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Selection of clays for use as landfill liners

R. M. Jones, E. J. Murray & D. W. Rix
Murray Rix Partnership, Hinckley, UK
R. D. Humphrey
Lincs Lab., Lincoln, UK

ABSTRACT: The need to design adequate landfill lining systems has been highlighted by recent publications and legislation. The careful selection of materials to form low permeability barriers is essential in engineered waste disposal. The term 'suitable' (for use as a natural clay landfill lining material) is introduced. Individual geological deposits within Lincolnshire have been classified as unsuitable, marginal or suitable based primarily on plasticity criteria. The term 'acceptable' (for use as an earthworks material) is also introduced. Use of the Moisture Condition Value test as a means of acceptability testing, earthworks control and a guide to the degree of achievable compaction is discussed. The results presented were obtained during a study of possible sources of natural material for landfill liners within Lincolnshire.

1 INTRODUCTION

In landfill operations the safe containment of waste and control of leachate is of paramount importance in the mitigation of ground and groundwater pollution and the protection of public health. Recent publications and legislation including the National Rivers Authority Groundwater Protection Policy 1992, Control of Pollution Act 1974, Environmental Protection Act 1990, and various EC Directives call for more stringent control on the containment of waste. Careful selection of materials coupled with rigorous design of containment cells are a vital part of engineered waste disposal systems.

The linings to these cells generally consist of low permeability clays possibly in conjunction with a synthetic liner or liners. This paper explores the use of a classification scheme to identify possible sources of natural materials suitable for use as lining material to landfill sites. It is based primarily on a study carried out within Lincolnshire. The classification is applied to individual strata identified from geological maps and use is made of available published and ground investigation information. Suitability criteria laid down by the National Rivers Authority (NRA) are appraised and the classification of material is based on these criteria and recent work on the relationship between plasticity and permeability.

Material suitability relates to material type and its potential to form a barrier of sufficiently low permeability. Within the study suitability is based primarily on the collation of plasticity data, and is closely linked to the definition of 'material characteristics' as given in BS 5930:1981

For individual landfill sites it is essential to examine in more detail the properties of the clay proposed for use as a lining. Thus in addition to the definition of suitability of material the term acceptability in earthworks is introduced and is closely linked to the 'mass characteristics' of a soil as defined in BS5930:1981. It relates to the ability of a material to be satisfactorily excavated, transported, placed and compacted. The definition of acceptability is comparable with that adopted by the Department of Transport in the Specification for Highway Works (1991) which is often used as a guide to

compaction requirements for clay linings.

Given the above it is apparent that if a material is unsuitable it is also unacceptable however a material which is suitable will not necessarily be acceptable.

2 MATERIAL SUITABILITY

It is generally taken that the overriding requirement of a material for use as a landfill lining is its capability of achieving a permeability of 1 x 10^{-9} m/s or less following compaction. This degree of permeability is sometimes defined as 'practically impervious' and often taken as distinguishing clays from higher permeability silts (Somerville 1986). In terms of plasticity the division between clays and silts is known as the A-Line as shown on Figure 1. In the study, data was collected from a large number of sources, but as might be expected, relatively few permeability results were obtained for specific deposits. It thus became necessary to identify potentially suitable deposits using other more readily available soil parameters such as plasticity. In practice permeability is related to a large number of factors and materials classed as silt based on plasticity data could achieve the required low permeability if adequately compacted within an acceptable moisture content range. Nevertheless because of the lack of test data and in accordance with the NRA requirements materials plotting below the A-Line were defined as unsuitable as were those materials with greater permeability e.g. sands and gravels. Conversely clays which plot above the A-Line were deemed as suitable or marginal in terms of permeability.

The NRA also define suitable materials as those clays with a Liquid Limit (LL) of less than 90%, a Plasticity Index (PI) of less than 65% and a clay content of greater than 10%. The upper limits to LL and PI specified by the NRA are based on criteria defined by the Department of Transport (1991) for modern earthworks plant. Materials in excess of these limits can give rise to problems in stability, deformation and compaction in earthworks. However these limits preclude the use of extremely plastic clays which would exhibit very low permeability characteristics and if used with care may be adopted as a lining material. Sources of such materials are scarce and have not been identified within Lincolnshire. Further study of the use of such deposits would be warranted. However for the purpose of the study materials above these limits were defined tentatively as marginal as shown on Figure 1.

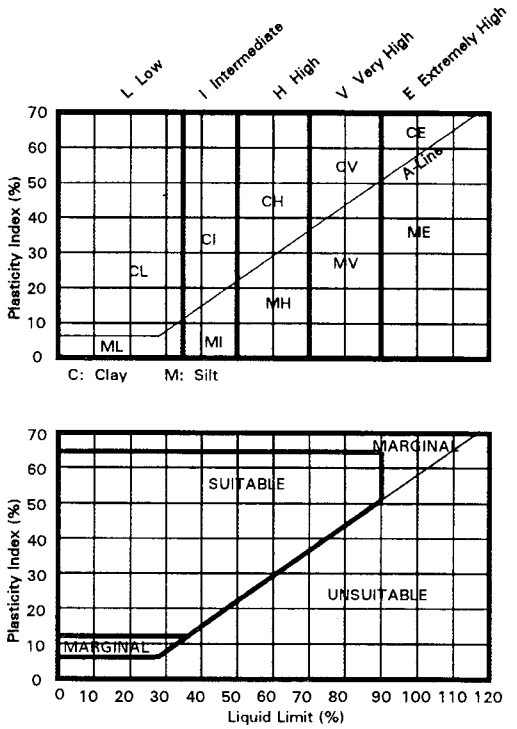

FIGURE 1: PLASTICITY AND SUITABILITY OF MATERIALS

From a standard Plasticity Chart the lower limit of PI for suitable clays would be 6% in accordance with the NRA requirements. However the permeability of clays varies with PI and Murray et al (1992) suggest there is a notable increase in permeability where the materials have a PI of 12% or less. A PI of 12% is also considered to correspond closely with a clay content of 10% (Skempton 1953) which forms one of the NRA suitability criteria. Results of percentage clay in deposits were

sparse and the adoption of a lower limit to PI of 12% was taken as an alternative to clay content in collating the data and classification in terms of suitability. Examination of the relationship between permeability, clay content and plasticity suggests that clays with a PI in the range 6% to 12% should be classed as marginal.

Figure 1 illustrates plasticity with respect to the suitability of materials. The availability of plasticity results from a wide variety of sources means initial classification of many deposits can easily be achieved in a study similar to the one undertaken.

For any deposit which includes both discrete cohesive and granular components the use of plasticity results as a method of classification will present a biased view since only the cohesive materials would have been selected for testing. Highly variable materials should be classed as marginal or even unsuitable since the end product, the landfill liner, must be homogeneous and conform to a specified standard.

The NRA preclude the use of organic material within landfill liners. However Postlethwaite (1991) suggests that under managed conditions peat could be used successfully within a composite lining system. There must obviously be reservations about the use of such highly organic materials and detailed investigation of these deposits would be necessary to justify their use.

Consideration of the degree of variability, as highlighted by the pattern of plasticity results, and effects of likely constituents of a deposit are important in classification of suitability.

3 MAPPING OF MATERIAL SUITABILITY

In the study initial identification and location of sources of potentially suitable material for landfill linings were based on published geological maps and memoirs. Identification of unsuitable materials i.e. rocks, sands and gravels was straightforward from such information however, for the cohesive deposits a more detailed assessment was required.

Figure 2 shows plasticity results for Alluvium and Fen Deposits. The wide spread of results is

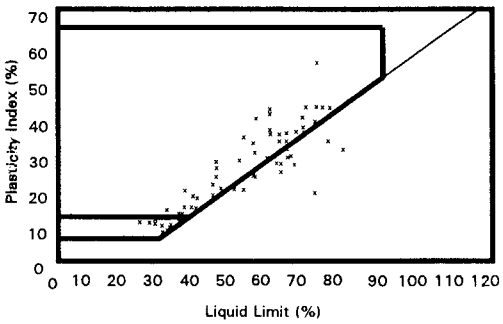

FIGURE 2: PLASTICITY CHART: ALLUVIUM AND FEN DEPOSITS

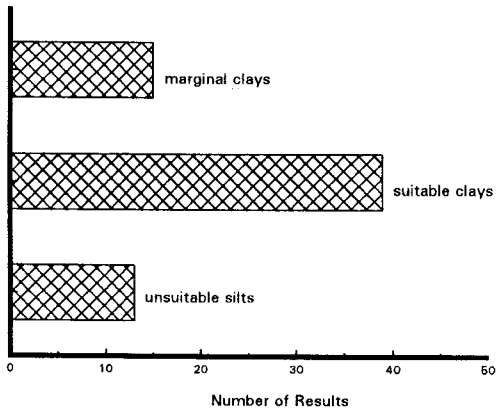

FIGURE 2A: COMPARISON OF PLASTICITY RESULTS

to be expected from an inherently variable material, and highlights the presence of clays of low to high plasticity along with silts. Figure 2A compares the number of results of marginal and suitable clays and unsuitable silts. The majority of results fall in the suitable clay category. However granular materials are also present within this deposit but cannot be represented on Figure 2 or 2A. An overall assessment of this material would suggest that due to the wide variation in results a marginal classification would be appropriate.

By contrast the results for the Lower Lias Clay, Figure 3, show a much less variable pattern with mainly intermediate and high plasticity clays. Although a proportion of results fall within the silt category, none fall within the marginal clay range. Those samples

yielding results below the A-Line were generally described visually as comprising silty clays suggesting a significant clay content. The relatively uniform results associated with the Lower Lias Clay are considered to represent a suitable material.

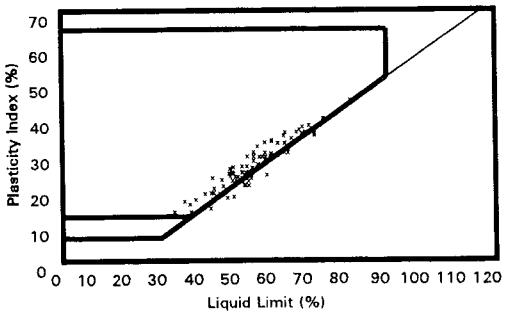

FIGURE 3: PLASTICITY CHART: LOWER LIAS CLAY

Following similar appraisals a map of material suitability was drawn up for the County. The map may be used to facilitate planning and as a basis for geographical and economic appraisal of potential landfill sites.

4 ACCEPTABILITY IN EARTHWORKS

Acceptability in earthworks relates to the excavation, handling, traffickability and compaction characteristics of the material in achieving a low permeability barrier. Problems may be experienced in general earthworks with materials which are too soft or too wet, whilst with very stiff materials the degree of compaction necessary to obtain the required permeability may not be achievable. Adequate compaction of suitable materials is essential to form a low permeability barrier. Structural features such as fissures and laminations in the emplaced lining may provide preferential seepage paths and hence increased permeability.

Interstratified or mixed deposits comprising both suitable and unsuitable materials will affect the acceptability of the strata as a whole. The ease of identification and segregation of different classes of material from a single deposit needs to be considered where such cases arise.

5 ACCEPTABILITY CRITERIA

In most earthworks operations it is strength which governs material acceptability. However in linings to landfill sites the overriding requirement is a low permeability. In achieving the desired permeability and in placement of the materials it is necessary to place restrictions on the moisture content, undrained shear strength and density of the emplaced material. These parameters usually form the basis of control measures in place of permeability because of the protracted time associated with permeability measurements. The use of alternative, less time consuming tests to establish limiting values of acceptability is advocated by the Department of Transport (1991). However the definitive parameter, in this case permeability, of placed material must be verified.

As an alternative control criteria the Moisture Condition Value (MCV) (Parsons and Boden 1979) may be used. The MCV is a compaction test which produces a degree of compaction which generally lies between those achievable using the BS 2.5kg and 4.5kg rammer tests. The use of the MCV test in general earthworks is described by Cobbe and Threadgold (1988). The MCV test provides rapid and reproducible results in determining the acceptability of materials, which combined with a maximum air voids requirement to control the degree of compaction may be used to assess the overall adequacy of the placed lining.

In adopting any form of control criteria the relationship of permeability to the control parameters needs to be established. Figure 4 illustrates the relationship between permeability and moisture content. The general pattern of decreasing permeability with increasing moisture content over a wide range of results is consistent with work by Murray et al (1992), Needham (1991), Seymour (1992) and Parkinson (1991). Close to and dry of the optimum moisture content the increase in permeability is likely to be attributable to difficulties in remoulding clays which are likely to be around or dry of their plastic limit. Wet of the optimum the general decrease in permeability is consistent with remoulding of the material and removal of discontinuities such

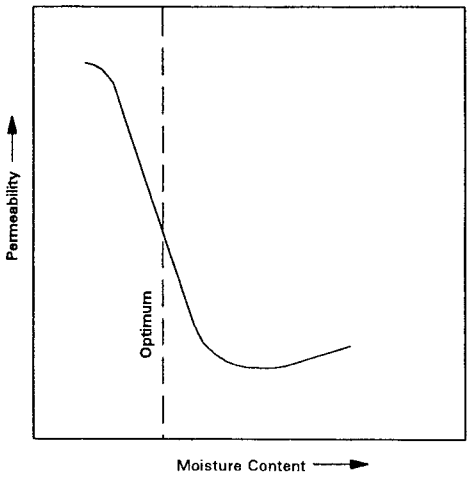

FIGURE 4: PERMEABILITY AGAINST MOISTURE CONTENT

as fissures. Remoulded wet clay was used as a seal in canal construction, where it was puddled against the sides and bottom of the canals to produce an almost watertight seal. However modern plant and equipment are unlikely to be able to traffic or compact such very wet and soft materials. Thus appropriate limits need to be placed on acceptability.

On the basis of the foregoing discussion the lower limit of moisture content or upper limit of MCV would be governed by the permeability requirement, whereas the upper limit to moisture content or lower limit to MCV would be likely to be controlled by shear strength (Murray et al 1992).

In order to ensure adequate compaction, limits should be applied to the density and air voids content of the emplaced material. Compaction trials are essential to establish the control parameters to be adopted and total reliance on laboratory testing is unwise.

6 SUMMARY

1. Based on a study within Lincolnshire a classification of natural deposits for use as landfill liners, using the concept of material suitability, is discussed. In the study materials were defined as unsuitable, marginal or suitable primarily based on plasticity data. Update and reassessment of the classification is appropriate as further information becomes available.

2. The definition of suitability takes into account the requirements of the NRA and more recent work on permeability of recompacted natural clay.

3. Following classification of clays as either suitable or marginal, consideration is given to material acceptability in earthworks. The proposed lining material must have acceptable mass characteristics of strength and structure to facilitate handling, trafficking and recompaction to form a low permeability barrier.

4. The overriding requirement of any landfill liner is low permeability but placement of material cannot be readily controlled by permeability tests. Establishment of relationships between permeability and other soil properties enables control of earthworks operations by more rapid acceptability tests. The use of the MCV test is discussed.

5. In control of earthworks the lower limit of moisture content or upper limit of MCV is governed by the maximum permeability requirement of 10^{-9}m/s.

6. The upper limit of moisture content or lower limit of MCV would generally be controlled by the strength of the material and handling, trafficking and compaction requirements.

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REFERENCES

British Standards Institution 1981. *Code of practice for site investigations BS 5930*

Cobbe M.I. and Threadgold L. 1988. Compaction control by the moisture condition test - a new approach. *Journal of the Institution of Highways and Transportation*, Dec 13 - 18.

Department of Transport 1991. *Specification for highway works.* HMSO

Murray, E.J., Rix, D.W., and Humphrey, R.D. 1992. Clay lining to landfill sites. *Quarterly Journal of Engineering Geology* Vol 25 No 4 p371 - 376.

National Rivers Authority North West Region 1989. *Earthworks to landfill sites.*

Needham, A. 1991. Clay liners - the answer lies in the clay. *Surveyor Special Supplement to Wastexpo International '91,* 18 + 19 Sept, Cannock, Staffs 11 - 13

Parkinson, C.D. 1991. The permeability of landfill liners to leachate. *The Planning and Engineering of Landfills,* Midlands Geotechnical Society

Parsons, A.W. and Boden, J.B. 1979. The moisture condition test and its potential application in earthworks. *Transport and Road Research Laboratory Supplementary Report 552.*

Postlethwaite, N. 1991. Dynamic permeability - peat as a landfill liner. *The Planning and Engineering of Landfills,* Midlands Geotechnical Society.

Seymour, K.J. 1992. Landfill linings for leachate containment. *The Institution of Water Management* Vol 6, No 4 August, 389 - 396.

Skempton, A. W. 1953. The colloidal activity of clays. *Proceedings 3rd International Conference on Soil Mechanics and. Foundation Engineering.* (Switzerland) Vol I, p 57.

Somerville, S.H. 1986 .Control of groundwater for temporary works. *Construction Industry Research and Information Association. Report 113*