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# WHITE PAPER

**CONTROLLED MODULUS COLUMN  
(CMC)<sup>®</sup> RIGID INCLUSIONS FOR HEAVILY  
LOADED SHALLOW FOUNDATIONS**

# CONTROLLED MODULUS COLUMN (CMC)<sup>®</sup> RIGID INCLUSIONS FOR HEAVILY LOADED SHALLOW FOUNDATIONS

**INTRODUCTION** Controlled Modulus Column (CMC)<sup>®</sup> rigid inclusions are a cost-effective alternative to traditional piling systems and are customized to support almost any shallow foundation size and configuration. CMC rigid inclusions are an extremely effective solution to support single-story to multi-story structures with heavily loaded spread footings up to 9,000 pounds per square foot (9 ksf). In addition, CMC rigid inclusion support is an ideal solution where soft/loose soils are present and settlement is a concern, or in contaminated environments where it is desirable to minimize spoils.

**BACKGROUND** Traditionally, heavy loads on soft/loose soils would eliminate any shallow foundation option, resulting in expensive deep pile foundations. A CMC rigid inclusion solution replaces piles, pile caps and grade beams with shallow spread and isolated footings, generating savings in both reinforced concrete and construction time.

1. Support of heavily loaded foundations using CMC rigid inclusions consists of a footing situated atop a load transfer platform (LTP) bearing on a customized configuration of CMC rigid inclusions. The load from the shallow foundation is transferred to the CMC rigid inclusions through the LTP. CMC rigid inclusions mitigate settlement and provide sufficient bearing under the building footings to allow structures to be built with a net bearing pressure of 8 to 9 ksf, depending on the geotechnical conditions. CMC rigid inclusions are patented ground improvement elements that are made of a specially designed cementitious lean mix. They are installed using a displacement CMC rigid inclusion tool that generates only a minimal amount of spoil (i.e., excess grout

and a very small amount of soil cuttings). CMC rigid inclusions reinforce the soil rather than function as distinct structural elements or piles. The improved ground has increased stiffness and therefore improved settlement and bearing characteristics.

## Design Methodology

The design of the CMC rigid inclusions for spread/wall footing support is conducted using a proprietary software package developed by Menard. This software provides a method of calculation that takes into account the interaction between the footing, the CMC rigid inclusions and the surrounding soils, modeling the transfer of the loads from the point of application directly under the footing to the bearing stratum, assuming strain compatibility. Menard has refined its design methods by incorporating adjustment factors to correlate the performance of the CMC rigid inclusions as predicted by the design theory to 20 years of experience with CMC rigid inclusions in various applications in a wide range of soils. Menard has developed a proprietary program that provides an estimate of settlement and also of the stresses in

the CMC rigid inclusions and in the soil, which is based on the previous methods.

In select cases for specific geometries or atypical soil conditions, 3D finite element analysis is also used to enhance the calculations performed by the previous semi-empirical method.

## LTP Design

The LTP typically consists of a dense graded aggregate with a minimal amount of fines that is typically compacted to 95% of the modified proctor. The LTP uniformly transfers the load from the spread footing to the CMC rigid inclusions and also separates the CMC rigid inclusions from the footing, allowing the CMC rigid inclusions to move separately from the footing under a seismic event or lateral loading of the foundation. The thickness of the LTP is dependent on the load at the LTP-soil interface and on the stiffness of the underlying subgrade soils. For building foundations, LTP thicknesses vary from 6 inches to 1 foot, while slabs-on-grade could require LTP thickness on the order of 2 to 4 feet thick.

## CMC Rigid Inclusion Design

The CMC rigid inclusion configuration is determined through an iterative process of balancing the loads per CMC rigid inclusion with LTP thickness, as well as the CMC rigid inclusion capacity and capacity of the surrounding soil strata. Finally, the required number and size of CMC rigid inclusions are determined through this design and positioned

to be fully encompassed within the footprint of the heavily loaded shallow foundation.

### Shallow Foundation/Footing Design

Using a CMC rigid inclusion solution allows the structural engineer to design the spread footing foundations using a uniform bearing pressure at a given allowable settlement. The LTP between the top of the CMC rigid inclusions and the bottom of the footing ensures that a uniform reaction from the ground improvement system is obtained. Therefore, the structural engineer can design the shallow foundation system as if it were placed on competent ground in the first place, while using the allowable bearing pressure developed collaboratively between the specialty contractor and the structural engineer. Typical uniform allowable bearing pressures achievable with a CMC rigid inclusion system at 1 inch total settlement/ $\frac{1}{2}$  inch differential settlement vary from 4 ksf in very soft soils with light column loads to 8 to 9 ksf in stiffer ground with higher column loads. Loads per footing typically vary from 80 kips to more than 2,000 kips for larger footings and structures. Figure 1 below depicts the transformation of a site with poor soils to a site improved by CMC rigid inclusions that provides up to 9 ksf allowable bearing pressure. On the

right, the CMCs are eliminated to show that the site can be regarded as having soils that provide uniform support of up to 9 ksf under foundations.

### Advantages to CMC Rigid Inclusion Supported Heavily Loaded Foundations over Traditional Pile Systems

1. Pile caps and piling systems often require extensive steel reinforcement and formwork which involves a large amount of time, labor and material (concrete and steel). Shallow spread footings are usually thinner than pile caps, with less reinforcement. CMC rigid inclusions are typically made of unreinforced plain mortar or grout, providing added economy.
2. Whereas piling systems are designed for virtually no foundation movement, CMC rigid inclusion systems are designed to control settlement within acceptable limits. Typical piling systems transfer the full structural load to a deeper substrata, and effectively disregard any obtainable bearing strength or friction capacity in soil layers that overlie the deeper bearing strata. CMC rigid inclusions share the load with the surrounding soil. Once the load is applied to the foundation, the soil surrounding the CMC rigid inclusions will minimally settle, engage negative skin friction
3. The pile installation process is more time consuming than a typical CMC installation due to greater drilling depths and reinforcement installation. Also, with drilled piles, spoils need to be managed during the drilling process. CMC rigid inclusions use displacement tooling that results in little to no spoils. When there are no spoils to manage, the project can be completed more quickly.
4. Uplift loads can be accommodated by a CMC rigid inclusion system by installing a centralized tension connection. The CMC rigid inclusions are attached to the footing using a specially designed detail in the LTP to ensure that strain compatibility between surrounding soils and footings is maintained.
5. CMC rigid inclusions, because they are typically not reinforced, can be cut off to a given elevation below the footings within a given tolerance (typically  $\pm 6$  inches). There is no need for the subsequent foundation contractor to cut the CMC rigid inclusions by hand for the excavation of the footings, or to chip concrete to expose reinforcement, saving time and labor costs.

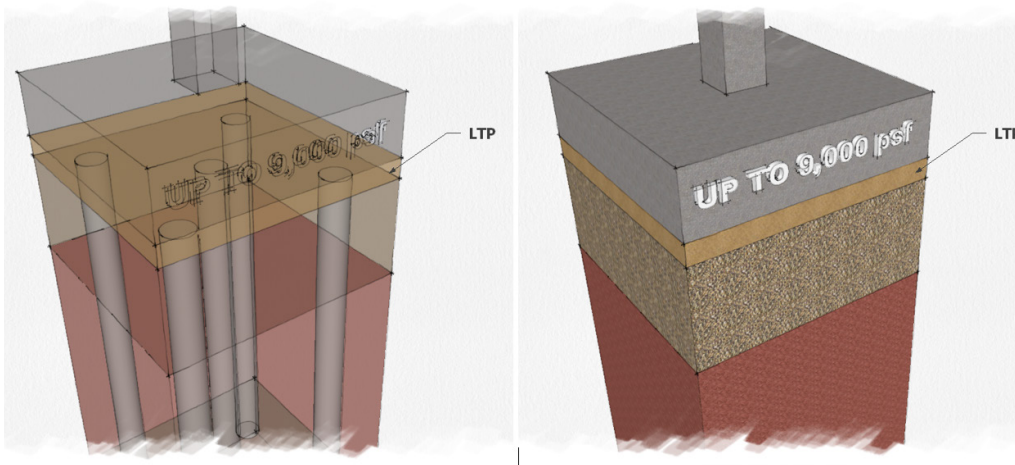


Fig 1: CMC support on left and the model that can be used for the foundation design on the right.

**CONCLUSION** CMC rigid inclusions are a cost-effective approach to support lightly to heavily loaded foundations and serve as an alternative to traditional piling systems in soft/loose soils where settlement poses a potential problem. CMC rigid inclusions share the load with the surrounding soil, resulting in less stringent design constraints than typical pile system that take on the entire load. More reasonable design constraints often result in overall cost savings to the foundation system. The CMC rigid inclusions can be customized to the desired foundation size and can support foundations with applied uniform pressures of up to 9 ksf, allowing the use of spread and isolated shallow footings. CMC rigid inclusion support systems can be installed to depths of up to 125 feet, far exceeding other forms of ground improvement.

**GOING FORWARD** When typical pile solutions are recommended to support footings with high loads, consider CMC rigid inclusion support as an alternative. Menard is available to address any needs or questions.

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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