Reinforcement of foundations with the geocellular confinement system for Impala Peru – Callao project.

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ABSTRACT
By 2011, Impala Terminals Peru began to execute the works of the project "Expansion and modernization of the Callao warehouses" in order to improve the work capacity and achieve international quality standards. Part of the expansion was developed in Cormin II and Toromocho warehouses. However, initial soil studies showed very low support capacity materials (clay loam) and the presence of high water tables due to the proximity to the Pacific Ocean. The proposed solutions ranged from the use of piloting to the replacement of the foundation at depths greater than three meters. Nonetheless, these solutions involved a high investment of money and did not fit into the budget of the project. Consequently, new alternatives such as the use of geocellular confinement systems, which have been very well received in recent years, were proposed. The Geoweb system filled with granular material was applied to all the foundations of the project structures. The thicknesses of reinforcement achieved were around 55 to 70 centimeters, according to the requirements of the project. This system made it possible to distribute the pressure exerted by the soil and external loads effectively. Likewise, with this solution a better soil performance was achieved, unlike a conventional load bearing due to the confinement and less deformation capacity that is provided to the soil.

Keywords: Geoweb, foundations, support capacity, Impala.

RESUMEN
Por el 2011, Impala Terminals Perú empezó a ejecutar las obras del proyecto "Ampliación y modernización de los almacenes del Callao" con la finalidad de mejorar la capacidad de trabajo y lograr estándares de calidad internacional. Parte de la ampliación se desarrolló en los almacenes Cormin II y Toromocho. Sin embargo, estudios de suelos iniciales evidenciaron materiales de muy baja capacidad de soporte (limo arcilloso) y presencia de altos niveles freáticos debido a la cercanía con el océano Pacífico. Las soluciones propuestas iban desde la utilización de pilotaje hasta el reemplazo de la fundación a profundidades mayores a los tres metros. No obstante, estas soluciones implicaban una elevada inversión de dinero y no se ajustaban al presupuesto del proyecto. En ese contexto, se optaron por buscar nuevas alternativas como el uso de sistemas de confinamiento geocelular, que han tenido gran acogida en los últimos años. El sistema Geoweb relleno de material granular fue aplicado para todas las cimentaciones de las estructuras del proyecto. Los espesores de refuerzo logrados se encontraron en el orden de 55 cm a 70 cm, de acuerdo a los requerimientos del proyecto. Este sistema permitió distribuir las presiones ejercidas por el terreno y por las cargas externas con efectividad. Asimismo, con esta solución se logró un mejor desempeño a diferencia de un soporte de carga convencional debido al confinamiento y menor capacidad de deformación que se le proporciona al suelo.

Palabras claves: Geoweb, cimentaciones, capacidad de soporte, Impala.

1. INTRODUCTION

In general, for materials stabilization, which are part of the filling layers of load support structures, asphalt and Portland concrete are used. Likewise, most structures also require adequate base and subbase layers that contribute to the load distribution from surface to the subgrade. Loose materials are ideal for this function due to their simple placement, flexibility and improvement of the rolling quality of the structure. However, these materials have low resistance.

Fine sands of uniform graduation are the best examples of the weakness of granular materials. In that context, Waterways Experiment Station of the U.S. Army Corps of Engineers developed an investigation aimed at finding methods for the rapid construction of sandy roads for landings on beaches and operations in the desert. According to the investigation, the use of three-dimensional cellular confinement of loose sand allows to obtain stable surface for the foundation.
In the late 1970s, Presto Products Company developed the Geoweb confinement system in order to stabilize losse aggregates. This system includes polyethylene belts connected by outdated ultrasonic welding cords, aligned perpendicularly to the longitudinal axis of the belts. When the interconnected belts are extended, the walls of a cellular confinement structure are formed, which can be filled with granular material. In addition, the texture of the surface and the perforations in the cell walls allow improving frictional resistance and lateral drainage.

Nowadays, the use of Geoweb system as a load support has a wide application. The increased friction between the walls of the cells and the filling increases the soil resistance to vertical deformations (PRESTO GEOSYSTEMS, 2008).

Consequently, there is and effective transfer of vertical strength to neighboring cells. Furthermore, this applied system to low cohesion soils and under concentrated loads is capable of interrupting the failure mechanism through the vertical walls of the cells. Figure 1 shows the failure mechanism in areas without reinforcement (a) and with reinforcement of Geoweb system (b).

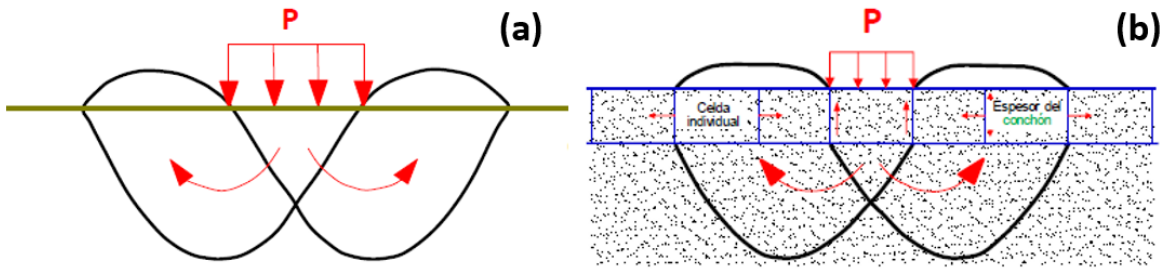


Figure 1: Bearing capacity failure mechanisms of the sand. (a) Soil without confinement system. (b) Soil with a geocell confinement system. (Koerner, 2012)

On the other hand, according to Koerner (2012) the cell confinement system (Geoweb System) in a foundation is represented by Equation 1. In addition, this equation is included in the load capacity equation proposed by (Terzaghi, 1943). The equations involved in the study of load support are represented below by using the Geoweb system (Equation 1 and 2).

$$\tau = \sigma_h tan\delta$$

$$q_d = 2\tau + cN_c + \gamma D_f N_q + \frac{1}{2}\gamma B N_\gamma$$

Where:
σ_h = Average horizontal strength in Geoweb
δ = Interaction angle between Geoweb walls and filler material

Figure 2: Project area at Impala Terminals Peru facilities.

In that context, for expansion and modernization of warehouses in Callao (Cormin II and Toromocho) the use of Geoweb system, as a load support, has been studied and applied. The application of Geoweb in the study area sought to improve the conditions of soil, in structural terms, in order to improve the foundations, avoid large earthworks and oversizing of the footings. For this, a bearing capacity design was performed using Geoweb system. The system was applied in the study area. Finally, area monitoring is carried out frequently, in order to guarantee the maintenance of the solution.

2. STUDY AREA AND METHODS

2.1 Study area

The study area is located in the facilities of Impala Terminals Peru, located on the central coast of Peru, specifically in the Provincia Constitucional del Callao (Figure 2). This area is characterized by presenting alluvial deposits, where sandy gravel soils with boulders can be found. Seismically, the study area is located in Zone 4, according to the seismic zoning map of Peru, with a zone factor of 0.45. The geotechnical parameters correspond to a soil of type S2, with a predominant period of Tp=0.6s and soil factor S=1.2 (MVCS, 2016).

According to geotechnical studies, it was determined that the soil of the work area had very low bearing capacity. In addition, the water table was very close to the surface due to its proximity to the Pacific Ocean. Figure 3 shows the level reached by the water table in areas where the main structures are projected. Initially, the need to replace large volumes of material and moderately increase the dimensions of the foundation was considered. However, in the case of the Cormin II warehouse, poor quality materials were found, such as clay silt.

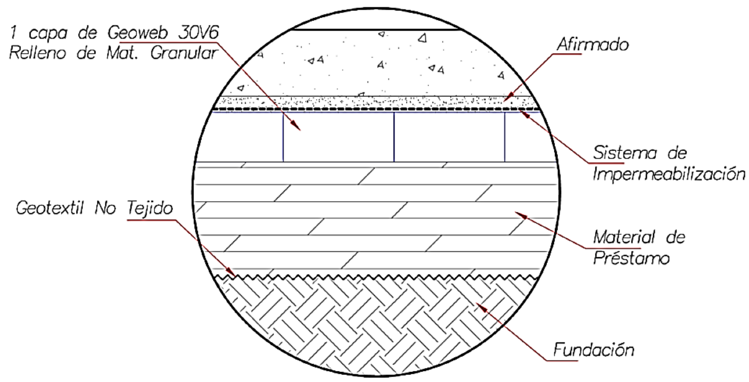
Figure 3: Water table level in critical areas of the project.

On the other hand, the proposed conventional solutions (driven piles) involved great cost and time. In this scenario, it was decided to look for new proposals that profitable and meet the needs of the project. The Geoweb for load support fulfilled that function and was applied in the project. The solution was divided into two parts. First, the foundation of slabs in storage yards. Second, foundations for the walls of the warehouses, where this foundation was also used for the freight train.

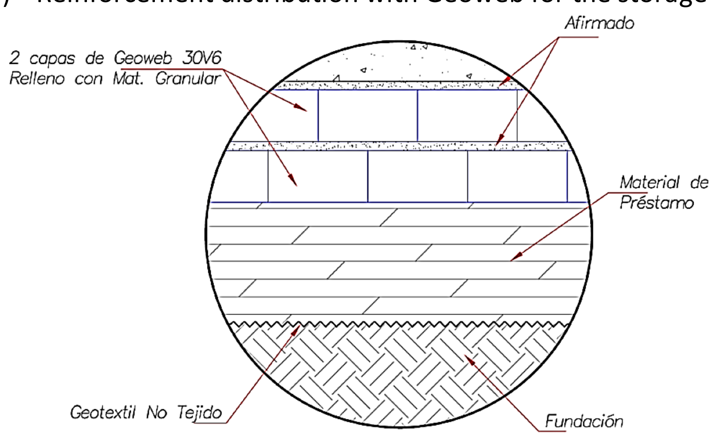
2.2 Methodology

The first part of the proposal (storage yards) involved the improvement of the permissible capacity of the natural soil. For this, the Boussinesq equation applied to a rectangular square area was taken into consideration. According to the calculation, it was possible to improve the distribution of the load from 340 kPa under the slab to strength of 100 kPa at the lowest possible depth. This was achieved with one (01) layer of 150 mm thick geocellular confinement cells and an additional filling of 350 mm base material. Moreover, a layer of 50 mm of road-surfacing material was placed above the geocell.

The second part of the proposal was aimed at improving the permissible capacity of the soil, through the design of the foundation of store walls. For this, the same design criteria developed for the storage yard were followed, but taking into account that water table was at a depth of 1 meter. According to the calculations, the permissible capacity of the natural soil improved from 0.50 kg/cm2 to a capacity of 1.50 kg/cm2. Likewise, the effects of settlements were also minimized.



a) Reinforcement distribution with Geoweb for the storage yard.



b) Reinforcement distribution with Geoweb for the warehouse wall area.

Figure 4: Soil reinforcement configuration with Geoweb system for the evaluated areas.

The configuration that allowed the increase in the permissible capacity of the soil consisted of two (02) layers of 150 mm geocellular confinement cells and filling of 350 mm base material. Additionally, a 50 mm layer of road-surfacing material divided by 25 mm above each geocell was placed. It is important to mention that the methodology applied to load support by Geoweb took into account the presence of the high water table in the project area (ANDEX DEL NORTE, 2011). In that context, the proposed solution considered methods for controlling groundwater flows over the material using "Over". Figure 4 details the different reinforcement configurations adopted for the two evaluated zones.

3. RESULTS AND DISCUSSION

3.1 Geoweb system application

Based on the developed calculations and the adopted reinforcement configurations, the system was applied in the study area. The construction procedures for both the store area and the warehouse wall area followed the same processes. Therefore, the installation process involved, in the first place, the improvement and control of the drainage of foundation. To do this, the fist layer of "Over" granular material was placed with the help of a front loader (Figure 5-a). This material was rammed and leveled for the placement of a non-woven geotextile separation (Figure 5-b).

Then, the Geoweb system was placed depending on the number of layers with respect to the adopted design and application area. In the first instance, the cells area stretched along the area to be reinforced. Bye means of a front loader, the filling material is placed inside the stretched cells, which involve a base material with a minimum CBR of 80% (Figure 5-c and 5-d). It is important to note that the maximum drop height for the landfill must be 1 meter (3 feet). The filling was compacted with a 95% quality control of the modified proctor, by conventional compaction equipment (Figure 5-e).

Figure 5: Construction process of Geoweb system for load support.

Alternatively, a waterproofing system composed of a geomembrane was placed immediately after Geoweb placement (Figure 5-f). Finally, the last layer corresponding to the road-surfacing material was placed. Similarly, to other layers, strict compaction control was followed in order to ensure system stability. On these reinforcement layers, the structures were cemented, such as the slab for the storage yard and the foundation s for the warehouse wall (Figure 5-g and 5-h).

3.2 Monitoring

Frequently, after the completion of the project, monitoring of the structures placed on the foundations with Geoweb is carried out. To date, no problems have been observed in the slab of the storage container yard or in the conveyor belt. All this represents a clear signal of the contribution of the system to the final project, where all the initial design requirements demanded in this project were met.

4. LOAD SUPPORT PROJECTS IN PERU.

4.1 New Container Yard Enapu Callao Port - Roaya - 2005

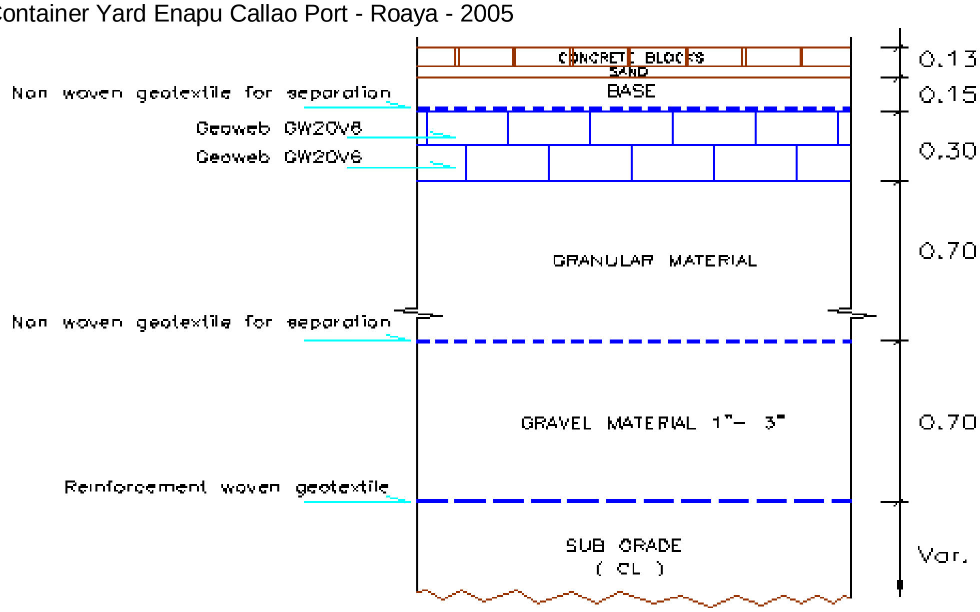


Figure 6: Original Design (Enapu - Callao Port).

Figure 7: Construction process of Geoweb system (Callao Port).

Figure 8: Callao Port -Project finalized.

4.2. Four Refinery Tanks Piura - Talara – 2013

Figure 9: Construction process of Geoweb system (Talara - Piura).

4.3. Tijguano Platform Access Road- Ecuador.

Figure 10: Construction process of Geoweb system (ECUADOR).

Figure 12: Ecuador Road - Project finalized.

5. CONCLUSIONS

The use of the Geoweb system, distributed in an appropriate manner and through the use of the recommended design criteria, will allow greater efficiency in the distribution of soil pressure and external loads than with respect to the natural soil itself. This is mainly due to the containment and reduction of the deformability of the material contained in the cells, which translates into a better system performance with respect to a conventional load support.

The traditional solutions initially proposed in the project were discarded due to the high budget involved in the use of the geocellular confinement system. In addition, the Geoweb system offers economically viable solutions, where its construction is simple since it does not require specialized labor and its construction performance is high. Moreover, to date the system has not shown any inconvenience after the completion of the project.

There are new opportunities to expand the use of geosynthetics due to the success of Geoweb system based on the experience presented in this document.

Monitoring of operation conditions should be followed in order to confirm that design criteria will remain valid, otherwise aid in the decision-making process for mitigation measures.

Always needed geosynthetics trust experts in order to guide the design phases, implementation and maintenance of the projects for their defined sustainability.

5.1 REFERENCES

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