from that optimum value (the actual mean deviation is, today, 1.6 units if all the available determinations are considered).

## THE MCV INDEX AS A SOIL CLASSIFIER

According to the previous experience in the correlation between the MCV test and the Proctor standard compaction test,it is possible to establish with enough accuracy which is the deviation of the soil moisture content with respect to the optimum moisture content by performing MCV tests only. If the soil moisture content is determined while perfoming the MCV test it could be possible to know which is its optimum moisture content simply by correcting the measured moisture content within the deviation amplitude of the determined moisture content with the MCV test.

The optimum moisture content in compaction is one of the most important parameters for classifying a soil because, for a determined formation, it exits a sufficiently adjusted correlation between this variable an other important values like the liquid limit, and the maximum dry density in the Proctor standard compaction test. Figure 6 shows two examples of such correlations.

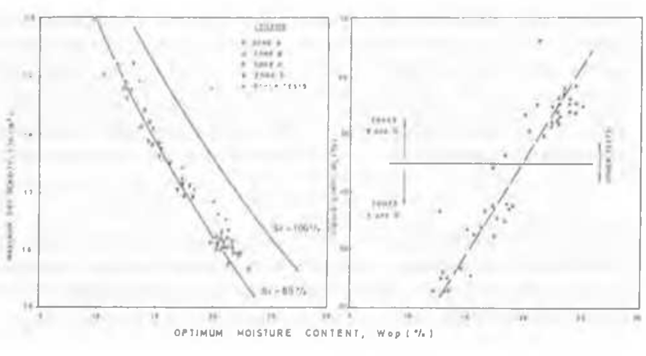


Figure 6. Examples of correlations between optimum moisture content and other properties

In this way, with relatively quick and easy tests (MCV and moisture content) it is possible to know, in few minutes and with enough accuracy, if the material is acceptable or not to be placed in zone 1 of the earthfill dam. Furthermore, its compaction control characteristics can be known (maximum dry density and optimum moisture content) which will be used as an execution control reference.

## CONTRAST WITH PREVIOUS EXPERIENCES

The MCV index variation with the moisture content in aluvial soils of the Barbate river was established through a relation of the type

$$W - Wop = b \cdot (N - MCV) \qquad (3)$$

where b and N have the mean values indicated in previous paragraphs. N would mean the MCV index correspondent to the optimum moisture content and b the relation between the moisture content deviation of that optimum value and the correspondent MCV variation.

This form of correlation between the MCV and the moisture content is convenient for normal situations near the optimum moisture content interval. The linear correlation precision may be poor for very wet or very dry conditions but the correlation has less practical interest at those extremes. It was Parsons (1981) who indicated that the correlation between moisture content and the MCV index could be established through an expression like

$$W = a - b \cdot MCV \qquad (4)$$

where a and b are soil type dependent constants.

It is evident that there is an equivalence between these constants and the ones defined previously; b would have the same meaning and

$$a = Wop + b.N \qquad (5)$$

Therefore, the previous experience might be comparable with the one obtained in Barbate dam with this equivalence. (See Figure 7).

The obtained parameters rank will have been expected to be closer to the higher plasticity zones of the chart shown in Figure 7. The fact that only a linear correlation, valid in the optimum moisture content interval, was searched here might be the reason for this deviation. If the correlation had been adjusted for a wide moisture content rank, other parameters might have resulted better for the fitting. Anyway, it appears to be more advisable to establish a correlation between the MCV and the moisture content in the form here explained by using N and Wop as correlation parameters because they have a more defined physical interpretation and they give more weight to the fitting in the moisture content rank of compatibility.

The MCV and W correlation appears to be sufficiently variable from one soil type to another. Therefore, its research in a certain formation could be required before using the MCV as an easy tool for the daily clasification of the field work.

## CONCLUSIONS

The tests that were done previously to Barbate dam indicate that the MCV test serves to know quickly if the soil natural moisture content is adequate for compaction and, if it is not, to quantify the correspondent moisture content excess or defect. Therefore, the MCV test can advantageously replace the traditional Proctor standard compaction method when the ground heterogeneity is high and the construction rythm is fast.

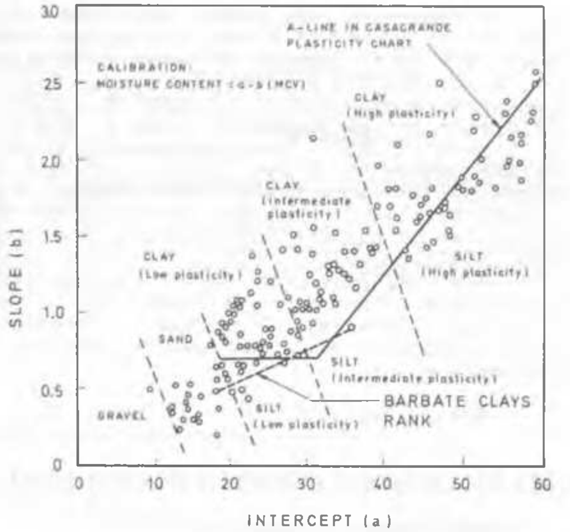


Figure 7. Comparisson with previous experiences. After Parsons (1981).

Besides, these tests indicate that after a good global characterization of the borrow pits, the MCV test serves to identify the type of material when it is accompanied by the moisture content determination.

The correlations given here are valid for the soils of the Barbate river valley used for the earthfill dam construction and are based both on the first 100 MCV tests done at the testing stage before starting construction and on the experience gained during the 1987 construction period. More tests are scheduled for the rest of the construction and the adquired experience will allow to determine precisely the data given here.

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