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WHITE PAPER

COMPARISON OF CONTROLLED MODULUS COLUMN (CMC)® RIGID INCLUSIONS AND DEEP FOUNDATIONS

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INTRODUCTION Controlled Modulus Column (CMC)® rigid inclusions often serve as a value engineered substitute to traditional deep foundations and piles, and provide cost savings, shorter schedules, and more economical footing and slab designs.

BACKGROUND Deep foundations consist of vertical elements constructed from reinforced concrete, wood, or steel that is driven, drilled, or otherwise inserted into the ground and rigidly connected to a structural pile cap or mat. Common types of foundations include augercast piles, displacement drilled piles, and driven timber, pipe or precast piles. Deep foundations are designed to transmit structure loads through soft soils into stiffer, more competent soils or rock at depth with minimal or no settlement. When used to support embankments, they require the use of a structural mat, relieving platform, or pile cap to connect the tops of the piles to the structural foundation system. Structural mats, relieving platforms or pile caps add significant costs to the project. When designing a piled foundation it is assumed that 100% of the structure's load is transferred from the heavily reinforced foundation directly into the piles and that no load is transferred to the soils surrounding the piles.

CMC rigid inclusions differ from pile supported foundations in a number of ways. CMC rigid inclusions are a ground improvement solution comprised of grouted inclusions which act to reinforce a soil mass for the purpose of settlement control and increased bearing capacity. While CMC rigid inclusions are typically installed with piling equipment, they are designed with a ground improvement approach and philosophy. CMC rigid inclusions provide both bearing capacity and settlement control for vertical loads. Reinforced CMC rigid inclusions can be designed to provide both lateral and uplift capacity to the foundation.

When CMC rigid inclusions are used, rigid connections to the foundation are not required, and the load concentration in each element is significantly reduced as compared to a deep foundation system. The structure is separated from the CMC rigid inclusions by a Load Transfer Platform (LTP) constructed from compacted dense-graded aggregate (DGA). The load is transferred to the CMC rigid inclusions through arching within the high phi-angle compacted LTP and through side friction below the top of the CMC rigid inclusions. The system is generally designed to transfer 50 to 95% of the load to the CMC rigid inclusions while the remainder of the load is transmitted to the soils between the CMC rigid inclusions. The ratio of load sharing between CMC rigid Inclusions and soil is dependent upon the type and stiffness of the soils between the CMC rigid inclusions, and can be controlled by varying the diameter and center-to-center spacing of the CMC rigid inclusions. The amount of load sharing that is relied upon in the design can be selected based on the allowable settlement of the structure.

A pile supported structure is designed such that each pile or pile cluster is part of a distinct load path. Individual pile loads can be quite high and the piles typically extend to a very dense bearing strata or to bedrock. A CMC rigid inclusion system can be visualized as a "bed of nails" type of support for the structure. CMCs often have lower load concentrations, tighter spacings, or shallower depths than a comparable piled foundation. Relatively small diameter vertical elements provide a redundant network of support to the structure. CMC rigid inclusions are not

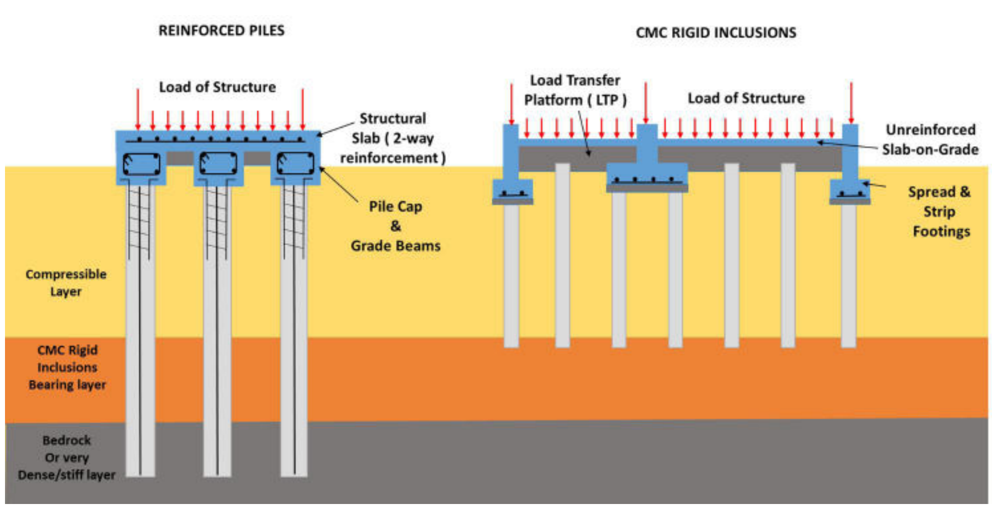

***Fig 1**: Comparison of a Piling and CMC Rigid Inclusions Solution*

***Fig 2**: Example of Spread Footing Supported by CMC Rigid Inclusions*

intended to directly support the loads imposed by a structure, but to improve the global response of the soil in order to control settlement and increase bearing capacity of the native soils.

The dimensions, spacing, and composition of the CMC rigid inclusions are based upon the development of an optimal combination of support from the columns and the surrounding soil to limit settlements of the structure to within the allowable range, and to obtain the required value for the equivalent composite deformation modulus of the improved soil. Footings and slabs are designed for direct bearing on uniform competent soil (slab-on-grade and shallow spread footings), as opposed to being designed to accommodate high punching stresses from rigid piling elements. As a result, slabs supported by CMC rigid inclusions are typically much thinner (4 to 12 inches) and either have no reinforcement or are very lightly reinforced. Similarly, spread footings are thinner and contain less steel than pile caps and grade beams.. A structure supported by CMC rigid inclusions would therefore be more economical due to concrete and steel savings.

In the case of non-displacement drilled pile or drilled shaft foundations, the soil is excavated or mined to the surface in order to create a void into which concrete and reinforcing steel

***Fig 3**: Excavation of Wall Spread Footings After Installation of CMC Rigid Inclusions*

may be placed. The volume of soil spoils generated during the pile installation is going to be roughly equivalent to the total volume of piles installed and must either be disposed of or reused in another place at the site. This can be problematic at sites that are very congested or that are contaminated.

CMC rigid inclusions are installed with a displacement auger which generates minimal spoil compared with piles installed using traditional drilling methods. During CMC drilling, the soils are displaced laterally as the auger penetrates the ground. In granular soils this lateral displacement of the soil results in compaction and improvement of the soils surrounding the rigid inclusion.

	CMC Rigid Inclusions	**Traditional Deep Foundations or Piles**
Depth	<10 ft. up to lengths >1500 ft.	20 ft. up to lengths >1500 ft.
Material	Generally only sand/cem150 ft. ıt – sometimes include reinforcement for tension or lateral loads	Timber, steel, reinforced co150 ft. r other materials
Diameter	12 in. – 18 in.	1 ft. to 5 ft. or more
Load Mechanism	Share the load with surrounding soils	Carry 100% of the structure load; structure assumed to transmit load into the piles alone
Cost	Typically more economical than piles and use economical shallow foundations (spread footings/slabs on grade)	Expensive and requires heavily reinforced structural foundations (pile caps, grade beams, structural slabs)
Structurally connected to superstructure	NO	YES
Load path redundancy associated with composite behavior	YES	NO
Designed for High Unit Stresses	NO	YES

***Table 1:** Comparison of CMC Rigid Inclusions to Deep Foundations/Piles*

CONCLUSION CMC rigid inclusions can be a more economical alternative to traditional pile foundations and result in time savings for projects on soft or marginal soils. The technique has been used to increase allowable bearing pressures to 8,000 psf and higher, depending on the soils present at the site, and decrease anticipated settlement. When evaluating the cost savings of CMC rigid inclusions as compared to a piling solution, it is important to also consider the savings associated with the use of slabs-on-grade and shallow spread or isolated footings versus structural slabs and pile caps (reduction in the quantities of concrete and steel).

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GOING FORWARD: Contact Menard USA today to learn more about how CMC rigid inclusions might provide your project with cost and schedule savings over traditional deep pile foundations.

Get in touch with Menard today at **412-620-6000** or visit us at **www.menardusa.com** today to find your local Menard representative.