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WHITE PAPER

SUPPORTING BULK LIQUID STORAGE TANKS WITH CONTROLLED MODULUS COLUMN (CMC)® RIGID INCLUSIONS

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INTRODUCTION When any tank is built and put into service, some amount of settlement occurs. The settlement is only problematic when it exceeds the tolerance for the tank or for the piping connected to the tank. The amount that a tank will settle is dependent on the tank dimensions and applied loads (e.g., the diameter and the weight of the tank and its contents) and the properties of the underlying soils. In addition to excessive settlement, bearing capacity failure may occur where weak soils are present. This happens when the underlying soils cannot carry the load from the tank, and the ground shears or ruptures, causing either a rotation of the tank or punching of the tank into the ground. While Controlled Modulus Column (CMC)® rigid inclusions have been used to support many different types of tanks, vessels, and silos, this paper focuses on steel tanks that are typically used to store liquid oil/petroleum and chemical products.

BACKGROUND When weak soils are present in areas that tanks are to be built, and it is not practical to change the location of the tanks, the weak ground can be replaced, bypassed with piles, or treated by a number of different ground improvement technologies. Removing and replacing soft ground with compacted backfill can be impractical or very costly when the soft ground extends below a few feet, if contamination is present, or if it is necessary to excavate below the groundwater table. For tanks, the goals of ground improvement are to reduce the total and differential settlement that occurs while tanks are in service, to increase the factor of safety against bearing capacity failure, and at some locales, to reduce the risk of soil liquefaction during seismic events (i.e., earthquakes).

CMC rigid inclusions are patented grouted inclusions that provide an environmentally sound and economical solution for improving soft or loose soils. CMC rigid inclusions are not intended to directly support the loads imposed by the structure, but rather to improve the global response of the soil in order to control settlement. CMC rigid inclusion columns typically range from 12 to 18 inches in diameter.

Some features of the CMC rigid inclusion technology include:

- The columns are grouted in place with the use of a displacement auger that pushes the soil aside, allowing for placement of a higher-strength grouted column that reinforces the ground.
- A load transfer platform (LTP) of compacted structural fill is placed over the CMC-reinforced ground to promote distribution of the stresses from the structure to the CMC rigid inclusions. The load is shared between the rigid inclusions and the surrounding ground, based on the stiffness of the soil (i.e., the stiffer the soil, the greater the proportion of the load it will carry).
- In granular soils, densification may occur between the columns by virtue of the displacement drilling process.
- Minimal spoils are generated by the drilling process, which eliminates the need to manage spoils and the potential unearthing of contaminated soils.
- The CMC rigid inclusion technology is well suited for very soft soil conditions such as organic clays, peat and wastes. Compared to stone columns and aggregate piers that require a significant degree of lateral confinement to avoid bulging when loaded, CMC rigid inclusions have no such limitations due to the relatively high stiffness of the grout that comprises the column.

Since the installation of CMC rigid inclusions does not generate vibrations, the technology is ideally suited for construction in developed areas (working close to sensitive structures).

CMC Rigid Inclusions For Storage Tanks

Menard's CMC rigid inclusions have been used to support hundreds of bulk liquid storage tanks around the world. Some of the factors why CMC rigid inclusions are so commonly used for support of storage tanks include:

- Many refineries, terminals and industrial facilities are located in coastal areas or along waterways where very soft alluvial soils are present. Other ground improvement techniques such as aggregate piers or stone columns do not function well in very soft ground due to bulging that results from a lack of stiff, confining soils around the column.
- Storage tanks with high density product or greater product heights may exert very high bearing pressures that render less robust ground improvement solutions such as aggregate piers or wick drains inadequate due to excessive settlement or bearing capacity failure.

- Because of the very deep zone of influence of large storage tanks, it is often necessary to extend the CMC rigid inclusions to depths of 100 feet or deeper. Achieving such depths with most other forms of ground improvement is typically not practical.
- The heavily reinforced concrete pile caps associated with deep foundations are not necessary for the CMC rigid inclusion system.
- Tanks are often constructed where contaminated ground is present. Only a small amount of spoils are generated. These materials are readily worked into the platform and disposal/management is not required.
- Because CMC rigid inclusions are sealed by virtue of the grouting process and self-cased drilling, aquicludes are not breached and potential migration paths for contaminated groundwater or leaked product are not introduced.

Tank Foundations

Traditionally, tanks have been founded on concrete ring walls, crushed stone ring walls, or concrete mats. The mats could be ground bearing or supported by deep foundations. Where CMC rigid inclusions are used, the options of using concrete ring walls, crushed stone ring walls, or concrete mats are still available.

In addition, Menard USA has teamed with its sister company, The Reinforced Earth Company (RECo) and also provides a mechanically stabilized earth (MSE) – type foundation upon which to build tanks. With this system, a reinforced earth mass is constructed of compacted coarse aggregate. The Perimeter wall facing consisting of precast concrete panels is placed approximately 2 feet outside of the tank footprint. The wall panels are held in place by steel or geo-synthetic strips that are attached to the inside face of the panel and extend back into the compacted coarse aggregate mass. Figure 2 shows a constructed tank founded on an MSE wall foundation system.

Working collaboratively, Menard teams with owners, engineers, civil contractors and tank builders to come up with the best way to support each tank on every project. It is critical that the team works closely together so that Menard's design can accommodate requirements for cathodic protection, leak detection, liners, sumps, and other below-tank features. The CMC rigid inclusion design must also be able to meet the requirements for total and differential settlement, factor of safety against bearing capacity failure, and tank edge levelness. Finally, the CMC rigid inclusion design accommodates different tank floor configurations – cone-up, cone-down, shovel bottom, etc.

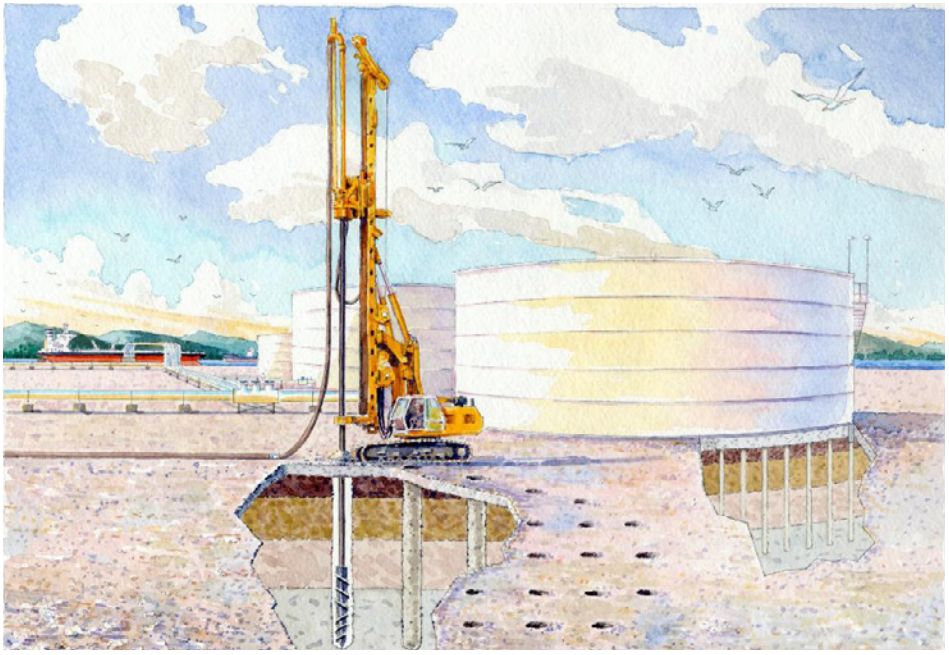

***Fig 1**: CMC Rigid Inclusion Concept for Tanks*

***Fig 2**: Tank Founded on an MSE/CMC Rigid Inclusion Foundation System*

CONCLUSION Because of their massive size, heavy loads, and the critical importance of safely containing their contents, storage tanks require a proven, time-tested and reliable foundation support system. Menard USA has the experience, expertise and resources to safely and economically deliver reliable CMC rigid inclusion solutions for your next tank project.

GOING FORWARD: Do you have a tank project you'd like to discuss?

Get in touch with Menard today at **412-620-6000** or visit us at **www.menardusa.com** today to find your local Menard representative and sign up for our newsletter, The Column.

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