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Investigation of change in shear wave velocity with increasing applied stress for two samples from Holme Pierrepoint

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Investigation of change in shear wave velocity with increasing applied stress for two samples from Holme Pierrepoint

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Foreword

This is a factual laboratory report detailing work done in support of a development of capability project investigating methods of assessing thickness of unconsolidated materials for rapid mapping.

Acknowledgements

We gratefully acknowledge Mr. Chris Stone of Tarmac PLC for the provision of the research site at Holme Pierrepoint quarry, Nottingham.

Contents

FIGURES

Summary

This report presents the result of acoustic oedometer tests on two samples taken from the Holme Pierrepoint test site. The variation of shear wave velocity with increasing overburden pressure was investigated for samples from unconsolidated and weathered consolidated material to determine if an interface could be distinguished between them in a field trial. The results showed similar values at the same applied pressures. This indicates that the interface would not be easily distinguished using a field shear wave method.

1 Introduction

1.1 OVERVIEW

The development of capability in the measurement of superficial deposit thickness has required laboratory testing to integrate with values obtained from field trials of a number of methodologies and equipment. The use of shear waves to detect the base of a deposit depends on an accurate knowledge of the internal velocities of the material in the deposit. It is also important to know the shear wave velocities of the materials at the deposit interface.

The site used for initial assessment of equipment and methodologies was a series of sand, silt and gravel layers overlying a weathered mudstone. There are a number of interfingered facies within the body of the deposit, which may have differing interval velocities. The object of this laboratory study is to determine the shear wave velocities through undisturbed samples of the deposit material and the underlying solid geology. The samples under test are silty fine sand and the weathered mudstone. The gravel layers could not be sampled in an undisturbed state and have not been included in this study.

1.2 ACOUSTIC OEDOMETER

The acoustic oedometer is an instrumented consolidation cell. It enables shear and pressure wave and resisitivity measurements to be made during various types of consolidation testing. In this instance it is being used to provide predetermined levels of overburden pressure to samples. This allows changes in shear wave velocity to be measured for changes in depth of burial. During the experiment, the ingress and egress of water to the sample was monitored using a simple gauge attached to the base of the sample. The testing was carried out along similar principles to BS 1377: 1990: Part 5: Test 3.

The applied pressures were monitored using a calibrated load cell within the acoustic oedometer. Equivalent buried depths are calculated using the sample density and the shear wave velocity profile plotted as a function of burial depth.

1.3 INDEX TESTS

In addition to the acoustic oedometer testing the following index tests were performed on the samples: moisture content, bulk and dry density and particle size analysis. These were performed so as to gain some understanding of the geotechnical parameters of the materials and to allow additional data to be obtained from the oedometer test results. These tests were carried out to BS 1377: 1990; Part 2:Test3.2, Test 7.2 and 9.2 with the fine grained sediments being tested using a Micromeritics X-ray sedigraph, which is analogous to the pipette method of sedimentation. The standard calculations used can be found in Head (1982) and Craig (1992).

2 Results

2.1 MERCIA MUDSTONE

Initial conditions

Ho	Gs	DDo	Void Ratio	Moisture content
46.364 mm	2.65	1.641 g/cm^3	0.615	20.9 %

Consolidation Data

Increment No	Pressure (kPa)	Settlement (mm)	Water gauge (cm^3)	Void Ratio
	0	0	6.0	0.615
1	10.05	0.105	6.0	0.611
2	30.92	0.197	6.0	0.608
3	44.45	4.805	6.0	0.448
4	58.23	5.729	6.0	0.415
5	84.91	7.175	6.5	0.365
6	125.88	7.907	9.0	0.339
7	194.16	8.458	10.0	0.320
8	263.99	8.932	11.0	0.304
9	402.24	9.598	12.5	0.281
10	539.71	10.195	13.5	0.260

Velocity Data

H (mm)	Δt (μs)	Velocity (m/s)	Depth of Burial (m)
46.364	-	-	0
46.259	-	-	-0.52
46.167	-	-	-1.59
41.599	319.60	130.33	-2.28
40.635	293.05	138.66	-2.99
39.189	247.30	158.47	-4.36
38.457	230.55	166.81	-6.47
37.906	204.30	185.54	-9.98
37.432	188.00	199.11	-13.56
36.766	174.80	210.33	-20.67
36.169	155.55	232.52	-27.73

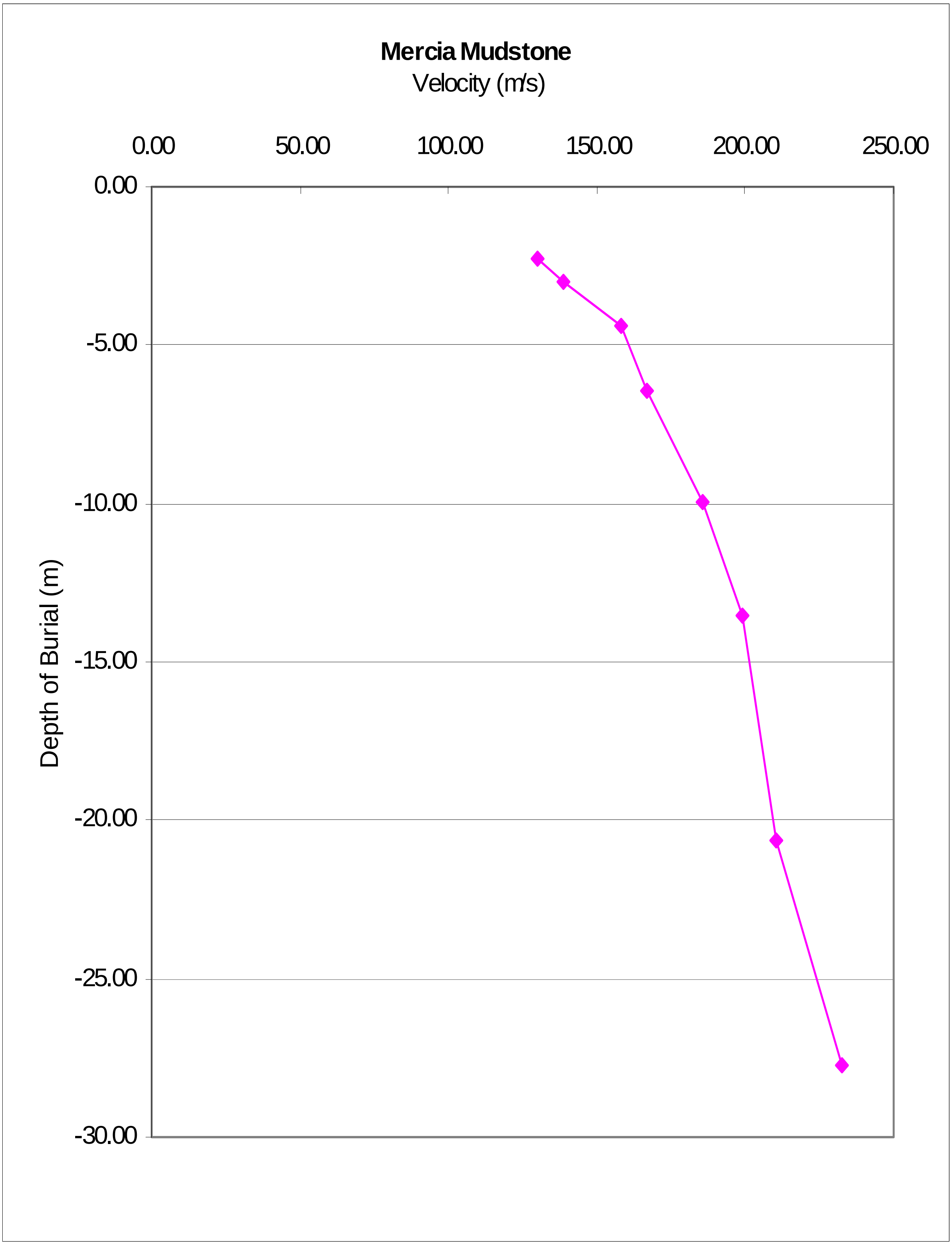

Figure 1 Variation of shear wave velocity with depth for Mercia Mudstone

2.2 SILTY SAND

Initial Conditions

Ho	Gs	DDo	Void Ratio	Moisture Content
44.364 mm	2.65	1.513 g/cm^3	0.751	23.9 %

Consolidation Data

Increment No	Pressure (kPa)	Settlement (mm)	Water gauge (cm$^{3)}$	Void Ratio
	0	0	10.0	0.751
1	1.67	0.261	10.0	0.741
2	15.72	3.400	10.0	0.617
3	29.89	3.487	10.0	0.614
4	42.13	5.710	10.0	0.526
5	69.96	5.807	10.0	0.522
6	109.90	6.822	10.0	0.482
7	175.87	8.139	10.0	0.430
8	243.64	8.733	10.0	0.407
9	380.08	9.808	10.0	0.364
10	516.13	10.514	10.0	0.336

Velocity Data

H (mm)	Δt (μs)	Velocity (m/s)	Depth of Burial (m)
44.364	-	-	0
44.103	-	-	-0.09
40.964	323.1	126.78	-0.85
40.877	319.6	127.90	-1.63
38.654	272.5	141.85	-2.29
38.557	252.3	152.82	-3.80
37.542	240.6	156.03	-5.97
36.225	226.5	159.93	-9.56
35.631	204.8	173.98	-13.25
34.556	183.3	188.52	-20.66
33.850	171.3	197.61	-28.06

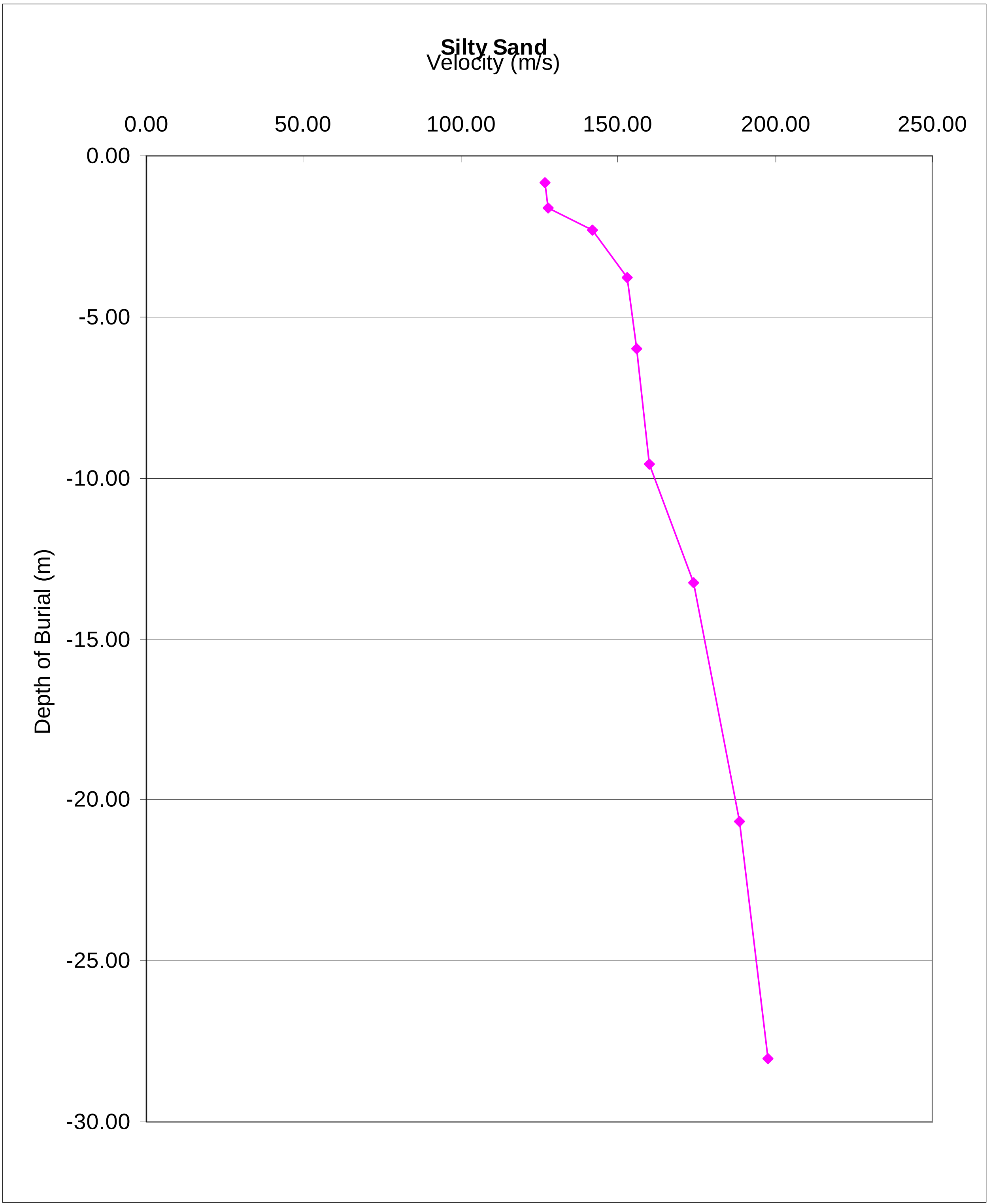

Figure 2 Variation of shear wave velocity with depth for Silty Sand

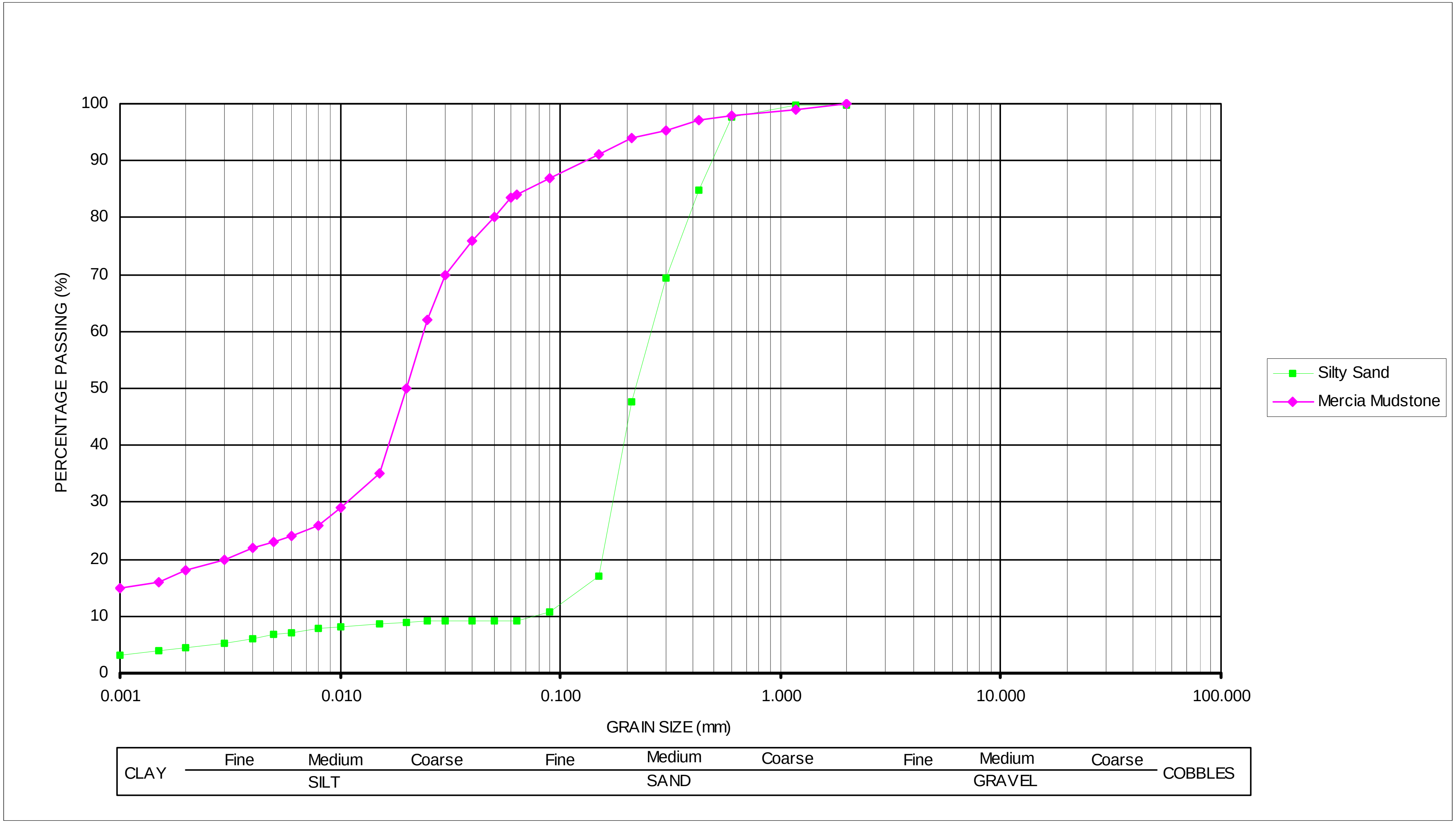

Figure 3 Particle size analysis for the two samples

3 Discussion of Results

3.1 MERCIA MUDSTONE

The variation of shear wave velocity with depth is shown in Figure 1. This shows an increase in shear wave velocity as the overburden load is increased. It also shows that the rate of increase reduces with increasing burial depth, which coincides with a reduction in the rate of void ratio decrease. The three initial values could not be obtained as no signal was detected at the receiver. There is also a significant gap in the displacement readings for these loads. This could indicate that the transmitter was not in good contact with the sample at this point and that the initial loads served to overcome the friction in the system bedding the shear wave elements into the sample. This is borne out by the perceived sample deformation. The sample appears to have undergone a 21% consolidation during the loading phases, however ignoring the first three readings this consolidation is reduced to 11 %. The water expulsion from the sample is 7.5 cm^3, which equates to 2.1% of the initial sample volume. A 21% decrease in sample length equates to a volume reduction of 28%, whereas an 11% decrease equates to a volume reduction of approximately 13%. Therefore it appears that the transmitter was not in sufficient contact with the sample, for the first three readings, to allow propagation of a shear wave. The applied pressures were monitored using a load cell within the oedometer cell. The graph is a representation of the likely shear wave velocities at the depths shown.

3.2 SILTY SAND

The variation of shear wave velocity with depth is shown in Figure 2. This shows an overall increase in shear wave velocity with increasing overburden load, as found in the Mercia Mudstone. It shows that the rate of increase reduces with increasing burial depth.

The shear wave transmitter was in contact with the sample at lower load levels and it is likely that the settlement values reflect sample size reduction rather than the friction in the system. This sample was also significantly softer than the Mercia clay of the previous sample, so less force would be needed to implant the transmitter element into the sample.

As shown previously there is a significant reduction in volume during the loading stages. This leads to similar volume reductions to those of the Mercia Mudstone sample. In this case there is no accompanying expulsion of water from the sample. It is likely that this volume reduction arises from grain reordering within the sample. The reduction in the rate of decrease of void ratio below 5m indicates that the majority of grain repacking has occurred in the early stages of the test and that below this depth there could be an increase in grain to grain contact and force on those contacts.

4 Conclusions

The two samples show similar velocities with depth of burial. The laboratory experiment shows that it would be difficult to distinguish the interface between the two layers in the field situation using shear wave based techniques.

References

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