CHARACTERISATION OF MATERIALS FOR EMBANKMENTS ON AN EXPRESSWAY ACCORDING TO THE NEW PG3 SPECIFICATIONS

E. Dapena
Laboratorio de Geotecnia, CEDEX, Madrid Universidad Politécnica, Madrid

F. Tobarra
Dirección General de Carreteras, Ministerio de Fomento, Madrid

SUMMARY. This paper analyses the results of tests carried out on 12 soil samples taken directly from a 7-km stretch of expressway, specifically in areas where cuts were to be carried out for subsequent use of the material as fills. The same classification was obtained both for soil plasticity and swelling except in four of the samples which would be rated as tolerable on their plasticity grounds but were classified as marginal and inadequate on account of their swelling. In two of these four samples the material on which the swelling test was carried out was only a fraction of the total. The proposal we make is for swelling to be taken into account in the classification of materials for fills and which needs to be pondered in accordance with the percentage of material utilised in preparation of the tests. In this particular case it was the percentage passing a standard 5 UNE screen.

1. INTRODUCTION

The new classification for embankment materials given in the Spanish PG3 specifications currently in effect is based on two groups of characteristics. One of them consists of the properties of the material itself, which are classified as intrinsic characteristics and do not depend on the degree of compaction applied at the time it is put in place, namely grading, Atterburg limits and composition (organic matter and content of gypsum and of other non gypsiferous soluble salts).

The other group of characteristics consists of the type that depends on the density and moisture content of the sample. Expansivity and collapsibility are properties belonging to this group. They are all illustrated in Figure 1.

In respect of the latter, for an embankment material to be classified as tolerable or high quality its degree of settlement in the failure test must be less than 1% and its swelling in the unrestricted swelling test less than 3%. For it to be considered a type of marginal soil the unrestricted swelling must be less than 5%.

One task our engineering community needs to perform, particularly those of us involved in designing and building linear works, is to check the suitability of these specifications or what modifications, if any, should be introduced in new versions of the PG3 to allow the maximum utilisation of materials that will behave appropriately in the works in which they are used.

By way of initial contribution to this end, we made a study of materials the majority of which came from areas in which cuts were planned over a 7-km stretch of the Mérida-Almendralejo Expressway in south-western Spain.

2. CHARACTERISTICS OF THE MATERIALS

Table 1 gives the characteristics of the materials obtained in the 12 samples studied.

2.1. Composition

The carbonate content, expressed in terms of calcium carbonate, varied between 2 and 65% but 20% can be taken as representative value. Figure 2 gives its distribution.

The sulphate content, expressed in terms of gypsum, was less than 0.05% in all the samples except for M-2089, which recorded 0.26% for gypsum content.

2.2. Grading

All the material passed a standard 20 screen in ten of the 12 samples. In the other two, 5 and 10% was retained. Consequently, in ten samples the material used for the Proctor test could be considered representative of the soil.

The material used for the swelling and collapse tests, passing a 5 UNE screen, was equal to or more than 95% of the total in nine of the 12 samples.

Between 27 and 90% of the material used to run the Atterburg limits passed a standard 0.40 UNE screen and was distributed as shown in Figure 3, where two groups are distinguished. One in which this material comprised between 74 and 90% and another in which it was between 47 and 59%.

The fines content, passing a standard 0.08 screen, varied between 35 and 81% as shown in Figure 4.
content

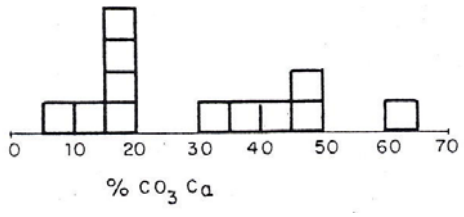

Figure. 2. Distribution of carbonate content.

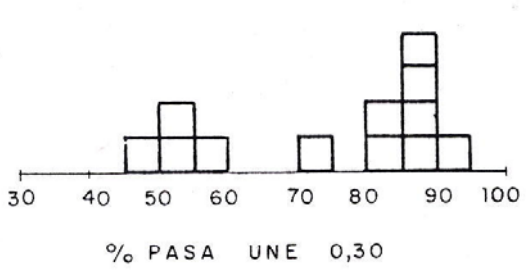

Figure 3. Distribution of material passing an 0.30 UNE screen

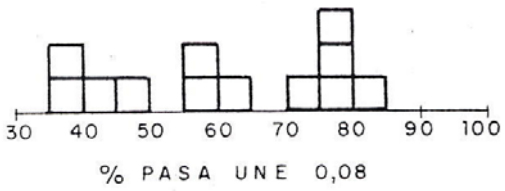

Figure 4. Distribution of material passing an 0.08 UNE screen

2.3. Atterburg Limits

The liquid limit of the samples ranged between 34 and 61% but the majority of the values fell between 42 and 54%
(Fig. 5). All the samples tested lay above Line A and were consequently clay based, occupying a position substantially parallel to Line A, indicating that they were similar soils.

2.4. Unrestricted Swelling

The unrestricted swelling index was measured on a 2-cm high specimen and on samples prepared with a 100% Proctor density and an initial moisture content we tried to keep at 1% above the optimum level.

The results of the unrestricted swelling after 24 hours stood at 5.5% (Table 1 and Fig. 6) but eight of the values recorded were below 3%, one was between 3 and 5% and three values were between 5 and 5.5%. These values were taken as reference for classification of the soils.

The swelling tests were left for several weeks until movements stabilised. Figure 7 gives the ratio between the end swelling and the index after 24 hours allowing us to confirm that the end swelling in these soils could be 15% higher than the swelling measured after 24 hours.

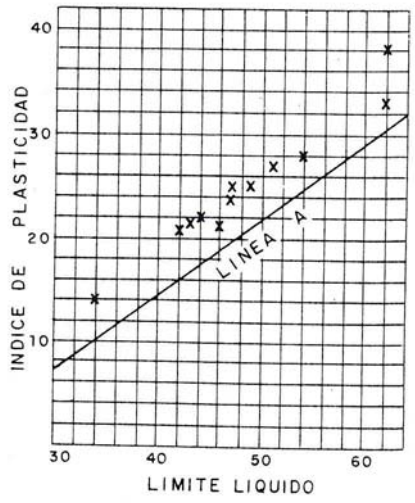

Figure 5. Atterburg limits of the samples tested.

Figure 6. Distribution of unrestricted swelling after 24 hours

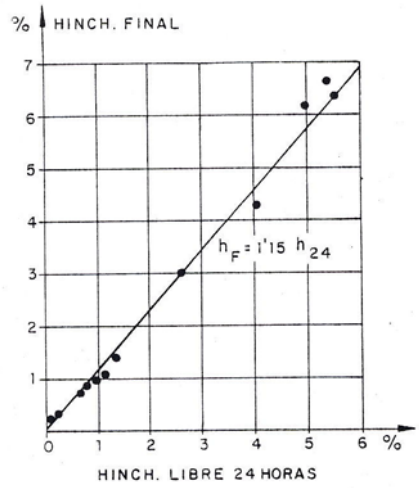

Figure 7. Ratio between end swelling and swelling produced after 24 hours

Although our intention was to compact the samples with a moisture content 1% above the optimum obtained in the Proctor test, the initial moisture contents actually achieved are shown in Figure 8 where it can be seen that they ranged from -1.2% to +1% of the optimum Proctor moisture content.

Figure 9 gives the ratio existing between the liquid limit and the swelling after 24 hours. In spite of having a relatively low liquid limit of LL=34, Sample M-2071 recorded very high unrestricted swelling.

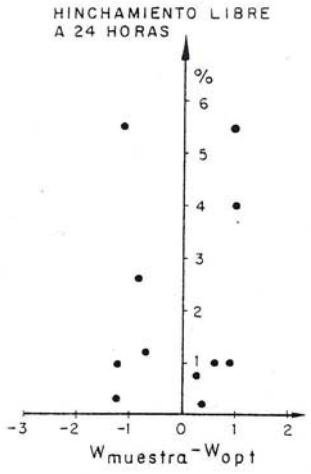

Figure 8. Ratio between swelling and excess or lack of moisture in respect of the optimum Proctor index.

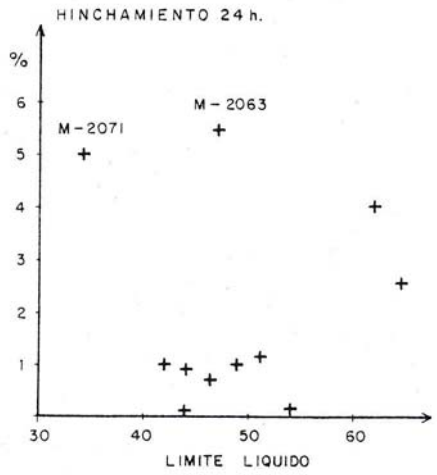

Figure 9. Ratio between the liquid limit and unrestricted swelling.

In respect of the fraction of sample used in the testing, in nine of the 12 samples involved we observed that the material passing a standard 5 screen was over 95% and there were two samples, M-2063 and M-2064, where the percentage of soil with particles smaller than UNE 5 was only 69 and 76% respectively and in view of the comparative behaviour of the full soils represented by the 12 samples, in the case of these particular two they ought to have had a lower potential swelling index.

In order to take into account the presence of larger particles than 5 mm, we propose that the swelling obtained by the sample percentage passing a standard 5 screen should be adopted.

2.5. Swelling Pressure

Table 1 gives the results of the swelling pressure tests carried out. The ratio existing between the unrestricted swelling after 24 hours and the swelling pressure of one sample is illustrated in Figure 10.

For the particular soils reported here, the samples with unrestricted swelling of less than 1.5% recorded swelling pressures of less than P_h=0.5 kg/cm^2, and the samples with over 5% unrestricted swelling recorded swelling pressures of more than P_h=1 kg/cm^2. For swelling pressures in the range of 0.2 kg/cm^2 $\leq P_h \leq$ 1.2 kg/cm^2, the following equation can be made:

$h=5P_h - 0.9$

where

h = percentage swelling after 24 hours

P_h = swelling pressure in kg/cm^2.

3. CLASSIFICATION OF MATERIALS FOR EMBANKMENT USE

The results obtained in the grading, Atterburg limits and composition tests carried out on these soils meant they could be classified under the PG3 specifications as tolerable soils.

Eight samples of the 12 unrestricted swelling tests performed recorded swelling of less than 3%, which means they also coincided in indicating that these soils were in the tolerable class.

For appraisal of the swelling in the four samples whose unrestricted swelling was more than 3%, the percentage of material used in the test in respect of the total was taken into account and the result pondered in line with this percentage. The corrected swelling indexes would be as follows:

Sample	% Pas-sing #5	Swelling		Classification
		Measured	Corrected	
M-2068	99	4	3.8	Marginal
M-2063	69	5.5	3.8	Marginal
M-2089	100	5.4	5.4	Inadequate
M-2071	98	5	4.9	Marginal

Applying this last correction, eight of the 12 samples initially classed as tolerable on account of their plasticity were confirmed as tolerable, three ought to be classed as marginal and only the material represented by Sample M-2089 needed to be classed as inadequate.

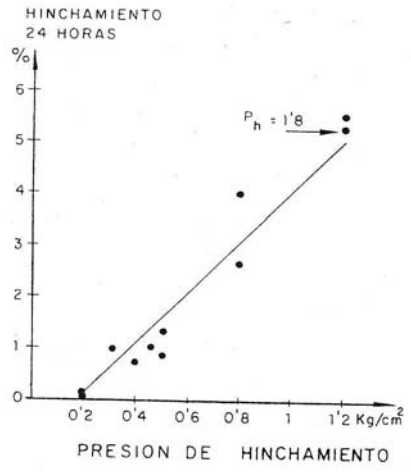

Figure 10. Ratio between unrestricted swelling (h) and swelling pressure (P_h)

CONCLUSIONS

A study was made of 12 samples of clay soils taken from a stretch of motorway.

The results obtained for the eight tests run on the samples meant that, taken as a group, these materials could all be classified as tolerable.

Three of the samples could be classed as tolerable for their grading and plasticity, but are bound to be classified as inadequate because their swelling index is equal to or over 5%.

If the material retained by a standard 5 UNE screen is taken into account and the unrestricted swelling index and a minorización lowering** minorisation** coefficient equal to the percentage of soil passing this screen is applied, two of the samples would meet conditions for classification as a marginal soil and only one sample would still have a swelling index of over 5% representing inadequate material for use in a road embankment.

ACKNOWLEDGEMENTS

José Luis Elvira, Technical Director, Directorate General for Roads, Spanish Ministry for Development, for his support in the carrying out of this work.

Table 1. Test Results

CEDEX Reference	Provenance	Standard Proctor		Swelling	End Swelling		Atterberg Limits		
		Wop %	γ gr/cm^3	24 h %	%	W %	LL	PL	PI
2062	30+500	26.9	1.48	2.6	3.0	26	62	29	33
2069	23+000	27.2	1.55	0.2	0.2	26	54	26	28
2070	22+500	17.6	1.69	0.1	0.2	18	44	22	22
2071	20+500	16.5	1.58	5.0	-	-	34	20	14
2068	24+000	26	1.47	4	4.3	27	62	24	38
2067	26+000	14.2	1.73	1	0.96	20	49	24	25
2065	26+300	19.2	1.68	0.9	0.95	18	44	22	22
2066	26+300	14.4	1.84	1	1	15	42	21	21
2064	28+000	19.7	1.69	1.3	1.4	19	51	24	2
2063	28+500	13.1	1.75	5.5	6.4	12	47	23	24
2089	24+300	21	1.63	5.4	6.7	-	47	22	25
2090	26+800	21.7	1.58	0.7	0.8	22	46	25	21

CEDEX REFERENCE	Grading: % Passing Screen Size					$CaCO_3$	Swelling Pressure		$CaS0_4$
	0.08	0.30	5	20		%	W %	P Kg/cm^2	%
2062	76		85	96	100	41	26.3	0.8	0.04
2069	74		88	99	100	30	27.9	0.2	0.04

2070	49	59	95	100	47	18.6	0.2	0.03
2071	76	86	98	100	63	14.8	1.4	0.01
2068	77	89	99	100	35	28.5	0.8	0.02
2067	81	90	100	100	9	19.1-	0.45	0.03
2065	61	84	98	100	15	19	0.5	0
2066	35	51	95	100	15	15.2-	0.3	0.03
2064	43	52	76	95	11	19	0.5	0.05
2063	36	47	69	90	49	13.1	1.2	0.03
2089	56	83	100	100	15	-	1.8	0.26
2090	55	74	93	100	16	-	0.4	0.03

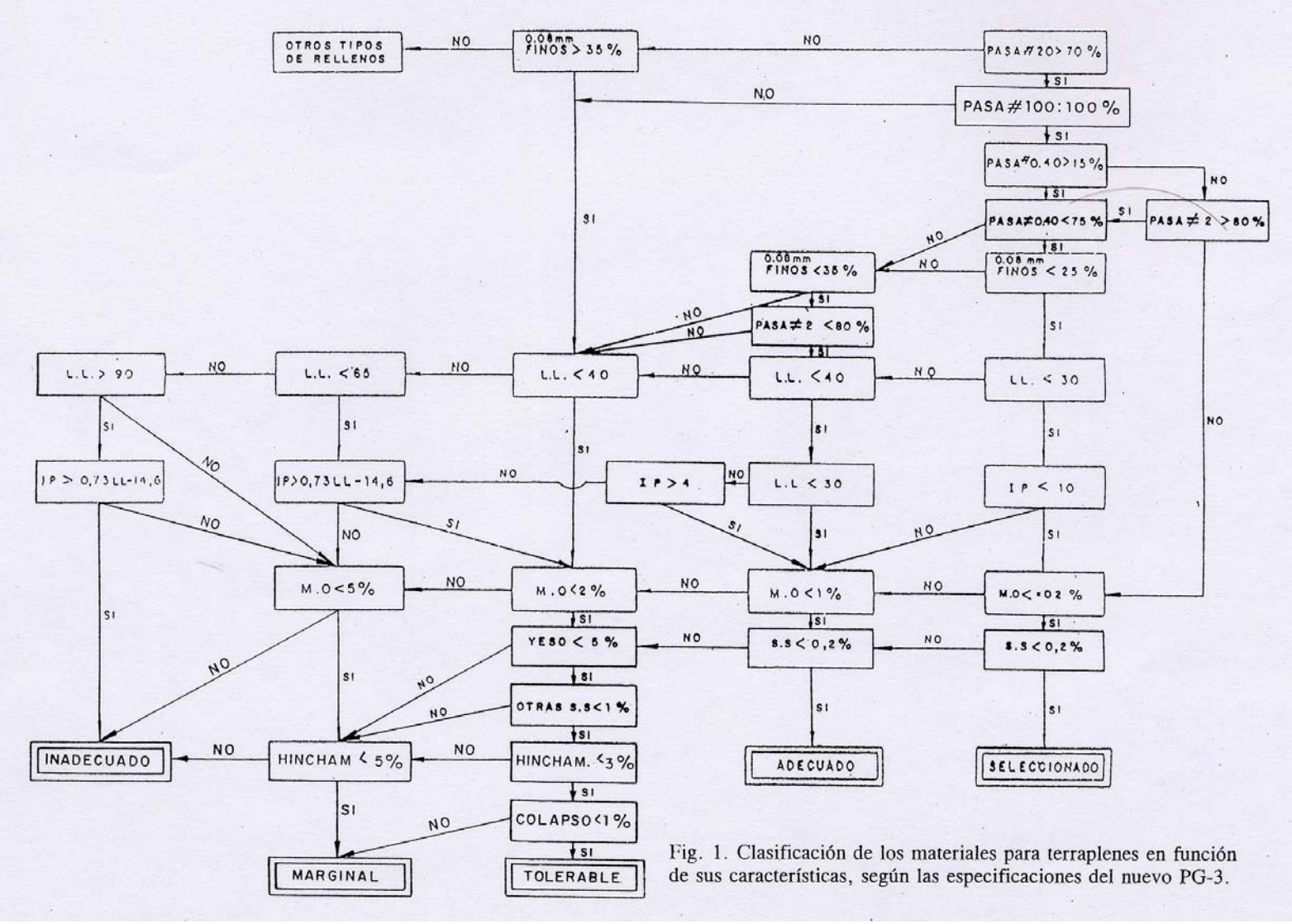

Fig. 1. Clasificación de los materiales para terraplenes en función de sus características, según las especificaciones del nuevo PG-3.

Figure 1. Classification of embankment materials as a function of their properties according to the new PG3 specifications