Interpretation of Moisture Condition Value tests

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Introduction
The Moisture Condition Value test (MCV) has been introduced comparatively recently, the results being used for assessing and controlling the suitability of soils for earthworks. The test method is based on repeated compaction of a soil specimen with a 7kg rammer until a limiting compression is reached; the effort to reach this limit, measured in terms of blows with the rammer, being the MCV. Tests on a number of specimens at different moisture contents are termed the Moisture Condition Calculation (MCC) and enable a relationship to be drawn between MCV and moisture content for a particular soil. The test has not so far been limited to any soil types. The form of the test is given by Parsons (1979(a)) who has also suggested (1979(b)) that the test can be used as an earthworks control without the necessity for moisture content or Atterberg limit testing. The advantage of the test is seen as being speed of result availability and a simplicity of operation and test result application. There are, however, some reservations for such a direct reliance on the MCV which should be considered (Dennehy, 1979).

There has been a growing trend for the Department of Transport's (DOT) site investigation documents to require these tests. It would appear from this that the MCV is under consideration as an alternative to the current moisture content stipulation based on a multiple of plastic limit, as a means of fill suitability control. At present, however, there is no standard test specification, although it is expected that this will be remedied by the current working party redrafting BS1377. Whilst the test method gives rise to some difficulties, principally with MCC tests, it is in the interpretation of the result that most arise. Experience within Soil Mechanics Ltd. has given rise to a number of points concerning the interpretation of both the MCV and MCC which it is the purpose of this Paper to illustrate.

In the ICE Conference on Clay Fills (1979) there is a considerable amount of background information on MCV testing. Some of it, however, is conflicting, and this may be due to differences in the methods of interpreting the results. The Transport and Road Research Laboratory (TRRL) are currently carrying out their own investigations into the reproducibility of the test between various commercial laboratories (see ref. RR90).

Test result

Alternative interpretations of result
The results of an MCV test are shown for a straightforward case in Fig. 1, where the change in the number of blows of the 7kg rammer falling through a constant drop of 250mm is plotted against the compression of a 1.5kg soil sample in a 100mm diameter mould. The MCV is taken as \( \log_{10} \) number of blows at which the line through the test points intercepts the 5mm change in penetration line. This 5mm criterion is an arbitrary value representing the limiting compression. For other than straightforward cases, however, there are differences in the way the MCV curve can be interpreted, as outlined below for (1) LR 750 and Working Paper 1980/2 and (2) SR 552.

(1) LR 750 indicates that the MCV should be taken as in Fig. 1, where the line through all the test points intercepts the 5mm change in penetration line. LR 750 does not illustrate cases where there is a curve in the lower section of an MCV determination such as that shown in Fig. 2. The TRRL Scotland also adopt the LR 750 approach which clearly states that where the MCV test line is curved the value taken is that where the plotted curve intercepts the 5mm line. Therefore, for example, the MCV in Fig. 2 would be 14, not 10. A difference of 4 in the MCV would represent a considerable difference in remoulded shear strength).

(2) The current TRRL interpretation of an MCV test is as indicated in the Appendix to SR 552, namely, the intercept value to be reported as the MCV should be that where the steepest straight line drawn through any portion of the test curve is projected to the 5mm line. Figs. 2, 3 and 4 show examples of this application which

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can lead in some cases to a noticeably lower MCV than would be obtained using the alternative approach above.

Fig. 3 shows how the steepest line qualification in SR 522 should not be interpreted. That is, the steepest sensible straight line should be drawn (say using a minimum of three approximately aligning points), and not the steepest straight line through any two points on the curve. Points below the 5mm change in penetration line are of assistance in this respect but should be used only circumspectly in assessing the position of the main down slope. It is clear that the application of SR 522 is open to misinterpretation by inexperienced personnel.

**Test influences**

Non-aligned points on the down slope of an MCV test result may arise for many reasons, one of which is the granular content of the sample. It is presumed that the reason the Scottish authorities do not prefer the interpretation given in SR 522, is the high granular content of many Scottish tills. As the test relates to 20mm down material and the internal diameter of the mould is 100mm, the gravel fraction, particularly coarse gravel, will therefore exert an influence on the test curve. In addition to this, experience shows that interpretation difficulties are also likely to arise when less than 15% of the material passes the 63 micron sieve.

When a curve such as Fig. 2 results, the lower concave part is probably due to a change in the dominant soil fraction in the compaction process. For example, in a gravelly clay, packing and crushing of the gravel particles may take over from compaction of the soil mass. Crushing is possible because of the high energy of the test. Interlocking of gravel particles and their subsequent freeing could also lead to changes in the slope of a test result.

For cohesive soils the lead-in portion of the MCV curve to the down slope may be influenced by the initial size of the prepared lumps. This could affect the overall slope of the curve and hence the interpretation.

The present obligation is to report the MCV only as a whole number, in line with the initial philosophy behind the test of simplifying site correlations to the moisture content range over which the air voids are similar, a point which is often overlooked. When assessing the effective calibration curve, points dry of 7kg rammer optimum (e.g. w = 12%, Fig. 5) should be ignored. The optimum moisture content can be assessed by examining the calculated dry densities of the test specimens. An appropriate moisture content range (say five points wet of optimum) should be used for the MCC specimens; this will narrow and also be numerically lower with decreasing plasticity. Plasticity also influences the slope of the calibration line; the less plastic the clay, the flatter the calibration tends to be and the more sensitive to moisture content changes.

For Scotland, SDD1 states that the calibration line should have a correlation coefficient greater than 0.90. This implies **inter alia** separate samples for each calibration point and a better accuracy of measurement than nearest whole MCV. A more stringent initial specimen weight tolerance than the SR 522 tolerance of 1.5kg measured to the nearest 20gm would also assist in achieving better correlations and more accurate dry densities.

**MCV tests on cohesive soil**

A typical calibration (MCC) of MCV’s for a clay is shown in Fig. 5. The calibration may be influenced by the method of specimen preparation for, currently, there is no stipulated procedure for achieving the different moisture contents required or for curing. An affect of the manner of preparation is that, generally, a straight line calibration results when separate specimens, air dried or wetted up from natural are used for each moisture content. However, where calibrations are carried out by re-using the same specimen, or by wetting from an oven dried state, the calibration line is sometimes curved. There are problems in achieving uniform moisture distribution in re-wetted oven dried samples which, with other drying induced effects, are the likely cause of this curvature. This practice is considered undesirable. Because of the influence of specimen preparation, it is important that test results state this, particularly as, at the construction stage, monitoring tests will usually be carried out on soils at their natural moisture content.

Individual MCV determinations, as shown on the lower half of Fig. 5, tend to flatten with decreasing moisture content. This knowledge may assist in isolating "rogue points" (which occur not infrequently) in a determination. Rogue determinations caused, for example, by gravel locks, should be excluded when assessing the calibration curve. Unless an accurate moisture content determination has been made before a test starts, the test must be stopped if seepage or slurry emanates, otherwise a rogue determination will result. If there is any doubt about the MCV result obtained for a very sandy cohesive soil, a useful check would be to wet up the specimen slightly and repeat the test.

When assessing the properties of remoulded soils it is important to limit the number of blows 'n' log scale

![Figure 3](image1)

![Figure 4](image2)
Difficulties of interpretation can also arise with other types of granular soil, such as the sandy gravel shown in Fig. 8. In this case the potential problem of crushing occurring in the test, mentioned earlier, appears to become an influence producing the extended intermediate section of the curve. The difficulty here is what to report as the MCV. As it is unlikely in the field that the compaction plant employed will lead to crushing of a durable granular material, logic would suggest that the projection of the initial section of the curve to the 5mm line should be used irrespective of whether this is the steeper section or not. This however, could produce a conservative value of MCV. Clearly without separate substantiation it is inadvisable to rely on either value of MCV from such curve.

An MCV test on granular soil may produce a result on the non-effective portion of the calibration curve. This might not be immediately obvious if only a single MCV test is being carried out and an MCC has not also been done. It is suggested that the result can be checked for effectiveness or non-effectiveness by retesting using a flooded sample; if the retest result is higher then the initial result must have been on the non-effective section of the curve and should be reported as such. Care must therefore be taken when reporting results from granular materials, and it is suggested that MCVs from predominantly granular soils should not be used in isolation for soil suitability assessment.

Particular attention should be paid to the insitu groundwater conditions when interpreting the results, as disturbed samples

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**Figure 5**

**Figure 6**

**Figure 7**

**Figure 8**
of granular materials from site frequently differ in grading and moisture content from their insitu condition depending on how they are sampled and stored. The point in the test at which consistent seepage emanates from the mould must be noted for two reasons: firstly, because the moisture content changes that occur after the test and the MCV obtained will not relate directly to the moisture content of the prepared sample; secondly, because beyond this point of compaction free drainage field conditions must exist for the soil mix to be representative of that required for achieving its MCV. Preferably, the test should be stopped to measure the moisture content when seepage occurs, or the seepage collected to avoid a rogue determination.

The more granular a material the more curved an individual MCV line tends to be, i.e. more like Fig. 2 than Fig. 1, but the overall set of MCV test results become flatter with increasing granular content c.f. Fig. 5 and 6. Often, therefore, the 5mm intercept value is not easily determined for granular soils, if it can be determined at all. Frequently the MCV lines become so flat, see Fig. 7 for example, that the interpretation of the results becomes very operator-sensitive and the resulting MCV is thus subjectively subjective. Clearly these are undesirable features of a soil suitability test.

Despite the difficulties discussed the implication from the literature is that the test can be used for granular soils. In fact LR750 suggests that the procedure and attainment of an intercept can be overcome by replotted results for changes in penetration over some arbitrary range such as n (ram blows) to 7n or 10n, 15n etc. instead of the conventional n to 4n. This steeper: the down line and makes the intercept more arbitrary but also produces a slight difference with the intercept value obtained using an n to 4n change in penetration. Any such interpretation variation of this kind should be clearly noted on the test report.

To current knowledge, MCV tests have not been used in England as a site suitability control for granular soils (as defined by the DOT Specification for roads and bridge work). The TRRL Scotland have, though suggested a test that an "all weather soil" will be one that produces an MCV of 8.5 or more irrespective of the degree of flooding of the sample. However, views have expressed that such a criterion can be manipulated (Parsons, 1988) and could lead to the rejection of otherwise suitable materials such as hard, durable, single-sized rock which produce very low MCVs irrespective of moisture content.

Practicalities of sampling and scheduling

If separate specimens are to be tested, an MCV will require about 10kg of material passing the 20mm sieve. Large bulk samples should therefore be taken, preferably from trial pits. However, such samples from boreholes are often wetter than insitu—requiring more drying back which can result in "lumping" of clay. If the MCV is a pre-known test requirement, consideration might include the use of a 5mm sieve and taking 3 undisturbed 100mm diameter samples solely for this purpose. In terms of the numbers of tests to be carried out, the MCV should be regarded as an index test to be performed on potential earthworks cutting materials like any other index test. As with moisture content testing itself, it is necessary, when considering the results, to bear in mind the sample type and hence the moisture content reliability.

The MCV will be used to classify strata types. A calibration obtained from one sample in a stratum will not take account of soil variation in the whole stratum. It is better to take an overview and test several samples and/or use multiple samples prior to calibration. This latter approach should, in any case, be adopted where there is a shortage of material rather than re-using material which could have an adverse influence on the calibration curve, as noted above.

Good laboratory practice is not specifically defined by the references but is under consideration by the working party on the revision of BS 1377. Currently the measurement of density is not part of the test, due to the admissible weight tolerance and the limitations of the apparatus—possibly producing air entrainment at low moisture contents. However, experience has shown that in the relevant area near optimum, the measured densities can be of great use in calibration assessment and limitation. It is suggested that as the MCV will almost always be a laboratory test, as opposed to the MCV which will often also be a field test, a stricter weight tolerance will produce an accurate enough guide density since the sample height is already very accurately measured as part of the test.

The MCV apparatus itself will show serious signs of wear and tear after about two years regular use and in order to produce consistent results replacement may be necessary.

Guidelines

Based on the foregoing discussion and practical experience the following summary guidelines for working with the MCV test are suggested:

Laboratory work
1) Clay samples should be diced as near as possible to a standardised 20mm before test and not crumbled further.
2) Moisture contents should preferably be on the 10mm sieve. Moisture contents on a small sub-sample should not be considered acceptable.
3) The density should be deduced for each specimen.
4) For the MCV separate specimens should be used. It is essential to the calibration that one point is at natural moisture content. Other test moisture contents should be achieved by air drying or wetting from the natural with thorough mixing and curing.
5) The point of seepage during the test should be noted.
6) Determinations on dry granular soils should be repeated on flooded samples to assist in assessing whether the initial test is effective.

Interpretation
1) In England the projection of the (sensibly) steepest part of the MCV test line at its intercept with a change in penetration of 5mm, would be reported as the MCV.
2) In Scotland the test curve itself is used to give the intercept value reported as the MCV.
3) Where difficulties of interpretation occur, supplementary plots of actual penetration as opposed to change in penetration, may assist in assessing the most appropriate part of the MCV curve to be used, or may more clearly indicate the onset of crushing.
4) The MCV calibration line should be collinear and points of optimum should be ignored in assessing the effective calibration.
5) The MCV specimens should also be correlated by the measurement of remoulded strength. This may assist incidentally, by back reference, in assessing the most appropriate part of the test curve to be used to obtain the MCV, and will facilitate the setting of suitability criteria. As remarked earlier a small difference in MCV can represent a greater difference in strength.

Reporting
1) Sample preparation, test procedures, seepage loss and method of interpretation influence the results obtained and should be reported.
2) Currently, the interpretation of MCV plots may be varied depending on how long the interpretation put upon them is clearly stated.
3) The MCV should not be used in isolation for soil assessments. An MCV should first be obtained for the soil type.
4) It is suggested to publish the MCV be reported to one decimal place.

Conclusions

The attention should be brought to any similarities of the differences between the two approaches to MCV determination before proceeding with interpretation of results, the implications of SR522 being largely "hidden" in an Appendix. English practice produces a more conservative result than Scottish practice and the higher the granular content, the greater the differences between the two. Apart from this, manipulation of the test data is allowed in order that an MCV can be derived, even though in these cases it is questionable whether the test is appropriate to the soil type. The author has not found it practical to utilise the tests in suitability assessments of (purely) granular soil.

An advantage of the MCV test is that it can be plotted immediately on completion. Thus any anomalies can be spotted immediately and if necessary the test repeated without delay. Currently there is no procedural difference when determining the MCV or the MCV. It is suggested that the latter should be revised to an accurate test. Any test, with the measurement of MCV to one decimal place and incorporating the measurement of density in order that an appropriate calibration can be produced.

It is to be hoped that the working party redrafting BS1377 will remove some of the present anomalies. In the meantime the test practice adopted or any variations must be made clear in reports etc. so that the eventual field checks follow the same interpretation. This variability in interpretation and the need to simplify procedures and methods make the test more accurate, detracts slightly from its use. For, although the test was formulated to be largely independent of operator influence and interpretation, it can now be seen to more central consideration in interpretation and application.

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(continued with the references on page 30)