"Physical properties of marine sediments and its applicability in the solution of engineering and environmental problems"

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ABSTRACT

For the present study four different physical properties were investigated: the velocity and the attenuation of P- and S- waves, the electrical resistivity and the natural gamma radioactivity. In addition, eight sedimentological parameters were used for correlations: sand, silt and clay contents, wet bulk density, porosity, water content, shear strength and C/P ratio (the ratio between the shear strength and the overburden pressure).

The results show that no technique used alone, can provide unequivocal evidence about the sediment characteristics. Some techniques respond primarily to lithology, some to porosity and density, and others to pore fluid chemistry. The velocity of shear waves, correlate very well with parameters relevant to engineering problems such as wet bulk density, porosity and shear strength. In addition, the velocity ratio Vp/Vs, traditionally used as a lithology indicator (Hamilton, 1979), gives no conclusive information about the kind of sediment. The attenuation seems to be insensitive to changes in the sedimentological parameters. The electrical resistivity appears to be more suitable for the evaluation of environmental than of engineering parameters. The absence of correlation between the coefficient of electrical anisotropy and shear strength indicates that the electrical resistivity is less sensitive to localised variabilities in the packing configuration. The natural gamma radioactivity shows the best correlation with parameters such as wet bulk density and shear strength. The method is very sensitive to small changes in the sedimentological characteristics of the sediment.

Moreover, the applicability of the physical models used to the characterisation of deeep sediments can not be used without making adjustments to constants or exponents, or introducing compensations.

INTRODUCTION

More than 1000 drill holes have been cored in different geological environments, after which many have in turn been logged using either downhole instruments or laboratory equipments. The most acquired physical properties are the velocity of S- and P- wave, electrical resistivity, natural gamma radioactivity and magnetic susceptibility. Also a great amount of data generated by the exploration of oil and gas fields at the sea have been used to improve the knowledge of the relationships between physical properties and sedimentological parameters of marine sediments.

However, the investigation of the uppermost layers (up to 300 m below the sea floor) has been neglected, either due to the technique used during coring or due to the absence of interess. These layers are of great importance for the evaluation of engineering and environmental problems.

The applications of such a research are:

- Sea floor stability
- Underwater mining
- Waste disposal
- Harbor engineering
- Dumping of contaminated dredge material

The physical properties of a specific material are directly related to its constituent materials. Therefore, the bulk physical properties of marine sediments are related to the physical properties of its solid phase (grains of different sizes, forms and composition), of its pore phase (water and/or gas and/or oil), as well as the structural arrangements and the grain-to-grain contact conditions.

RESULTS AND DISCUSSIONS:

In order to investigate these relationships measurements of P- and S-wave velocity and attenuation and electrical resistivity were performed on cores taken at the Norwegian Sea and at the German Bay of the North Sea respectively. Natural gamma radioactivity measurements were determined under "in-situ" conditions at the Baltic Sea using a penetration system which is able to acquire informations down to a depth of 10 m below sea floor. These data were correlated with sedimentological parameters of the same material such as sand, silt and clay content, wet bulk density, porosity, water content, shear strength and C/P ratio.

Figure 1 shows the plots of Vp and Vs versus density. It can be seen that the velocity of shear waves are much more sensitive to variations in density than the velocity of P-waves. The correlation coefficients between Vs and silt and clay content, wet bulk density, porosity, water content, shear strength are higher than 0,5 while the correlation coefficient of Vp and the same parameters were always lower than 0,4.

The attenuation seems to be insensitive to changes in the sedimentological parameters (Fig. 2). However, the results may be affected by the quality of the data and by the method used to compute the attenuation. The small amount of data points available for this investigation does not allow confident results concerning the relationship between Qp and Qs and the various sedimentological parameters.

The results of electrical resistivity showed that, although it correlates qualitatively very good with the sedimentary layers, it has a relative weak direct correlation with the sedimentological properties(Fig. 3). This is basically caused by the strong influence of the chemical properties of the pore fluid. This characteristic feature may be, in future investigations, used in the evaluation of some chemical parameters that may result from pollution by organic matter or heavy metals.

The correlation between natural gamma radioactivity and the sedimentological parameters presented very good correlation coefficients (up to 0,89). It showed the best correlations with density, water content, and shear strength. This is an indication that the compaction processes are a major factor controlling gamma radioactivity in shallow marine sediments (Matolin, 1984). Figure 4 shows the plots of natural gamma radioactivity and shear strength.

CONCLUSIONS

Geophysical methods have been traditionally used in the exploration of raw material. Today, this technology is also applied in the evaluation of some engineering and environmental parameters. The results obtained in this work show that it is possible to use the physical characteristics to evaluate some sedimentological parameters of the sediments of the seafloor.Further experiments must be concentrated in the investigation of some unsolved questions such as:

a) What kind of relationship exists between Vp and Vs? The already published empirical relations between both velocities (best et al., 1994), when applied to shallow marine sediments, give disappointing results. The understanding of this relationship is important since Vs gives more precise informations about the geotechnical conditions of the sediment but Vp is much more simple to determine using normal seismic interpretation tools.

Figure 4: Plot of natural gamma radiocativity versus shear strength

b) The electrical resistivity of the sea floor was shown to be primarily dependent upon the chemical composition of the pore fluid. It could therefore be used in the determination of the degree of contamination of marine sediments. This is especially important for dredging works at harbours where the sediments are often contaminated. Thus, the relationship between electrical resistivity and some harzadous waste and organic contaminants as well as the effects of clay content and salinity needs more detailed investigation.

c) Radioactive properties showed the best possibilities for the investigation of geotechnical surveys. It showed the best correlations with all the parameters determined in this study, speacially with density, porosity and shear strength. However, today`s methods and tools used in the acqusition of natural radioactivity are based on downhole measurements. This kind of technique gives information relative to one point not allowing lateral correlations. This is only possible either by logging in several places, which is very time consuming and consequently very expensive, or by making use of seismic profiles.

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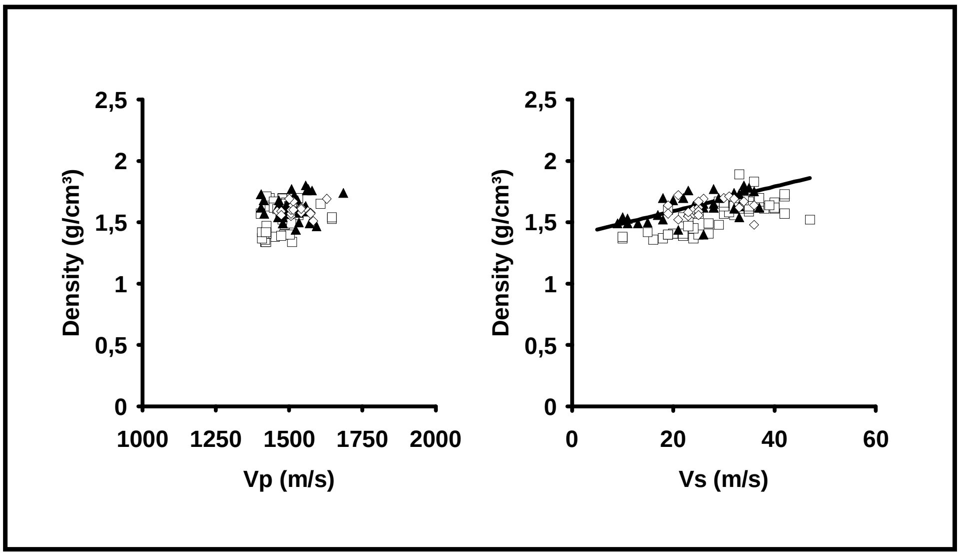

Figure 1: Plots of Vp and Vs versus wet bulk density

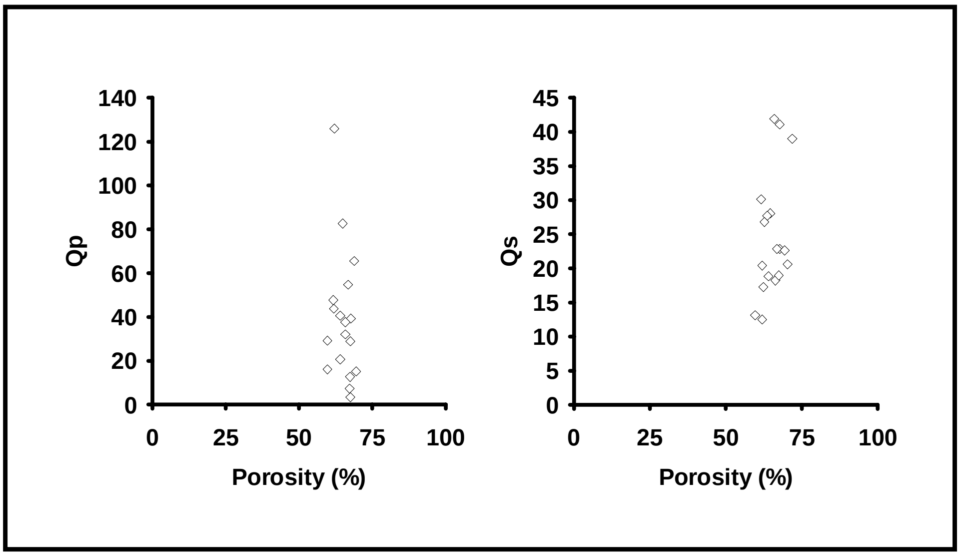

Figure 2: Plots of Qp and Qs versus porosity

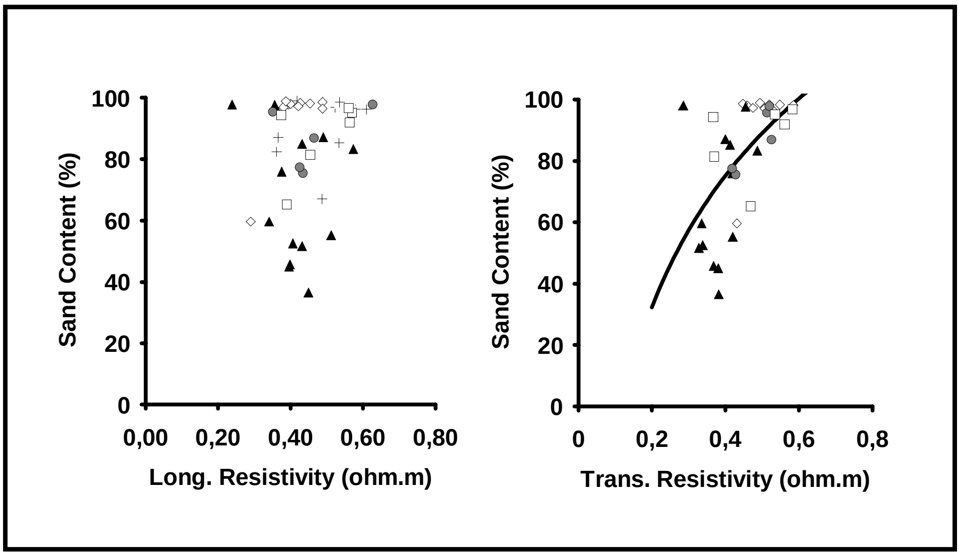

Figure 3: Plots of electrical resistivity versus sand content

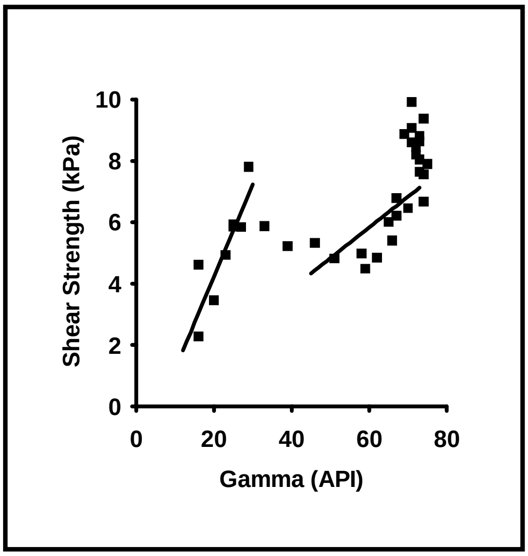

Figure 4: Plot of natural gamma radiocativity versus shear strength