SOIL IMPROVEMENT

Consolidation

provocare l'espulsione dell'acqua, stabilizzazione di un terreno, drenaggio (soft soils)

- vertical drains wick
- id con vacuum
- Beau Drain IFCO PTD
- Sand Drains System

Compaction

provocare una struttura porosità, affidabile (sabbie)

- meccanica, HEC
- con cemento ALLU
- Vibroflottazione

methods to improve, reinforce stabilise soils

- stone columns
- piling the ground
- soil mixing
- local mixing in a grid

FACTS ABOUT

Soil Improvement

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WHAT IS SOIL IMPROVEMENT?

In the dredging industry soil improvement is typically implemented:

- To prevent excessive settlement of reclaimed land when it is being utilised for construction purposes (roads, airports, bridge and other foundations);
- To enhance the soil stiffness in order to prevent liquefaction and subsequent damage to structures in seismic-sensitive regions;
- To enhance the shear strength of the soil to prevent slip failure;
- To enhance the bearing capacity of the soil; and/or
- To immobilise or stabilise contaminants in dredged soil in order to eliminate environmental impacts.

Soil improvement techniques vary depending on the characteristics of the soil. Some techniques are applied to consolidate existing loose subsoil and some are specifically for compaction of newly reclaimed soil.

WHAT IS THE DIFFERENCE BETWEEN COMPACTION AND CONSOLIDATION?

A distinction should be made between compaction techniques for new land and consolidation techniques for loose soil. Compaction is used for coarse-grain soil (sand) and can be done with smooth rollers, HEIC, or dynamic impact or rapid impact compactors or vibroflotation. When the soil is too fine, or too silty, replacement methods are used. These can be sand poles, grind poles and mixing with cement or other suitable materials that render the soil almost immediately ready for use. Other techniques are used exclusively for expediting consolidation of loose soils. These include vertical drains, sand drains and a system known variously as BeauDrain, IFCO or PTD, as well as vacuum consolidation, all methods in which soil improvement takes a longer period of time.

WHY IS CONSOLIDATION FOR SOIL IMPROVEMENT USED DURING LAND RECLAMATION?

Land reclamation along coastlines is one of the most significant activities of the dredging industry. In most countries coastal properties are already densely populated and yet areas nearby water continue to attract people for recreation and residence. Consequently, with the growth in the worldwide population, land along the coasts has become scarce, causing land prices to escalate.

Creating new land is often a less expensive solution. Typically the land chosen as potential reclamation sites are shallow coastal areas or marshy lowlands. The soil in these areas often consists of thick layers of soft clay or silts. Reclamation works increase the load on these soft layers, causing widespread settling. Waiting for the natural settlement of this land is a time-consuming and thus costly option. To accelerate the settlement process, the dredging industry has invested in extensive technological research in the consolidation of these soft soils. In addition, the newly reclaimed soil is often in a loose state and needs to be compacted.

HOW IS SOIL IMPROVEMENT USED TO REDUCE ENVIRONMENTAL IMPACTS?

Soil improvement is also applied to improve the mechanical characteristics of contaminated soft soil by immobilising heavy metals and other soil contaminants. Many techniques have been developed to consolidate contaminated sediments such as dewatering the sediment to reduce the quantity of soil, or combining the sediment with additives, such as mixing sediment with cement which allows the recycle use of the sediment as construction and/or reclamation material.

HOW DOES SOIL IMPROVEMENT HELP IN EARTHQUAKE PRONE REGIONS?

In certain regions of the world like Japan and California, the frequency of seismic activity can be threatening to maritime construction. This can be a serious issue when installing offshore equipment and other marine structures such as tunnels, wharfs, ports, airports in the sea and so on. Here too, advanced technologies have made steady advances in developing countermeasures for coping with the threat of seismic instability by limiting the chances of soil liquefaction.

What is soil liquefaction?

Liquefaction occurs in saturated soils, that is, soils in which the space between individual soil particles is completely filled with water. The water exerts a pressure on the soil particles that influences how tightly the particles themselves are pressed together. Water pressure in soil is generally relatively low. However, when an earthquake occurs, the shaking can cause the water pressure to increase to a degree where the soil particles begin to move around and create an unstable situation. Such an increase in water pressure can also be activated by construction-related activities such as blasting. Liquefaction decreases the strength of the soil and reduces the capacity of the soil to support the foundations of buildings, bridges and other structures. The possibility of liquefaction can occur in existing loose soils as well as in reclaimed land.

Is Soil Improvement always necessary?

In the case of reclaimed land, consolidation left to its natural course may take a decade or more. Given the urgent need for expansion this is a long time to wait to be able to build. In fact, if the new land is not usable for construction purposes within a reasonable timeframe and the facilities being built are delayed until the land has settled enough to support buildings or an airport or houses, the project may be jeopardised. A lengthy turnaround period can thus have crucial social and financial implications, since for both economic and social reasons the reclaimed land is usually needed as soon as possible.

The ground improvement techniques being used today have significantly shortened the timeframe for preparing the new land for use and therefore secured the economic viability of many projects. The consolidation phase has become an essential part of soil improvement and several techniques have been developed to stabilise the new ground. Amongst these are prefabricated vertical drains (PVDs) and in-situ soil mixing or cement deep mixing methods. High energy impact compaction (HEIC) is used for compacting the top 2 or 3 metres of new land.

What are vertical or wick drains?

Soil stabilisation using prefabricated vertical drains (PVDs) or wick drains are applied in areas with loose, compressible and water-saturated soils such as clay and silty clays. These soils are characterised by a very weak soil skeleton and a large pore space, usually filled with water (pore water). When a load such as a road embankment, a hydraulic fill or a dike, is placed on soft compressible soils, significant settlements may occur. These settlements can create serious problems. Any increase in load can result in an increase of pore water pressure. In impermeable soils, this water dissipates very slowly, gradually flowing from the stressed zone. Increased pore pressure may also cause soil instability and slip plane failures may result.

A vertical drainage system – drains are generally placed in a square or triangular pattern, spaced at about 1 to 3 metres – allows for a faster removal of excess pore water decreasing the risk of slip plane failure. The consolidation of soft cohesive soils using vertical drains can reduce settlement time from years to months ensuring that bearing capacity is adequate and construction can commence rapidly.

What is vacuum consolidation?

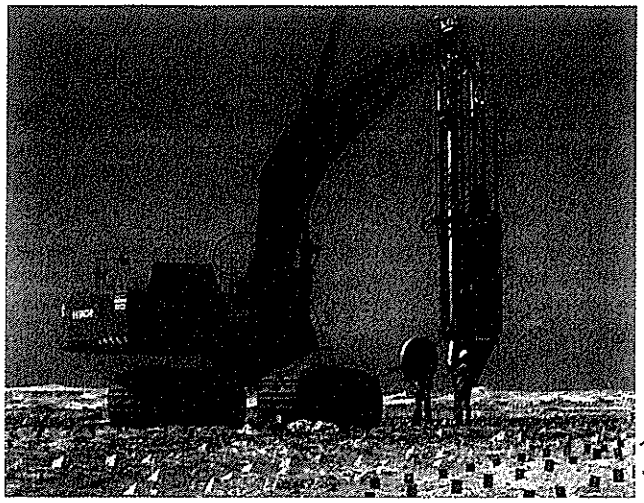
Vacuum consolidation is a process whereby vacuum pressure is applied to an area already installed with PVDs to potentially increase the drains' effectiveness. Generally this technique requires the application of a surcharge loading to squeeze water out of the soft clay soils. Such loading must be equal to or in excess of the service loading to which the developed land will be subjected. In vacuum consolidation, the vacuum pressure applied contributes to the surcharge loading, and therefore actual surcharge heights are reduced. An additional important advantage of the vacuum is the isotropic nature of the vacuum pressure and the correlated improvement of the stability under preloading, reducing considerably the risk of slope failure resulting from the surcharge.

What are the BeauDrain, IFCO and PTD systems?

Recently several new systems for forced consolidation by pumping off groundwater have been developed. Variations of this technique are called IFCO, PTD and BeauDrain. The BeauDrain-IFCO-PTD concept combines existing, proven methods such as vertical drainage (wick drains), atmospheric loading (vacuum consolidation), and the possibility to apply additional surcharge to accelerate the consolidation process of soft, compressible soils. The IFCO and PTD have slots made in the sand a short distance from each other at a depth of about 7 metres, with a drain at the bottom. The excess groundwater streams away from the surrounding land through this drain at a faster pace. The BeauDrain system works with closely placed rows of vertical wick drains, all connected to a horizontal collection drain. The horizontal collection drain is installed at a depth of approximately 1 to 2 metres below the top of the compressible strata and is connected to a vacuum pump, which through pressure, removes excess water.

Are there other methods to improve, reinforce or stabilise soils?

To reduce settlement and improve shear strength and



The wick drain system is one method used to hasten the removal of water from soil. Here, wick anchor plates are being used to mark the location of each wick prior to installation.

stiffness and thus improve the soil, other methods include stone columns, piling the ground, a variety of soil mixing techniques, or local mixing of soils in a grid. Where a grid of columns, piles, or in-situ mixed columns is used, a bridging mattress may be required across the site to transfer the surface loadings into the discrete soil supports. Significantly less or no surcharging is required with these techniques, and they generally provide a significant time saving. These treatments are typically more costly.

What is High Energy Impact Compaction (HEIC)?

The High Energy Impact Compaction, used to compact the upper 2 or 3 metres of newly reclaimed land, consists of a non-circular, asymmetric compactor module towed along the ground by a tractor. In every rotation, the module rises up on its contact point with ground and drops to create an impact energy, which provides the compaction. The impact compaction mechanism enables the compaction energy to reach deeper levels than can be reached by normal static bulldozers or vibratory compaction methods.

What is the in-situ soil mixing or cement mixing system?

In many parts of the world soft subsoil is a very serious problem for maritime construction. For these situations, in-situ soil mixing is often implemented. This method is variously known as the cement deep mixing method, soil cement columns / piles, auger mixing, cement soil mixing, rotary mixing or just soil mixing. The basis of all these mixing systems is that cement hardener is first mixed with water in slurry form which is then ejected into the soil by high power pumps. Simultaneously, during this injection phase, the soil is stirred thoroughly by rotating mixing blades. The cement reacts with the pore water of the soil, resulting in an in-situ hardening process. In this way, the soil is improved in specific locations and to the standards required in the shortest time and in an economical manner.

These cement mixing methods are applied for the following purposes: Foundation of breakwaters, revetment and wharfs; seismic reinforcement of existing marine structures; foundations of bridge piers, tanks, railroads, roads, river dikes and buildings; cutoff walls and braced walls; and countermeasures for liquefaction.

What is vibroflotation?

Certain kinds of vibration can cause loose, cohesionless soil to be re-arranged so that they become extremely dense. This compaction is permanent and increases the bearing density of the soil, reducing the chances of settlement or of liquefaction from seismic tremors. Vibroflotation is especially effective in soils with a silt content of up to 20 percent.

What is the sand drain system?

The sand drain system allows the mixing of soil improvement ingredients, such as cement and anti-separating agents, with the sand which is left in a casing. When dry, this forms sand posts or piles which provide greater bearing capacity in the sub-sea soil in order to suit the needs of the project.

A specially developed sand drain vessel equipped with casings is available which uses this system. The vessel can mix the soil improvement ingredients with the sand on board forming sand posts at the desired locations. These casings are driven into the seabed to the required depth. The soil improvement is then carried out within the casings which form high quality sand piles on site.

How are geotextiles used for Soil Improvement?

Geotextiles have many applications including filtration and drainage. Specific types of geotextiles can also be used for embankment stabilisation and improving the bearing capacity of soft soil foundations on marine projects. Attention must be given to the composition of the geotextile for specific situations. Using a suitable geotextile can increase safety against underground failure and reduce the settlement of the subsoil foundation.

What are other advantages of Soil Improvement?

Some types of soil improvement methods can also provide a cost-effective means of reducing soil contamination.

International Association of Dredging Companies, PO Box 80521, 2508 GM The Hague, The Netherlands
tel. +31 (0)70 352 3334, fax +31 (0)70 351 2654, e-mail: info@iadc-dredging.com, www.iadc-dredging.com

Dewatering contaminated soil has a twofold effect. Some of the improved soil can be reused for construction projects, eliminating the need to mine new pit sand. The remaining unusable sediment is reduced in quantity decreasing the amount of space needed for storage, which is always a costly, environmentally sensitive issue. In addition, when additives such as cement are used during soil improvement they both increase the bearing capacity of soils for construction works and also immobilise contaminated marine sediments.

Is Soil Improvement worth the effort?

In reclamation projects, the costs of dredging and filling operations, including soil improvement and building seawalls, are still less than the prices per square metre of existing land at the waterfront. Recent studies have compared existing waterfront properties in Rotterdam, Singapore, Dubai and Tokyo with newly reclaimed land. In all cases the costs of reclamation and soil improvement compared to using urban land at high-priced shorelines make the new land financially attractive and viable. In addition, the environmental advantages to improving soil can be seen in mitigating instabilities during seismic events and thus limiting the possible catastrophic collapse of subsoil and the infrastructure construction built upon it. Environmentally speaking, the use of improved stabilised dredged soil reduces the necessity of mining sand.

Is one Soil Improvement system preferable over another?

Reviewing many trials and tests, the conclusion must be drawn that many options exist which can successfully accelerate the consolidation of soils and dredged sediment to develop newly reclaimed land or compaction methods to stabilise subsoils in vulnerable seismic areas. Each technique has its own advantages and disadvantages in relation to time, cost and performance. The best method is always to consider the specific needs of a project and contact specialist contractors to evaluate the needs of the project. Although this evaluation stage may bring additional costs, proper preparation, be it through undertaking trials or field and laboratory testing and intense performance monitoring, will ultimately be recovered in the heightened efficiency with which the land is secured. A well-managed soil improvement system appropriate to the site will enhance the prospects of on-time and safe project delivery.

For further reading and information

Jay Ameratunga, Cynthia De Bok, Peter Boyle, Bill Tranberg (2007). "Planning for the Future - Ground Improvement Trials at the Port of Brisbane", *Terra et Aqua*, Number 108, September.

J. Ameratunga, P. Shaw and P. Boyle. (2003). *Challenging Geotechnical Conditions at the Seawall Project in Brisbane*, Coasts and Ports Conference (PIANC) 2003, Auckland, NZ.

M. Andrews, P. Boyle, J. Ameratunga and K. Jordan (2005). *Sophisticated and Interactive Design Process Delivers Success for Brisbane's Seawall Project*, Coasts and Ports Conference, Adelaide, Australia.

Sina Avsar, Mark Bakker, Gert Bartholomeeusen and Jan VanMechelen (2006). "Six Sigma Quality Improvement of Compaction at the New Doha International Airport Project", *Terra et Aqua*, Number 103 June.

Frederic Gladstone Bell (1993). *Engineering Treatment of Soils*. Taylor & Francis Publishers, UK.

C.J. Dykstra and A.H. Nooy van der Kolf (2003). "Recent Innovations in the Design and Construction of Railway Embankments", *Terra et Aqua*, Number 93, December.

H.A. de Leeuw, E.P.T. Smits, F.A.J.M. Mathijssen and A.L.Ph. Estourgie (2002). "Reclamation on Soft Subsoil by Spraying Thin Layers of Sand: The "IJburg" Project near Amsterdam". *Terra et Aqua*, Number 89, December, pp. 9-30

J. Van Mieghem, F. Aerts, G.J.L. Thues, H. De Vlieger and S. Vandycke (1999). "Building on Soft Soils", *Terra et Aqua*, nr 75, June.

Raj Purushothama (2005). *Ground Improvement Techniques*. Firewall Media Publishing.

J. Spelt (2007). "TechNote: Vertical drainage installed from pontoons in Bremerhaven storage depot", *Terra et Aqua* nr. 106, March, pp. 26-28.

This brochure is presented by the International Association of Dredging Companies whose members offer the highest quality and professionalism in dredging and maritime construction. The information presented here is part of an on-going effort to support clients and others in understanding the fundamental principles of dredging and maritime construction.

Stabilizzazione
Stabilizzazione

La stabilizzazione è usata per consolidare terreni incoerenti. In più, la stabilizzazione riduce i cedimenti dei terreni. L'effetto è raggiunto miscelando il giusto ammontare di legante col terreno. Il legante è solitamente calce, cemento o una miscela dei due.

Mediante l'uso di questa metodologia si possono realizzare rinforzi strutturali per la costruzione di strade, vie di percorrenza, tratti ferroviari, come anche zone di deposito, laddove lo spessore del suolo da stabilizzare è di pochi metri.

Il Sistema di Stabilizzazione ALLU è un'invenzione finlandese che costituisce un metodo di lavoro veloce, economico e rispettoso dell'ambiente per il consolidamento di terreni incoerenti e per migliorarne le caratteristiche portanti. In aggiunta, il Sistema di Stabilizzazione ALLU può essere utilizzato per bonificare terreni contaminati.

Il Sistema di Stabilizzazione ALLU consiste di 3 parti. ALLU PF pressure feeder inietta il legante nel suolo, ALLU PM power mix, un accessorio per escavatori, miscela il legante nel suolo e ALLU DAC. misura, controlla e riporta l'intero processo di stabilizzazione.

Il Vaglio Disgregatore ALLU è un accessorio efficiente per escavatori o pale. Esso facilita la pre-lavorazione, la vagliatura e la miscelazione del legante nel cumulo che deve essere stabilizzato. Un metodo di lavoro proficuo è altresì la stabilizzazione e la vagliatura direttamente nel canale di riempimento per la realizzazione di condutture.

La rivoltatrice di cumuli ALLU è una soluzione ideale per la stabilizzazione e la miscelazione di grandi cumuli all'aperto. Possibili applicazione includono la stabilizzazione di terreno contaminato, argilla, torba o miscelazione con rifiuti vegetali di terreno contaminato da olii.

Lo spargitore ALLU e.p.m. è un accessorio molto utile nei lavori di stabilizzazione. Con ALLU e.p.m. potrai facilmente distribuire il binder sul cumulo.

More information: info@allu.net

Sistema di Stabilizzazione

Sistema di Stabilizzazione

Il Sistema di Stabilizzazione ALLU costituisce un metodo di lavoro rapido, economico e poco invasivo, per consolidare e stabilizzare terreni incoerenti, e migliorarne le caratteristiche. Il Sistema di Stabilizzazione ALLU è altresì indicato nei contesti di bonifica. Il Sistema di Stabilizzazione ALLU è formato da tre unità. ALLU PF (pressure feeder) è un alimentatore a pressione, che stiva il binder e lo inietta attraverso dei tubi di alimentazione che sfociano al centro dei tamburi rotanti dell'ALLU PM. ALLU PM (power mix) è un accessorio per escavatori, che miscela il binder nel terreno. ALLU DAC., infine, misura, controlla e riporta l'intero processo.

La stabilizzazione di massa è un metodo rapido ed economico per consolidare del terreno incoerente aggiungendo del legante in profondità. Per esempio, tipi differenti di argilla, torba, fango e altri materiali soffici possono essere trasformati in un solido strato utilizzando il sistema di stabilizzazione.

Il Sistema di Stabilizzazione ALLU inoltre accede in quei siti le cui capacità portanti sono troppo scarse per altri tipi di lavorazione. Il sistema di stabilizzazione può essere usato altresì per incapsulare materiale contaminato all'interno del suolo, impedendo che il contaminante possa spargersi nell'area circostante.

Progetti che hanno previsto l'uso della stabilizzazione di massa:

Lavori di stabilizzazione per la costruzione di strade e progetti specifici:

- Consolidamenti per la costruzione di edifici industriali e ponti
- Terreni, parcheggi, campi sportivi e aree di stoccaggio
- Riduzione cedimenti strutturali
- Consolidamento di terreni estremamente soffici per la perforatura
- Preparazione al lavoro di fondazione per la realizzazione di strade e ferrovie • Fondamenta per diversi tipi di serbatoi e bacini
- Strati protettivi sotterranei
- Siti di lavoro per la realizzazione di condutture e gasdotti
- Barriere anti-rumore
- Strati di protezione per falde acquifere
- Rivestimenti vari
- Riduzione di erosioni
- Strati protettivi per il ghiaccio
- Speciali fondamenta dove la stabilizzazione di massa è parte della struttura stessa

Lavori di bonifica:

- Isolamento /incapsulazione del suolo contaminato
- Neutralizzazione dei rifiuti tossici

Miscelazione di diverse sostanze:

- Riciclaggio di sottoprodotti industriali
- Solidificazione di rifiuti liquidi

Read more about Mass stabilisation (PDF 3,8Mb)

PORTO DI CAGLIARI — MOLO DI LEVANTE
CAGLIARI PORT — EAST BREAKWATER

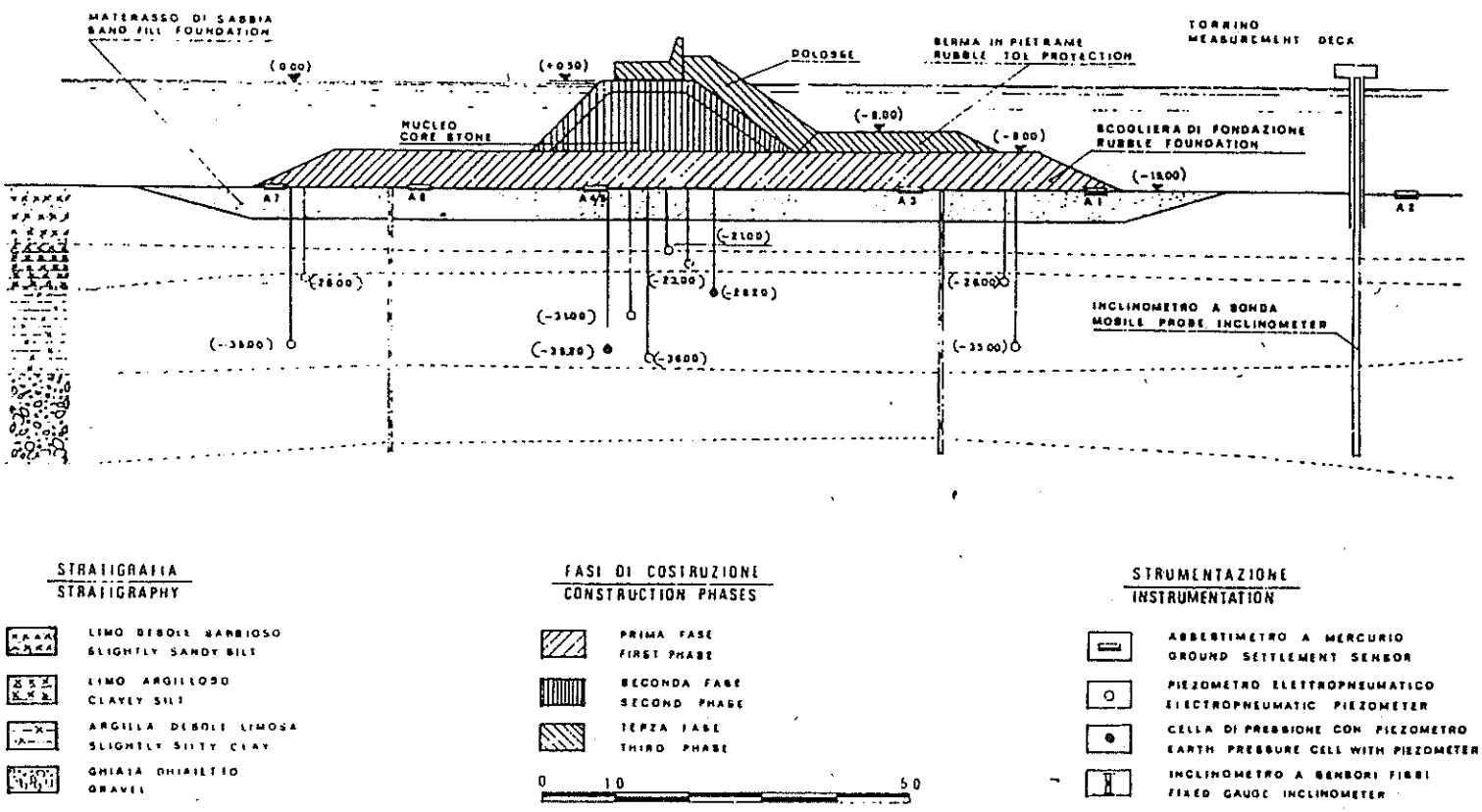


Fig. 5: Prog. 112 MT Instrumented Cross-Section