Building Blocks

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Controlled Modulus Columns

An Attractive Alternative

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With widespread acceptance in the market place, many engineers are choosing ground improvement techniques to provide a suitable subgrade for shallow foundations at sites that would have traditionally required deep foundations. This article discusses the Controlled Modulus Column (CMC) ground improvement technique and some case histories highlighting the use of this technique. CMCs are a sustainable and cost-effective ground improvement technology that transmit load from the foundation to a lower bearing stratum through a compacted soil load transfer layer and the composite CMC/soil matrix. CMCs are constructed using 2000-3000 psi grout and range in diameter from 11 to 18 inches. CMCs have been installed in a variety of soils including uncontrolled fill, organics, peat, soft to stiff clay, silt, municipal solid waste, and loose sands. Typically, the CMCs are installed through the soft or compressible soils and into dense sand, stiff clay, glacial till, or other competent material that serves as the bearing stratum.

The CMC installation is an attractive option from an environmental perspective because it utilizes reverse flight augers, which displace the soil laterally. This installation technique achieves two goals: it densifies the soil around the CMC, which improves load transfer into the element, and it eliminates spoils and the associated disposal requirements and costs. The use of traditional augers, used to install auger-cast piles or drilled caissons, might appear to result in a similar foundation system but would not include the benefits of the CMC installation technique. In addition, the hole created by the displacement auger is backfilled with pressurized cement grout that further densifies the surrounding soils. The result is a CMC element that is significantly stiffer than the soil around it. Therefore, the CMCs attract load from above, and transmit that load to the more-competent deeper soils or bearing stratum. In the past, CMCs have been designed with a central steel reinforcing bar, if additional strength is required.

When selecting the appropriate ground improvement technology, knowledge of the benefits of each system is key. Because CMCs are a relatively new technology many potential users are not aware of their benefits. Some of these benefits include:

- Promotes development of brownfield sites underlain by poor quality soils.
- Avoids excavation and replacement of poor quality soils and limits spoil, reducing waste generation.
- Avoids driving long steel piles to bedrock.
- Provides a cost-effective solution compared to conventional pile foundation systems.
- Allows for the lengths of CMCs to be adjusted in the field without splicing or cutting.
- Reduces schedule for installation.
- Reduces the cost of a structure needing a traditional deep foundation, and its design, by replacing pile caps, grade beams and structural slabs with spread footings and slabs-on-grade.
- Improves the performance of a methane barrier system, when required, by eliminating complex detailing around pile caps.
- Eliminates the need to hang utilities under a structural slab, as utilities are installed directly within the load transfer layer.
- With CMCs, the slab-on-grade can be built after the building is erected, in a controlled environment, resulting in a better quality finish. With traditional pile foundations, the structural slab is typically built before the building.
- Reduces the carbon footprint associated with foundations.

While CMCs are an attractive financial and sustainable option, it has also been demonstrated that the performance of the system is comparable to that of deep pile foundations. Typical CMC designs limit total settlement of a structure to 1 inch and differential settlement to 0.5 inch. Foundation subgrade is typically evaluated for both strength (bearing capacity) and service (settlement). The traditional approach was to use piles to control settlement at sites with poor quality soils. The piles became the supporting elements for the foundation and were designed to resist lateral and vertical loads applied to the foundation. However, the pile capacity required to control settlement may be significantly lower than that required to support the foundations. Therefore, the service goal may require an inefficient system because the pile system ignores the strength of the soil surrounding the piles. Ground improvement is typically more efficient because its design utilizes the strength of the surrounding soil and additional soil-improved strength to meet service load requirements.

While the use of CMCs for building foundations are provided in the following case studies, CMCs also have been used for a variety of other applications including foundations for tanks, mechanically stabilized earth (MSE) walls, and embankments.

Philadelphia Produce Market

Ground improvement using Controlled Modulus Columns (CMCs) was used at the site of a 550,000 square-foot warehouse on the southeast corner of Essington Street in Philadelphia, Pennsylvania. The original foundation design proposed the use of either 8-inch-diameter timber piles or 12-inch-diameter grouted steel pipe piles, both driven to

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CMC Installation at the Essington Warehouse Site. Multiple rigs were on site to accelerate the construction schedule.

a depth of approximately 50 feet. In addition, thickened reinforced pile caps, internal grade beams, and a 12-inch-thick reinforced, 2-way structural slab would be required to connect the piles to the superstructure. Instead, the warehouse was supported using 12.5-inch-diameter CMCs drilled to a depth of approximately 35 feet. The CMCs were placed under individual footings and beneath the slab. The CMC support allowed for the use of spread footings and a 6-inch-thick slab-on-grade, and eliminated the need for internal grade beams.

The main purpose of the CMCs was to minimize the settlement of the warehouse, which could have been significant if some type of support was not provided. The building was constructed over municipal solid waste and organic soils that were present in the subsurface profile. CMCs were designed to penetrate the municipal solid waste and organic soil and terminate in the dense sand at depth.

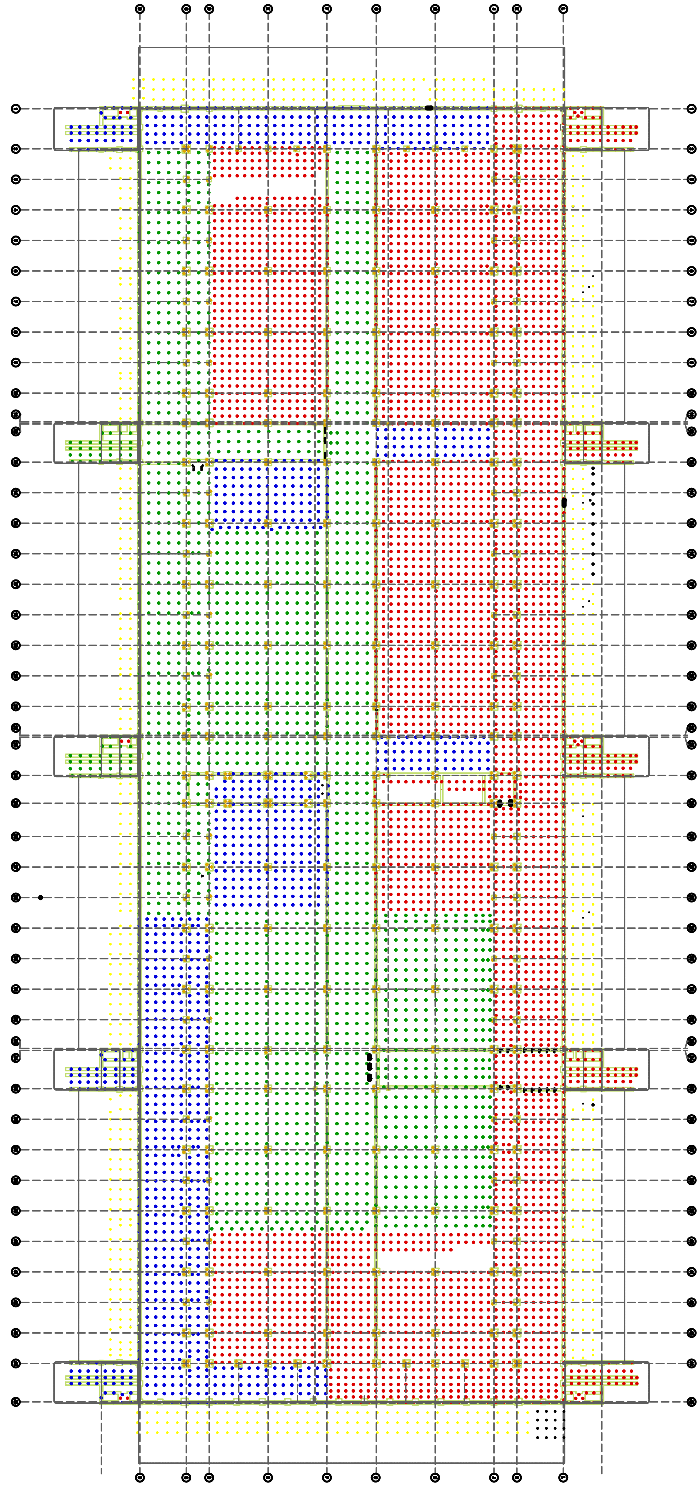
Because the site was a former landfill, the spoils would likely require special, costly handling for disposal. An obvious advantage to using CMCs, or any displacement installation method, is that no spoils are generated. In addition, CMCs contain grout only, which is a more sustainable material than reinforced concrete or steel. A comparison of the environmental impacts of a pile foundation and the CMC ground improvement showed a 25% reduction in the carbon footprint of the foundations when using CMCs.

The carbon footprint offset calculation was based on the difference in quantity and carbon footprint values for the concrete, steel, and grout associated with the two different schemes. It does not include any benefits of the accelerated schedule associated with the CMC design, nor with the additional carbon footprint required to dispose of extra, potentially contaminated, soils associated with the deep foundation scheme.

The ground improvement was completed in the summer of 2009, and the structure is in the final phases of construction.

Bayonne Crossing

Ground improvement using CMC was used at the site of seven new buildings, which form a new shopping complex, at Bayonne Crossing in Bayonne, New Jersey. The seven buildings vary in size from a restaurant measuring 1,645 square-feet to a box store measuring 146,583 square-feet. The difference in use, proposed loading, structural performance criteria, and soil conditions required specific analysis and design of the CMC system for each building. The CMC size, spacing and configuration can easily be modified to optimize the system for varying building geometries, loading and subsurface conditions. The CMCs were placed under individual footings and beneath the slabs for each of the structures, as required. The original design proposed the use of timber piles; however, CMCs were selected as an alternative design by the Contractor. The CMC support allowed for the use of spread footings and 4- to 6-inch-thick slabs-on-grade, and eliminated the need for internal grade beams and pile caps. Originally, CMCs were only selected to replace the piles for one of the buildings, a Lowes Home Improvement Warehouse. However, as design and construction progressed and the benefits of using the CMC system became obvious, CMCs were selected for the remainder of the buildings.



CMC Layout at the Essington Warehouse. CMC support was provided in a grid pattern beneath the slab and beneath a utility line running along the exterior of the building.

The soils at the site contained uncontrolled, contaminated fill, organics and sand. Environmental investigations performed at the site identified potential chemical hazards that may be present, including volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), polychlorinated biphenyls (PCBs), and metals including hexavalent chromium. Because the soils at the site were contaminated,

Aerial photograph of the completed Essington Produce Market Warehouse. Courtesy of R. Alan Adams Photography.

uncontrolled and compressible, CMCs were an attractive foundation option. In addition to the benefits described previously, the CMC installation auger can also penetrate obstructions in the underlying soils that may damage concrete piles or significantly slow the advancement of steel piles. The CMCs were designed to penetrate the uncontrolled fill and organic soil, and terminate in the dense sand at depth. More than 4,500 CMCs were installed beneath the seven buildings over 4 to 5 months. The length of the CMCs varied depending on the depth to the dense sand layer, with a total of over 165,000 linear feet of CMCs being installed.

Because of the contamination at the site, using CMCs with the auger displacement system eliminated spoils, and reduced the time and costs associated with permitting and soil disposal. In addition, the schedule for the installation of the foundation system was significantly reduced. While a formal carbon footprint offset calculation has not been performed, past experience leads to anticipation of a 15 to 25% reduction in the carbon footprint of the foundations by selecting CMCs instead of pile foundations. As discussed previously, this would account for the difference in quantity and carbon footprint values for the concrete, timber, and grout associated with the two different schemes. It does not include any benefits of the accelerated schedule associated with the CMC design, nor with the additional carbon footprint required to dispose of extra, potentially contaminated soils associated with the deep foundation scheme.

The ground improvement was completed in the summer of 2010 and the structures are currently under construction.

Conclusion

The use of ground improvement and the CMC system provide cost and schedule savings and a more sustainable method for construction of foundations on sites with poor quality soils as compared to a more traditional solution using piles, piles caps, grade beams and a structural slab. The CMC system is especially suited to Brownfield developments, and has been successfully designed and applied to a number of projects for warehouses, retail developments and condominiums. A carbon footprint calculation can be used to demonstrate the benefits of the system. A more detailed calculation, including soil disposal issues should be considered.▪