# Ground improvement techniques allow flexibility for ports

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Port facilities see an increase in demand on nearly a daily basis. This demand is fuelled by the constantly changing role of international shipping in the global economy. For example, new shale oil plays and tar sands in North America may lead to the export of energy from the US; ten years ago the idea of energy exports from the US was unimaginable. Another change in global shipping is the increase in use of intermodal transport. This article discusses a variety of ground improvement and specialty foundation solutions that can support bulkheads, heavy storage warehouses, grain silos, large-diameter tanks or any other port structure. These solutions are designed to efficiently provide a foundation-related maintenance-free operation for the design life of the structure, and are well-suited to the poor ground conditions often associated with port and shipping facilities.

## Foundation solutions for difficult ground conditions

Some of the worst soil conditions are concentrated around navigable bodies of water. The Mississippi Delta and the US Gulf Coast are elementary cases of poor soil conditions in areas historically utilised for shipping. The ground conditions improve further up the Mississippi River; however, as the ground conditions become more suitable for building large heavy structures, the likelihood of a seismic event also increases. Today's ground improvement and specialty foundation solutions can be designed and constructed to overcome the difficulties of working in a delta bayou or the lateral loads associated with large scale seismic events.

As shipping facilities are redefined and capacity increases are needed, many of the world's ports have reached their practical limits of development. Therefore port designers and owners are challenged to find economical foundation options for the facilities with poor subsurface conditions. In past years, foundation designers were given few simple options to support a variety of port facilities. In cases where the ground was less than favourable, a deep foundation consisting of driven piles was nearly always selected.

Another issue today is the reuse of sites near a port facility. Often these sites consist of poorly compacted fill, construction debris from previous operations at the port, or some other problematic soil condition. As the engineering community learns more about long-term settlement and reliability, the ways of yesterday are being re-evaluated. With modern ground improvement options at their disposal, the designers can increase reliability, increase loading capacity and decrease construction costs.

## The storage tank example

Let's consider one critical port structure: large storage tanks. When a tank undergoes differential movement exceeding limits set by the American Petroleum Institute (API), the operator must make a choice about the tank's future. They could raise the tank by first lifting it and then placing sand beneath the floor to level it, but this is only a temporary solution, as the tank will eventually settle again and be out of service during the next repair cycle. Permanent solutions include specialty techniques like compaction and jet grouting which modify the ground conditions beneath existing tanks for a one-time fix. Alternatively micropiles can be installed to carry loads down to competent bearing elevations. These same techniques can be utilised should the owner want to increase the tank storage capacity by adding additional height to the tank. In this case, the ground conditions below the tank may already be supporting the maximum possible load. The tank has already gone through a cycle of primary settlement; increasing the height of the tank will result in additional settlement. Grouting would eliminate the secondary settlement and provide support for the new loads. While this is a specific case history for a tank, the same repairs can be completed for dry storage facilities such as silos or warehouses.

## Problem ground under planned structures

Ground conditions dictate which improvement methods are effective for planned structures. Because no two sites are the same, this presents a challenge for those trying to understand and remediate the world below our feet. One site may experience too much movement during a seismic event, while an adjacent site may be located near or on a slope, requiring design solutions for slope stability. An increasing number of technologies are available to provide solutions for any underground challenge. Through this vast array of innovative geotechnical tools, designers can now look past the problems they cannot see below ground and focus on building a viable structure. Following a thorough subsurface investigation the soils can be understood, allowing selection of the most cost-effective and technically appropriate ground improvement method.

## Considering the options

Temporary fill material can be utilised to surcharge sites underlain by soft wet soil. This settlement may strengthen the soil enough to allow construction to proceed. However, the desired design capacity of the structure might not be attained for months or years depending on the soil properties. Installing wick drains, a cost-effective method also known as vertical drains or prefabricated vertical drains, into the soil accelerates the surcharge process. The wick drains are the lowest cost ground improvement method. Millions of feet of wick drains have been installed in port

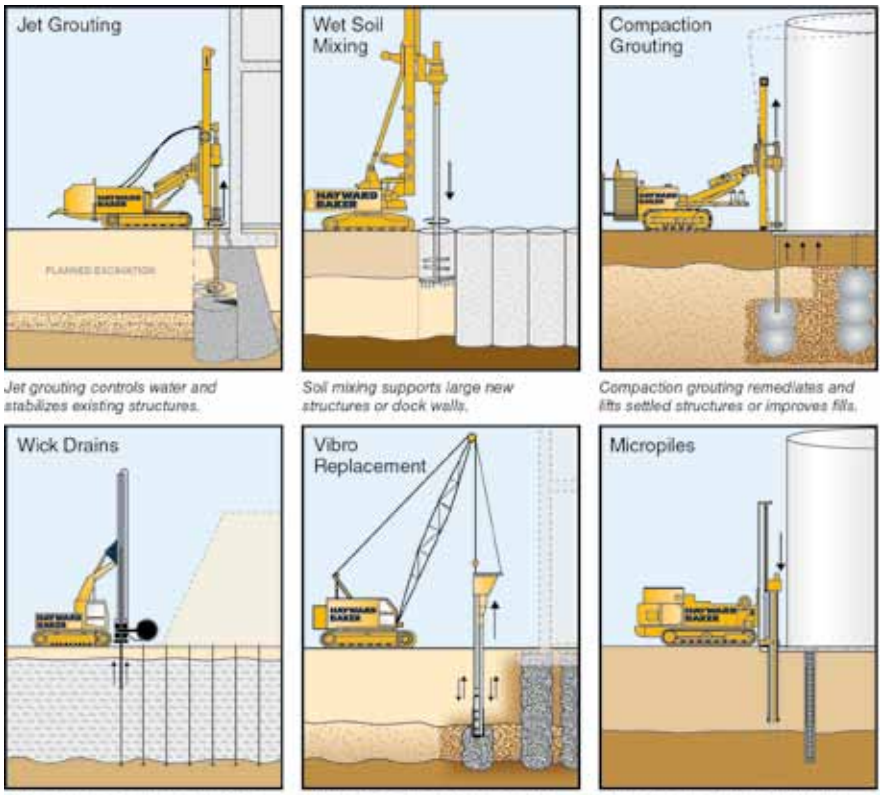
facilities around the globe. Capable of installation in harbours, wick drains may be designed to accelerate consolidation of material in the waterways and reduce the need for dredging. As with all ground improvement solutions, the soils must be appropriate for the technique.

If the proposed site is going to settle too much or won't support the structure's weight, rather than drive piles, consider increasing the soil's strength with ground improvement. Stone columns, Vibro PiersTM or aggregate piers can be highly effective for such sites. Well-researched and utilised for over 60 years, stone columns have improved bearing capacities and decreased settlement under structures and embankments around the world. In the proper soil conditions, stone columns also provide liquefaction mitigation. They are the next most cost-effective solution for reinforcing soils at your facility.

When stone columns do not provide sufficient reinforcement or improvement in capacity, soil mixing can be used. During this process, cement and other binders are mixed with the existing soil to strengthen it. This improved material supports significant loading, even in the worst soil conditions. Soil mixing can be completed as distinct columns or as mass soil mixing. Column mixing extends from the surface down to competent bearing stratum. Mass soil mixing treats nearly 100 percent of the poor soils to maximum depths of 20-feet. If the poor soils extend deeper, the two techniques can be combined effectively. Soil mixing is used at port facilities on a global scale. Soil mixing also has advantages over traditional backfill behind bulkhead walls. Sheet pile wall depths and thickness can often be reduced, thus making cost savings because the strengths of the soil mixed material is known from the design phase. One last consideration is the aging infrastructure at most of the world's port facilities. There is an economic need to get the most out of each bulkhead wall or other structure. Often ground improvement techniques such as jet grouting are utilised to reinforce these structures and/or add a few more years of design life to a failing structure.

## In conclusion

As your development expands, consider ground improvement to reduce cost. A variety of ground improvement solutions can be designed to meet the challenges faced by every port owner. Ground improvement techniques have proven track records of working well in port environments. As technology advances, poor ground conditions become less of a concern. If your ground is bad, don't live with it, improve it.




Jet grouting controls water and stabilizes existing structures.

Soil mixing supports large new structures or dock walls.

Compaction grouting remediates and lifts settled structures or improves fills.

Wick drains accelerate consolidation beneath large fill areas or port improvements.

Bottom feed vibro replacement stone columns support new structures.

Micropiles support settled structures, new loads on existing structures, and new structures in areas with limited access.

## About the author

Jeffrey Hill has 14 years of experience in specialty geotechnical construction and engineering. Jeff is currently a senior engineer with HBI's Central Region where he is responsible for the development of specialty projects throughout the 20 states in the centre of the United States. He has experience in the structural and geotechnical design of micropiles, earth retaining structures, specialty grouting, including chemical and compaction grouting programs, and Vibro Improvement Programs. He has worked throughout North America on projects including heavy industrial, dams, bridges and roadways. Jeff has also consulted on HBI's parent company Keller on projects in Europe and Australia. Jeff is involved with ASCE – Geotechnical Committee as a founding member of the local Geo-Institute Section, ADSC, DFI, the Engineers Club of St Louis, AGC – St Louis Chapter, and AREMA Committee member Chapter 8, Foundations and Concrete Structures. Jeff received a BS in civil engineering from the University of Illinois – Urbana Champaign. Jeff is licensed as a PE in Missouri, Illinois and Arkansas.

## About the organisation

Hayward Baker (HB) is North America's leader in geotechnical construction. Annually ranked by Engineering News-Record magazine as the #1 Excavation/ Foundation Contractor, HB is the industry leader in ground modification, earth retention, structural support and grouting technologies with a 60-year record of experience. HB is part of the Keller Group of companies, a worldwide geotechnical construction organization. Don't let the ground dictate what you can build or the service life of your existing structures. Just Ask HB.

## Enquiries

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