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Project Report

SEDIMENT BEARING PRESSURE ANALYSIS USING SEDIMENT CLASSIFICATION TECHNIQUES

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1. Introduction

Understanding the geology and geotechnical qualities of the seafloor necessitates a comprehensive examination of the surface sediment topography and composition. This is based on the categorization of sediments concept. Using sediment classification methods accurately determines the sediment-bearing pressure, strength, and stability of sediment layers required for offshore construction and exploration. Estimating sediment-bearing pressure at the bottom is one of the most important uses of the Acoustic Seafloor Classification System. The Indian Ocean Region has vast quantities of petroleum, natural gas, and essential minerals such as iron, manganese, nickel, and gold [1]. To anticipate geotechnical and acoustic qualities in the upper few metres of the seabed, civilian and military communities must establish seafloor and sub-bottom ststructuresThis data is utilised in seabed engineering trafficability calculations and as input to sonic propagation models [2].

Exploration and extraction need offshore infrastructures, like drilling rigs, tanks, and refineries, which are supported by seabed foundations. For offshore projects, sediment-bearing pressure affects site selection and the construction of foundations and piles that serve as support structures. The defence also requires bearing pressure for creating artificial islands, transferring military equipment, and other associated infrastructure. The results of sediment classification systems may be utilised to identify the parameters necessary for sediment-bearing pressure estimates.

Sediment-bearing pressure is significant in the design and strength of structural foundations. The sediment-bearing pressure was utilised to calculate the foundation's depth, the underwater tunnel system, and the profile of the tunnel cross-section over the Xiang River in Changsha, China. Furthermore, the tunnelling approach is founded on such concerns [3]. The rock-fill Atasu Dam in Turkey was built on basalts with a good rock mass quality. Empirical methods were used to determine the basalts' ultimate bearing capacity values [4]. Due to the difficulty of well-sinking through considerable depths below the bed level for building bridges, many challenges are faced during well-sinking due to problematic strata such as rocky strata, the existence of sloping rock, extreme tilts, and so on. The most critical component is foundation depth, which is determined by scouring depth. The depth of the foundation is the essential element, which is determined by scouring depth, which is a function of discharge, and silt factor, which is connected to the size of the medium of the bed material. The pile foundation difficulties were also addressed in light of the piles' high load capacity [5]. In Jizan, Saudi Arabia, one of the intriguing uses of sediment-bearing pressure analysis may be seen. The city is on the Red Sea coast and prone to mild to severe earthquakes. The identification of soil profiles and assessment of dynamic soil attributes were used to make systematic geotechnical and geophysical field data measurements. The relative stability and strength of sediments were established to calculate a safe bearing capacity for structures near coastlines, which will be integrated into National Earthquake Hazards Reduction Program (NEHRP) requirements [6].

2. Sediment Bearing Pressure Analysis

Underwater sediment modelling is traditionally accomplished using in-situ sampling, which refers to the treatment and analysis of sediment following a physical sample at the sediment detection site. Extensive laboratory testing is performed on the sample to establish geotechnical characteristics and sediment classification. Several experiments, including the Vane shear test and the Triaxial test, are performed on soil samples to get the necessary data. The sediment-bearing pressure is computed using exact estimates of shear wave velocity, the single and most influential soil parameter representing a family of geotechnical soil parameters ranging from compressive strength to void ratio, from shear rigidity to cohesion, etc. [7]. This approach, however, is limited in scale, time-consuming, and expensive [8]. A remote sensing acoustic-based technique has thus been developed called the Acoustic Seabed Classification System (ASCS) for predicting acoustic impedance, sediment type, and various specified geotechnical parameters of the seafloor in near real-time.[9]

2.1 Remote Sensing Techniques

Seafloor classification utilising acoustic remote sensing techniques is now the most appealing because of its broad coverage and low cost.
There are primarily two kinds of such approaches:

- Empirical method
- model-based approach

They may depend on backscatter signal characteristics (empirical technique) or utilise physical models to estimate the sediment type based on the most significant feasible match between the modelled and observed signals or signal properties (model-based) [10].

Physical models are used to determine the kind of sediment based on the best possible match between the simulated and observed signals or signal properties [SBP8]. Data from different acoustic sensors, including as Multi-Beam Echosounders (MBESs), Single-Beam Echosounders (SBESs), Side Scan Sonars (SSSs), and Sub-Bottom Profilers (SBPs), are used to support such models. Depending on the depth, environmental conditions, region of interest, and resources available, these systems can be hull-mounted, towed, or suspended.

2.2 Data collection using acoustic systems

With a wide variety of sensors available based on the survey's specifics, the Sub-Bottom Profilers are of interest to this circumstance. Acoustic Sub-Bottom Profiling devices are utilised to evaluate the physical properties of the sea floor and to image and characterise geological data a few metres beneath the sea floor. The non-linear parametric sub-bottom profilers simultaneously emit two signals with slightly differing high frequencies. Their interference produces a new low-frequency signal through interference. They have very high vertical resolution and are especially useful in shallow-water settings [11]. Because the seabed may be composed of layers of sediments with variable characteristics, it is required to distinguish the sediment layers extending deep after the seafloor and their attributes with high precision. SBP is an excellent choice for this. Authors in [12] and [13] deployed such SBPs using towlines below the seawater surface behind the surveyor ship. Due to its stability and ability, an AUV can be the best option to operate close to the target [14]. The parametric echosounder can be operated from small vessels. Typically, the transducer is affixed to the ship's side, and only signal processing and recording equipment are required on board.

Sub-Bottom Profilers are available in several configurations, including chirp SBP, parametric SBP, etc. Fishers' SBP-1 has an advantage over most other competition as this unit is either pole mountable for shallow water searches or boat towable for search in deeper areas allowing superior versatility for the end user. The SBP-1 system consists of a sonartowfish made from corrosion-resistant, high-impact PVC, 150' of cable, a topside sonar processing box, and a laptop computer pre-loaded with JW Fishers SONAR VIEW for Sub Bottom Profiler software. The 36-inch-long by 24-inch-wide towfish offers an exceptionally sturdy platform for the sonar transducer, enabling the finest possible pictures to be produced. The SBP-1 is capable of probing seafloor depths of up to 40 metres. The SONAR VIEW software provides the sub-bottom operator with comprehensive control over all system operations via simple pull-down menus and on-screen icons. The standardisation of size measuring tool annotation and automatic bottom tracking. The operator may alter colours, ranges, amplifier gain, and other settings with a mouse click. Sub-bottom pictures can be kept in the computer's memory for replay and post-processing at any moment in the future. Copying and sending small file parts, including screenshots, is possible. The computer-connected GPS gathers location coordinates alongside the data. When a GPS is attached, any item on the screen may be selected with the mouse, and its location coordinates will be shown. Sonar files can be kept on the hard disc of the computer. The optional Sonar Coverage Mapping programme illustrates the boat's journey across the search region. All of the information is shown on a grid with latitude and longitude as the X and Y axes. This tool makes searching huge regions simple and guarantees that no portion of the area is overlooked [15].

Innomar's parametric sub-bottom profilers are often used in shallow and highly shallow waters with limited access for vessels and boats. A remotely driven surface vehicle is pre-configured with the "smart" or "small" Innomar SBP to support such surveys. This vehicle autonomously scans a predetermined region or operates in protected locations, such as water reservoirs. It is also possible to integrate third-party equipment, such as ADCP, MBES, or side-scan sonar Components, including dotOcean Calypso inflatable survey platform control box with electronics and thruster battery dotOcean AYB / Atlantis cloud auto-navigation payload PC and sensors inclusive of uninterruptible power supply. The package includes the "smart" parametric sub-bottom profiler from Innomar, a Transducer with a mounting bracket, a payload battery box, underwater thrusters, WiFi and LTE/4G antennae and a payload battery box. [16].

Another SBP that can be used is the PLS product, which is a family of portable parametric sub-bottom profilers and uses single-beam parametric technology for sub-bottom profiling exploration and accurate water depth survey.
The PLS provides optional primary frequencies, including 100kHz, 200kHz, and 300kHz. The range of secondary frequencies is wide, and real-time data for bathymetry and sub-bottom profiling can be both acquired.
The standard hulls are 2000m and 6000m depth rated and also can be customized, small form factor, and portable, which is suitable for integration into ROV and AUV. It works in a primary frequency range of 85 ~ 115 kHz and a secondary frequency of 5 ~ 25 kHz. It has a power supply rated 24VDC / 220V AC to 24VDC. The Transducer is made with Titanium and weighs 12 kg in air, and 6 kg in water, measuring 415mm in length and 160mm in Diameter [17].

2.3 Model-based acoustic classification

Several models might be employed to classify sediment type and get several acoustic and sediment characteristics as output. While for this particular application, different models can b chosen, the Biot-Stoll model is one of the best choices. A variety of authors have used the Biot-Stoll model, including the authors of [18], to determine density, sound speed, attenuation, and other quantities that are then connected to sediment particle size. It is a thorough model of acoustic wave propagation in porous media that are saturated with fluid, like marine sediments. 13 physical parameters must be used with the Biot-Stoll model [18]. The model includes the use of the Hilbert transform [19], The KozenyCarman relation [18] and various corrections factors for viscosity, permeability, porosity etc. [18].

2.3.1 The Biot-Stoll Model

The Biot-Stoll model is frequently used to determine the geotechnical qualities of sediments. To create predictions with the Biot-Stoll model, it is necessary to calculate the thirteen parameters in Table 1. Historically, this has been accomplished using a mixture of handbook values, empirical calculations, in situ measurements, and references from the literature [20].

Symbol	Parameter
ρ_f	Density of the pore fluid
ρ_r	Density of sediment grains
$K_b = \mathrm{Re}\, K_b^*$	Real frame bulk modulus
$\mathrm{Im}\, K_b^*$	Imag frame bulk modulus
$\mu = \mathrm{Re}\, \mu^*$	Real frame shear modulus
$\mathrm{Im}\, \mu^*$	Imag frame shear modulus
K_f	Fluid bulk modulus
K_r	Grain bulk modulus
β	Porosity
η	Viscosity of pore fluid
k	Permeability
α	Tortuosity
a	Pore size parameter

Table 1: Parameters for the Biot-Stoll model

To investigate the Biot-Stoll model's predictions, it is useful to have parameters for a range of seafloors. Table 2 provides values for six Biot-Stoll parameters for five distinct sediments.

Sediment	ρ_r	K_r	β	k	α	a
Fine Sand	2670	4.0×10^{10}	0.43	3.12×10^{-14}	1.25	1.20×10^{-6}
Medium Sand	2690	3.2×10^{10}	0.385	2.5×10^{-11}	1.35	6.28×10^{-5}
Gravel	2680	4.0×10^{10}	0.30	2.58×10^{-10}	1.25	1.31×10^{-4}
Silty Sand	2670	3.8×10^{10}	0.65	6.33×10^{-15}	3.0	4.25×10^{-7}
Silty Clay	2680	3.5×10^{10}	0.68	5.2×10^{-14}	3.0	1.24×10^{-6}

Table 2: Biot-Stoll parameters for five different sediment types

Holland and Brunson [21] provide the parameters of fine sand, silty clay, and gravel. Beebe, McDaniels, and Rubano [22] present the criteria for silty sand. For characteristics other than medium sand, Table 3 fluid parameters will be utilised.

Symbol	Estimate
ρ_f	1000
K_f	2.4×10^9
η	1.01×10^{-3}

Table 3: Typical fluid parameters for the Biot-Stoll model

The chosen model considers several parameters. We will examine them one by one.

Density of pore fluid:

The pore fluid in marine sediment is seawater. For instance, the density of saltwater at 20 degrees Celsius, 35 percent salinity, and a depth of 0 metres is 1,025 kg/m3. In the case of pure water, the density at 20 degrees Celsius is 998 kg/m3.

Density of grain:

The grain's density can be measured. The average density of sand is approximately 2,650 kg/m3.

Bulk modulus of pore fluid:

The bulk modulus of the pore fluid is 2.37x10^9 Pa for the density of 1,025 kg/m3 and the sound velocity of 1,522 m/s (temperature 20C, salinity 35, depth 0). In the case of pure water, the bulk modulus is 2.195x10^9 Pa for the density of 998 kg/m3 and the sound velocity of 1483 m/s (temperature 20C).[23]

Bulk modulus of grain:

Stoll used 3.6x10^10 Pa for the bulk modulus of the grain [24].

Porosity:

Porosity is measurable. Unconsolidated marine silt has a porosity greater than 0.35. Hamilton provided an empirical equation demonstrating the connection between grain size and porosity which goes as follows [25]:

$$\beta = 0.3105 + 0.0552\phi$$
$$\phi = -\log_2 d,\ d\ in\ mm$$

Permeability and pore size parameter:

Permeability is determined usin the KozenyCarman relation, given by

$$k = \frac{d^2}{36k_0}\frac{\beta^3}{(1-\beta)^2}$$

where d denotes the grain diameter, k0 is a constant determined by the shape of the pore, and the tortuosity.

The pore size a, for spherical grains is obtained by Hovem and Ingram [26,27] as follows:

$$a = \frac{d}{3}\frac{\beta}{1-\beta}$$

Structure factor:

Stoll utilised y = 1.25 for sand and 3.0 for silty clay [24], but Turgut and Yamamoto utilised y = 1.25 for silt, medium sand, and coarse sand [29]. Berryman obtained the relation,

$$\gamma = 1 + r\left(\frac{1-\beta}{\beta}\right)$$

where r = 0.5 for isolated spherical particles and lies between 0 and 1 for other ellipsoidal shapes [27,30]. According to the Berryman equation, the structure factor depends on the grains' porosity and shape.

Shear velocity:

Using the recorded shear wave velocity and the density, the relationship between porosity and the frame shear modulus may be expressed as :

$$\mu_r = \rho c_s^2, \; c_s = 4.40\beta^{-2.69}$$

The frame response parameters are the modulus of shear and the bulk modulus Kb. Typically, they are assumed to have complex values to account for losses caused by intergranular friction. There are several empirical formulas for their calculation. Bryan and Stoll [31] assumed that,

$$\mu_l = p_a a \, exp(-b\varepsilon)(\sigma_0/p_a)^n$$

where pa is the atmospheric pressure,

$$\varepsilon = \frac{\beta}{1-\beta}$$

is the voids ratio, and the mean effective stress due to over-burden pressure is

$$\sigma_0 = \frac{1+2k_0}{3}\int_0^z g(1 - \beta(z))(\rho_r - \rho_f)dz$$

where z is the depth into the sediment, K0 is the coefficient of earth pressure at rest, generally 0.5, and g is the acceleration due to gravity.

Another empirical modification $\mu = FF.\mu_1$ where FF = 2, can be used where

$$\mu = a \times 10^5 \varepsilon^{-b}\sqrt{\sigma_0}$$

$$\mu^* = (1 + i\Delta_\mu/\pi)\mu$$

$$K_b^* = \frac{2(1+\nu)}{(1-2\nu)}\mu(1 + i\Delta_{K_b}/\pi)$$

Where Δ_{μ} and Δ_{K_b} are the log decrements for compressional and shear vibrations and ν is the Poisson ratio. Only three Biot-Stoll characteristics significantly influence shear wave speed: shear modulus, porosity, and grain density. [32]. The shear wave speed is used in the formula $\mu = \rho c_s^2$. [20]

The findings of the computer model were largely unaffected by the estimated model input data, such as mean grain size and porosity, as well as other factors including grain density, permeability, sediment pore factor, grain bulk, and shear modulus, as well as seawater density and elastic modulus.

The model's output must be utilised to do more research on the sediment carrying pressure.

2.4 Acoustic Data Processing

It is crucial to be able to link the numerical values recorded by the data logging system with voltage values from the transducer to gather quantitative data using the sub-bottom profiler. Additionally, to enhance the system, it is essential to thoroughly examine its features and search for potential sources of mistakes or areas for development [33]. The data is analysed using acoustic system software, which displays the results in real-time graphs and curves created from the analytical signals.

The data received by the acoustic sensors need to be processed before further analysis, i.e. preprocessing of data, is carried out. This often entails adjustments for variables like the sound speed that affect the acoustic signal's propagation and provide ambiguous findings. Authors in [34] corrected sound velocity variation through the water column, corrected for tide variation at various water depths, filtering motion sensor information, and removed data outliers. Before the sonar survey, a tide gauge was set up in [35], and the data were adjusted to the Lowest Astronomical Tide. Daily sound velocity profiles were gathered to account for local fluctuations in the sound velocity of the water column. Track spacings were created so that neighbouring lines would always have a 50% overlap, allowing for data rejection at acute grazing angles.

The data must be processed to obtain information from the deformed audio signal. Filtering is the process of obtaining useful information from acoustic input while decreasing noise [36]. The signal is subjected to a rapid Fourier Transform, multiplied by a window function for a brief duration, and the Fourier transform of the windowed acoustic data is acquired as the window is slid down the time axis. This approach gives a time-representation of a non-stationary spectrum, enabling time-frequency analysis. For this study, a Gabor wavelet can be selected.

Filtering is the process of reducing noise and extracting relevant information from acoustic data. For acoustic data processing, the spectra of acoustic data are often computed, and the Fourier transform (FT) or the fast Fourier transform (FFT) is one of the most commonly used methods for the computation. Nonetheless, the FT is unsuitable for localised spectrum analysis in time, and its application to a nonstationary time series is improper. The Parametric-SBP(PSBP) delivers high-resolution acoustic data at primary and secondary frequencies with distinct acoustic properties; hence, a time-frequency structure technique would be more suitable for analysing the high-resolution data.

The short-time Fourier transform is one of the fundamental time-frequency analysis techniques (STFT) The signal is multiplied by a window function for a brief amount of time, and when the window is slid down the time axis, the Fourier transform (FT) is calculated for the windowed acoustic data. This technique produces a non-stationary, time-representable spectrum and permits time-frequency analysis. In addition, STFT's resolution in the time and frequency domains is limited by the indeterminacy principle. Since the window size is constant in STFT, so is the frequency resolution, and the window size is proportional to the frequency resolution. Therefore, it is not viable to simultaneously enhance the time resolution and frequency resolution in time-frequency analysis. It also implies that STFT complicates the time-frequency analysis of high (primary) and low (secondary) frequency components with optimal resolution.

To circumvent the problems in STFT, the wavelet transform (WT) is used to analyse seismic data and has since been applied in various other scientific fields. The WT offers orthonormal basis expansions of a signal utilising wavelets that have favourable localization qualities in the time and frequency domains. Therefore, the WT is useful for both high (primary) and low (secondary) frequency component time-frequency analyses. Continuous wavelet transform (CWT) is formulated as follows:

$$W(a, b) = \frac{1}{\sqrt{a}} \int_{-\infty}^{\infty} f(t) \psi\left(\frac{t-b}{a}\right) dt$$

where ψ is the mother wavelet, a is the scaling factor, and b is a translation of the mother wavelet.

The noise encompasses a range of noises, including as underwater, artificial, platform, and electrical noises, and is impacted by the local environment. Therefore, the variable time-scale window is appropriate for the noise's time-frequency analysis. Several mother wavelet functions have been suggested for the WT, and their selection is often influenced by a number of factors. The Gabor wavelet is selected for this research based on the characteristics of mother wavelets. The Gabor wavelet is an exponent function that is multiplied by the Gaussian window.

$$\psi(t) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{-\frac{t^2}{2\sigma^2}} e^{i\omega t}$$

where σ is the dispersion in the Gaussian window. The Gabor wavelet has the virtue of minimising the standard deviation across the time and frequency domains; hence, it gives excellent resolution in both domains. In addition, the Gabor wavelet is excellent for the extraction of local characteristics and the analysis of acoustic data supplied by the PSBP.

Data processing includes solving the model's different equations. These are addressed by making appropriate assumptions so that the equations may be solved numerically. These assumptions depend on the acoustic systems employed and the location [37]. In this case, the acoustic challenges posed by the Indian Ocean Region must be studied to make appropriate assumptions such as including backscatter echo, approximating relationships between parameters, corrections based on specific environments, using a frequency range, and so on to determine the required parameters.

Hamilton,1980, described various regression and empirical equations to deduce sediment surface properties like shear wave velocity, wave velocity, density, and porosity for different oceanographic formations. An approximate first-order dependence of attenuation and frequency is established [38]. Edwin L. Hamilton and Richard T. Bachman 1982, proposed regression equations interlinking various sediment properties under different environments.[39]

Assumptions:

The Indian Ocean Region (IOR) is a crucial location that has seen a surge in commercial and military activity, particularly in the twenty-first century. But, the IOR has distinct geopolitical, social, acoustical (tropical littoral seas), and other features. Its warm temperature renders it vulnerable to climatic fluctuations like monsoons, tsunamis, cyclones, and high winds. The tropical littoral waters of the IOR have a high SOFAR channel depth, making it acoustically shallow and leading to sub-optimal performance of any kind of sonar. Furthermore, surface roughness and bottom-type fluctuations contribute to multiple interactions of the signal pulse with the water surface and sediment boundaries. Additionally, the rich biodiversity in the littoral waters of IOR leads to additional signal decay by aggravating the attenuation. This leads to a complex propagation model, and suitable corrections must be made to get relevant data. [40] [41]

When determining the necessary parameters, it is essential to consider the acoustic difficulties presented by the Indian Ocean Region. For example, backscatter echo must be taken into account, approximate relationships between parameters must be used, corrections based on particular environments must be made, and so on.

2.4 Signal Parameter Correlation for Sediment Classification

Using the variation of different acoustic parameters with depth or pressure, a comparison can be made with established literature and data. The closest match is found with the experimental graphs plotted using raw data from laboratory analysis of in situ samples [42].

Authors in [43] showcase predicted values of density, specific gravity, porosity, shear modulus etc., of the sediment from the Anderson–Hampton model as scatter plots varying with saturation or any other relevant parameter. In [44], density, porosity, and amplitude are shown to vary with reflection coefficients, and the results for various parameters are tabulated.

The density, porosity, permeability, and mean grain size are all critical criteria to consider when calculating the undrained strength of sediments [45]. The solution of the model may be used to calculate the approximate ranges of such parameters. A customised Graphical User Interface (GUI) must be built for this purpose, taking in data from the acoustic systems, encapsulating the appropriate processing, and showing the desired results in graphs, curves, tables, and so on or in real time or within a short span from the time of the survey.

3. Acoustic classification-sediment bearing pressure correlation

The primary aspect is to link sediment classification data to sediment Bearing pressure. The undrained shear strength, overburden pressure, and pore water pressure are all essential components in determining the bearing pressure. The bearing capacity variables used to compute the shear strength of the sediment are heavily influenced by the sediment's internal friction angle. Terzaghi [46] proposed a theory that links the friction factor of soils to density, cohesiveness, depth, and slope inclination. This may be used to compute the soil's bearing pressure coefficients. Meyerhoff's [47] theory might be used to calculate bearing pressure coefficients independent of slope inclination. The results from the acoustic classification model can be used to manually check the ranges for the bearing pressure coefficients, friction angle, etc., and with proper correction factors for shape, size, inclination, etc. The sediment-bearing pressure can be analyzed using the described theories.

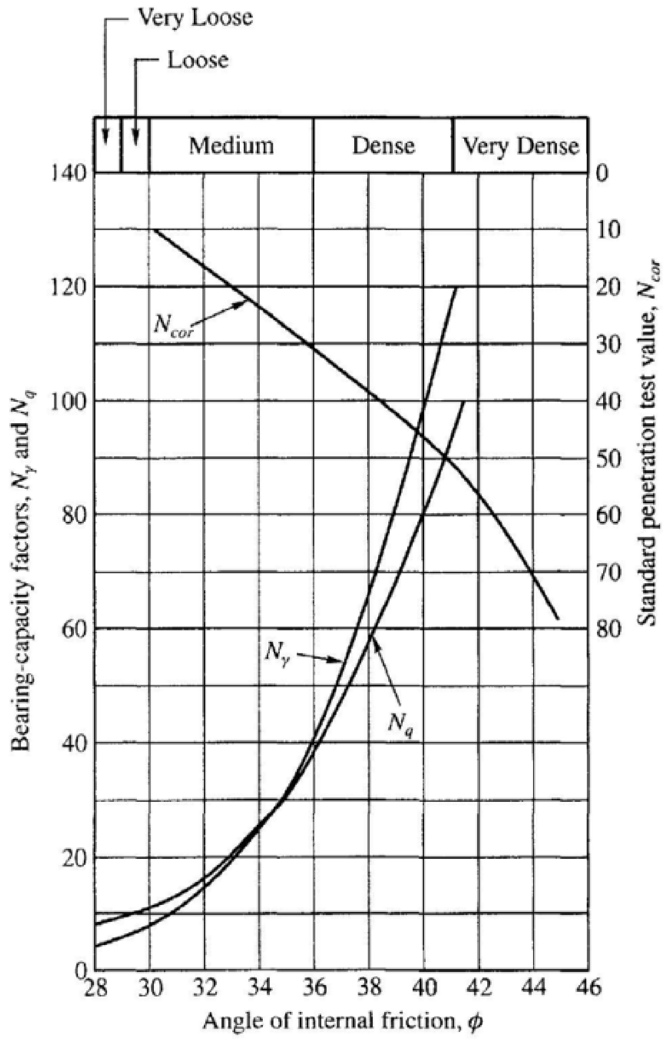

Fig 1: Terzaghi's bearing capacity factors for the transitional state

In fig.1, the angle of internal friction and bearing capacity factor can be related by knowing the type of soil present.

From the obtained parameters of the shear modulus, modulus of elasticity, bulk modulus, subgrade coefficient, Poisson's ratio, and correction factors, including the width of the foundation, Tezcan et al. [48] suggested a seismic technique for calculating the sediment-bearing pressure. These are also easily derived from the results of the acoustic classification models.

Once the seismic wave velocities, Vp and Vs, are measured by the acoustic classification model for a particular sublayer in the field, several parameters of elasticity, such as shear modulus G, oedometric modulus of elasticity Ec, modulus of elasticity E (Young's modulus), bulk modulus K, and Poisson's ratio v may be obtained from the following expressions. The shear modulus G and the oedometric modulus Ec are related to the shear and P-wave velocities [48].

Parameter	Formula
Shear modulus	$G = \gamma V_s^2 / g$
Modulus of elasticity	$E = k_s H = 4\gamma H V_s$ (alternate) $E = (3\alpha - 4)G / (\alpha - 1) = 2(1 + \nu)G$
Oedometric modulus	$E_c = (1 - \nu)E / (1 + \nu)(1 - 2\nu)$ $E_c = \alpha E / 2(3\alpha - 4)$
Bulk modulus	$K = E/3(1 - 2\nu) = 2(1 + \nu)G/3(1 - 2\nu)$ $K = (\alpha - 1)E/3 = \gamma(V_p^2 - 4V_s^2/3)/g$
Poisson's ratio	$\nu = (\alpha - 2)/2(\alpha - 1)$ $\alpha = 2(\nu - 1)/(2\nu - 1)$
Subgrade coefficient	$k_s = 4\gamma V_s = 40\, q_f$
Allowable bearing pressure	$q_a = q_f / n = 0.1\, \gamma V_s \beta / n$

Table 4: Various elasticity parameters in terms of Vp and Vs

Based on actual experimental data, Hardin and Black (1968) and Hardin and Drnevich (1972) discovered crucial relationships between the shear wave velocity, void ratio, and shear stiffness of soils [49] [50]. Similarly, Ohkubo and Terasaki (1976) provided several formulas connecting the seismic wave velocities to water content, permeability, weight density, and other variables [51].

Using the proper adjustments for the selected theory, one can compute each sediment layer's sediment bearing pressure, strength, and stability, and hence the adequate bearing pressure required for the foundation design.

4. Conclusion and Discussions

The acoustic-based sediment-bearing pressure determination is a game changer in terms of the survey regions, time and capital required. Acoustic systems are more extensive than the conventional techniques and provide a detailed representation of the sea floor. The model-based techniques allow the user to focus on the relevant parameters and save resources.

The advances in the techniques used for determining sediment-bearing pressure have led to a more comprehensive and less tedious process. Even with various models and algorithms, one can't just take up a well-established model for any region. There are challenges in choosing a particular technique or model for the process.

Most acoustic classification algorithms are verified using data collected from actual samples taken from the seafloor and boreholes. Higher costs and longer turnaround times are the effects of this.

Various pre and post-processing procedures with varying levels of complexity, accuracy, and processing time might be utilised depending on the model chosen, the acoustic sensors, and the desired outputs. It is essential to ensure that these strategies are appropriately chosen to gather real-time survey data for accurate analysis. Different domains have used sediment-bearing pressure in diverse ways. In light of this, various organisations may carry out surveys, including the government, military, environmental organisations, businesses, etc., emphasising various factors according to the surveyor's needs. It is necessary to apply various acoustic sensor methods, models, and strategies while considering the user's needs.

The following directions could be world upon for improvement in the acoustic sediment bearing pressure calculation like deducing a time-efficient, self-validation AI/ML-based model for processing acoustic signals to reduce dependence on laboratory data for validation, Developing a customised Graphical User Interface (GUI) taking in data from the acoustic systems, encapsulating the appropriate processing and providing relevant results while considering the requirements of various users and developing long-term policy interventions needed to distribute the model and the results to a variety of users.

5. Resources

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