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GROUND IMPROVEMENT SOLUTIONS FOR HARBOURS

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ABSTRACT

Over recent years the world witnessed the construction of new port infrastructures has they play a crucial role on the development of worldwide trading and regional economic growth. This type of infrastructures commonly requires the occupation of considerable areas of land, allowing the creation of large shipping and storage areas. However, the availability of free land together with deep water coast lines, compatible with the use of large draft vessels, is becoming increasingly hard to find. The solution then involves the construction of deep quay walls and the creation of technically demanding artificial platforms, challenging the engineering capacities. Seeking for inexpensive and appropriate technical solutions, capable to overcome the challenges imposed by the construction of such infrastructures, use has been made of ground improvement solutions. Its wide range of techniques, easily adapted to different technical scenarios and geological conditions, are considered to be an added value in most projects. This paper describes the contribution provided by different ground improvement techniques on the construction of new harbours and maritime facilities.

Jet Grouting

Ground improvement using jet grouting is considered to be one of the most versatile technique, has it can easily adapt to a considerable range of situations and different geotechnical conditions. In most cases, new harbours involve the construction of deep quay walls. In the African shoreline, the new Container Terminal at Lomé - Togo, demanded the construction of a 1000m long quay wall. It comprised a twenty nine meter deep reinforced concrete diaphragm wall, connected to an anchored dead man wall through a forty five meter long steel tie rod system.

As a consequence of a complementary site investigation undertaken during construction, a weak clayey silty layer was detected in some areas along the quay wall demanding the ground improvement at the wall base. As the diaphragm wall was already constructed, a solution consisting on jet grout columns was then used, allowing preventing punching and contributing to increase the overall wall stability. Jet grouting columns, installed at the passive side of the wall had contributed to increase the overall quay wall stability, whilst, jet grout columns intersecting the wall provided higher skin friction, increasing the bearing capacity.

The versatility of jet grouting columns also enables its use on temporary earth retaining structures, allowing overcoming earth stability problems during construction. A case study of jet grouting walls located at the transition zone between a new quay wall and an existent breakwater are presented. It consists of two different solutions, according to the excavation geometry and the main constraints observed at the site. The first solution comprised a temporary gravity wall and the second solution refers to the junction of the perpendicular quay wall with the existing breakwater. Both adopted solutions were found to be profitable to overcome demanding local constraints, such as the presence of distributed blocks from the

existing rock fill. To be well succeeded, both jet grouting and vibro techniques require an exhaustive geological-geotechnical campaign, carried out before and during the works, as well as the execution of appropriate field trials.

Preliminary field testing shall constitute the basis of any ground improvement solution, allowing the adaptation of the design assumptions to the real conditions observed at each site. In addition to laboratory field tests on jet grouting samples, suitable to determine the composite soil-cement material stiffness and resistant properties, it is to highlight the advantages of using non-destructive methods to assess the jet columns diameter at the site. Regarding this matter, direct measurements undertaken on an exposed jet grout column were compared with resistivity measurements according to the electric cylinder method. It has been found that the electric cylinder method provides accurate results, making of it a valid method to estimate the jet grout columns diameter. One of the most important advantages of the aforementioned method is that it provides results shortly after the jet grout columns installation, thus, reducing the time ussually consumed on this kind of task.

Deep Soil Vibration

Ground-improvement techniques by deep soil vibration have been broadly used in port facilities, aiming to create stable platforms with suitable characteristics for container storage and equipment operation. At the Lomé Container Terminal, upper frictional soils were found to be inadequate to receive the design imposed loads and therefore vibrocompaction works were carried out to improve soil characteristics.

The proposed port platform required the placement of up to 3.50m thickness of fill material to form a base for the concrete pavement slab. Being a cost effective and a high production rate technique, vibrocompaction is considered to be a competitive solution on improving the characteristics of platforms formed by granular soils. Once again, field trails were found to be crucial to confirm the adequacy of the solution and determine the adequate grid spacing of the compaction probe. Independent of the treatment grid spacing adopted, vibrocompaction clearly increased the relative density of the granular materials, typically corresponding to behaviour soil type index behaviour (I_c) of between 1.31 and 2.05. Conversely, no evident improvement was found in soils with a behaviour soil type index (I_c) higher than 2.05. Based on the results of soil relative density testing two and ten days after vibrocompaction treatment, it is confirmed that the relative density tends to increase with time after vibrocompaction.

Careful use of vibrocompaction is advisable when at the presence of dense sands, typically with CPT (cone penetration test) cone resistance values varying from 25 to 30MPa, as a decrease of soil initial stiffness may be expected. During vibrocompaction works, any contact with underlying clay layers may lead to soil contamination due to washed in clay material, precluding the achievement of higher relative density results in the upper granular soil layers.

Final Remarks

An overall appreciation of the different ground improvement works presented in this study had clearly demonstrated how jet grouting together with vibro techniques can contribute to solve different engineering problems in new Harbours and maritime facilities construction.

REFERENCES

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