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WHITE PAPER

SUSTAINABLE USE OF CONTROLLED MODULUS COLUMN (CMC)® RIGID INCLUSIONS IN BROWN-FIELD REDEVELOPMENT PROJECTS

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INTRODUCTION Because ground improvement techniques have gained widespread acceptance in the marketplace, engineers are more often choosing them in lieu of traditional deep foundations to provide economical foundation systems at sites with poor soil conditions. One technique in particular, Controlled Modulus Columns (CMC)® rigid inclusions, offers a sustainable and cost effective ground improvement solution that transmits load from the foundation to a lower bearing strata through a composite interaction between the rigid element and the softer soil matrix.

CMC rigid inclusions have been installed in a variety of soils, including uncontrolled fills, organics, peat, soft to stiff clay, loose silts and sands, and municipal solid waste. Typically the CMC rigid inclusion is installed through soft, compressible soils into a dense sand, stiff clay, glacial till, or other competent material that serves as a bearing stratum.

BACKGROUND CMC rigid inclusions are attractive from an environmental perspective because the installation technique utilizes reverse flight augers, which displace the soil laterally. Lateral displacement augers compress the soil mass and generate virtually no spoil at the ground surface. This installation technique has two advantages: it densifies the soil around the element (especially in granular soils), which improves the load transfer process, and it avoids bringing contaminated soil to the surface, eliminating the need for costly handling and disposal.

Advantages of CMC Rigid Inclusions
From a financial perspective, CMC rigid inclusions reduce the overall cost of construction as compared to conventional deep foundations or excavation and replacement. Fewer construction materials are needed, installation is quicker than installing piles, and soil generation and disposal is significantly minimized. Some financial and schedule benefits include:

- Avoids installing piles to deeper depths
- Avoids splicing or cutting because lengths of CMC rigid inclusions can be adjusted in the field
- Reduces design and construction costs associated with pile caps, grade beams and structural slabs
- Eases installation of utilities under buildings

Environmental benefits of CMC rigid inclusions include:

- Minimizes waste generation by eliminating over-excavation and replacement of poor quality soil
- Limits spoil generation, reducing costs associated with handling and disposal
- Promotes redevelopement of brownfield sites that are underlain with poor-quality soils because costs can be reduced
- Improves the performance of the barriers or cap systems, if required over contaminated sites, by eliminating complex detailing around piles and pile caps

***Fig 1**: Installation of CMC rigid inclusions*

- Reduces the overall carbon footprint associated with foundations by significantly reducing the amount of steel and concrete

Case History: Produce Warehouse in Philadelphia

The produce distribution warehouse located near the Philadelphia International Airport was built on a former municipal landfill. The brownfield redevelopment project included the construction of a single-story, 550,000-square-feet produce logistical center. The building was approximately 34 feet high with a footprint of 425 feet by 1,295 feet and a continuous full-perimeter loading apron for loading/unloading of delivery trucks. To support the high surface loads, CMC rigid inclusions were proposed as an alternative to piles (deep foundations).

The ground conditions at the former municipal landfill were heterogeneous, which created a challenge in the design of the ground improvement system. The site was underlain by a thick layer of municipal solid waste (MSW), which varied widely in thickness and composition across the site. Thicknesses ranged from 14 feet to 33 feet, and in areas the waste was overlain by a layer of fill that did not contain waste. In general, the MSW was loose and easily penetrated, however, obstructions such as wood, metal, concrete debris and bricks were encountered.

The MSW was underlain by a 2- to 18-foot thick layer of organic silt with some clay and sand. Beneath the organic layer was a layer of dense sand with standard penetration test (SPT) N-values around 50 blows per foot. The dense layer of sand provided a competent bearing layer for the CMC rigid inclusions.

The original foundation design proposed the use of 8-inch diameter timber piles or 12-inch diameter grouted steel pipe piles, both driven to a depth of approximately 50 feet. In addition, thickened reinforced pile caps, internal grade beams, and a 12-inch-thick reinforced two-way structural slab was required to connect the piles to the superstructure. The disadvantages to this system included:

- High cost of the superstructure: Because of the need to span the slab load to the piles, the slab and pile caps were originally designed to be heavily reinforced in both directions, and the thickness high compared to that of a conventional slab-on-grade solution.
- Due to the presence of MSW, a methane gas collection system included an impervious membrane liner under a layer of clean granular fill. The multiple pile caps resulted in numerous penetrations to the membrane liner, which required a mechanical connection between the pile caps and the liner, increasing the potential for a methane release into the building.
- ·Because of the risk of long-term settlement of the MSW and organics, all piping under the building had to be attached to the structural slab with hangers.
- The structural slab had to be constructed prior to the roof construction which would create a lower-quality finish because the slabs cured in open air rather than in a controlled environment beneath roof cover.
- Environmental risk of cross contamination between the layers of MSW and the soils below when driving the piles which creates a risk of contaminated lower clean aquifers by transporting contaminants to lower depth during the drilling process.

Menard's alternative design proposed CMC rigid inclusions to support the entire facility, including the perimeter loading apron. CMC rigid inclusions were installed under the footings and the slab, down to a depth of approximately 35 feet. This design allowed for the use of spread footings, a 6-inch unreinforced slab-on-grade, and eliminated the need for internal grade beams.

As far as constructability was concerned, the most significant advantages of the alternate design were:

- The change from a structural slab and pile caps to a thinner slab-on-grade with conventional spread footings provided significant cost savings. This was made possible by constructing a Load Transfer Platform (LTP) made of dense-graded aggregate (DGA) compacted to 95% of the modified proctor maximum density. The LTP was placed between the top of the CMC rigid inclusions and the bottom of slab.
- A simpler and more continuous vapor barrier system had minimal penetrations, providing a more reliable system (lower risk of leaks) at much less cost.
- The slab-on-grade was constructed after the building roof was in place allowing for a higher-quality floor finish.
- All utilities were installed within the LTP, which eliminated the need to hang the piping from the slab.
- On the environmental side, the CMC rigid inclusion system was a superior solution to the initial design using piles:
- By using a displacement method for the installation of the CMC

rigid inclusions, the risk of contaminating the lower aquifer was reduced. The drilling tool effectively seals the outside of the bored hole and immediately fills the gap with grout, not allowing any transport of contaminated materials into lower clean layers.

- The process dœsn't generate a large amount of spoil, virtually eliminating the need to dispose of contaminated excavated materials resulting from the drilling operations.
- There is a significant reduction in the overall quantities of concrete and steel on the structure itself (thinner unreinforced slab, shallow footings), therefore reducing the carbon footprint of the overall construction.
- Use of recycled fly ash (a recycled waste product) in the CMC rigid inclusion mortar reduced the amount of cement needed to build the project.

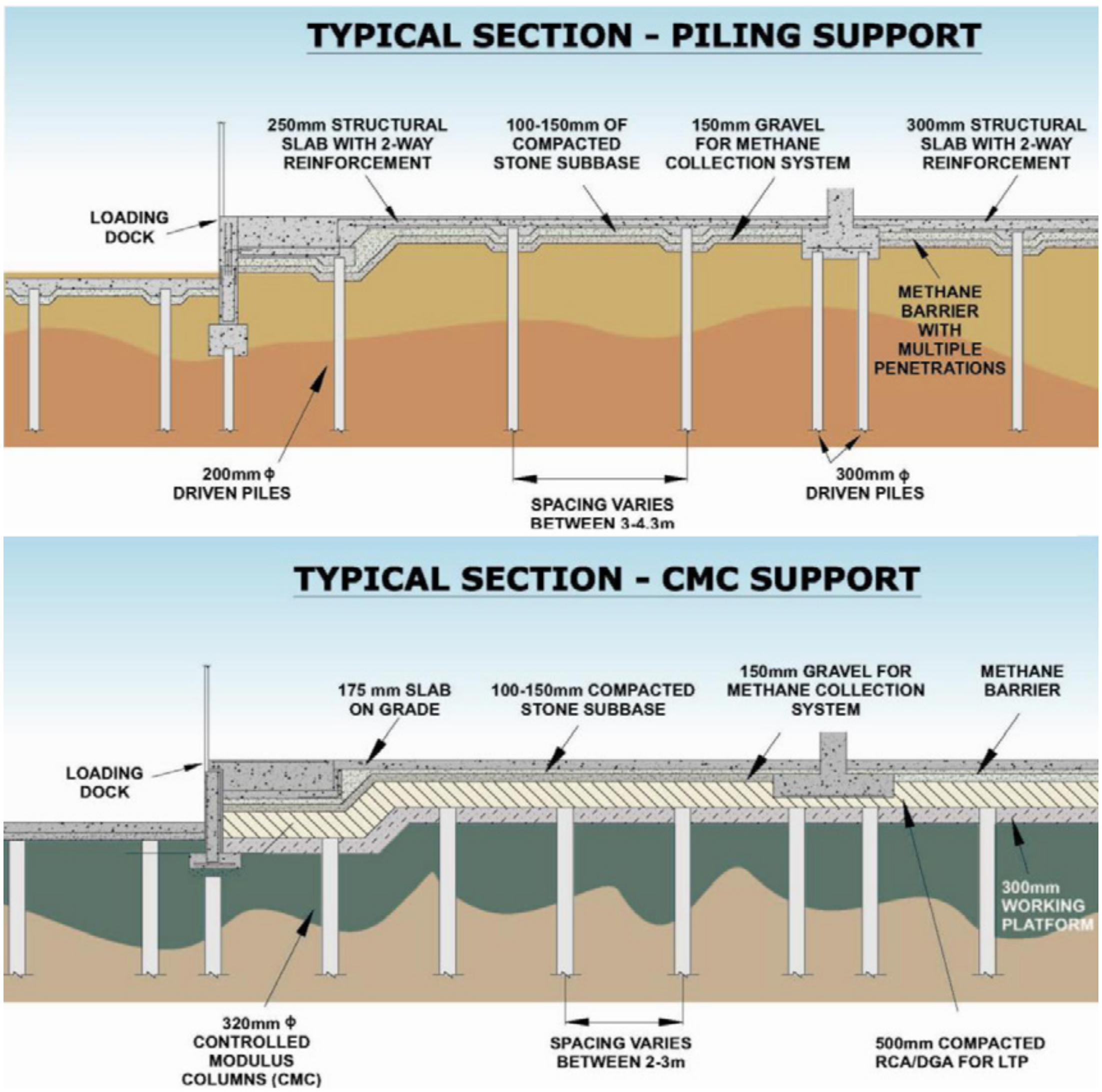

Fig 2: *The original piled foundation system is shown at top. At bottom is a section of the CMC rigid inclusion solution. Note the thinner slab, and reduced methane barrier penetrations associated with the CMC rigid inclusion approach.*

CONCLUSION Given that the work took place in a former landfill, environmental concerns were emphasized and needed to be addressed during the initial phase of the development of the site. Spoils generated during foundation works would have required special handling and disposal. The CMC rigid inclusions, which contained fly ash, provided for a much more sustainable approach as compared to the driven pile approach reinforced concrete and steel used in piling. The redesign of the foundation itself significantly reduced the amount of concrete and steel, again saving significant costs and providing a more sustainable solution. A comparison of the environmental impacts of the pile foundation versus the foundation system utilizing ground improvement by installing rigid inclusions found a 25% reduction in the carbon footprint

GOING FORWARD If you have a project that could benefit from the sustainable use of CMC rigid inclusions, give us a call.

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

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