Site-Redevelopment for Commercial Expansion
Using Plastic-Dome Forms for Aerated Floor Construction

A case study application of a new methane mitigation system used in the redevelopment of a former landfill site in Arizona.
The redevelopment of sites for commercial expansion sometimes requires that the new structures incorporate a soil gas mitigation system beneath the structure to prevent soil gases from intruding into the structure's interior. For example, when redeveloping a former landfill site, a sub-structure/slab mitigation system may be needed to vent residual landfill methane gas. Another example of when a sub-structure/slab mitigation system might be necessary is in locales where subsurface radon levels are high.

**Traditional Methane Mitigation Systems**

Traditional methane mitigation systems include sub-slab and raised-floor systems. Traditional sub-slab systems include a network of perforated/slotted horizontal pipes embedded in gravel under the floor to provide preferred pathways for soil gases to be collected and transferred through vertical pipes that discharge to the atmosphere above building rooftops. Geotextile may also be installed above gravel and then overlain by an impervious membrane to serve as a vapor barrier and impede upward movement of soil gases toward the concrete slab and building interior.

Traditional raised-floor systems include concrete piers and/or steel piles with beams and forms to create a floor system above the subgrade. A mechanical ventilation system, with inlet vents around the periphery of the building between the floor and subgrade, is then installed to exhaust subsurface air between the building foundation and raised floor to the atmosphere.

**Novel Mitigation System Using a Plastic-Dome Matrix**

An emerging, low-cost methane mitigation system uses a sub-slab matrix of thermoplastic, structural domes to provide improved sub-floor aeration and collection of soil gas beneath building floor slabs. This new plastic-dome matrix system is referred to by its commercial name, Cupolex, manufactured by Pontarolo Engineering (http://www.cupolex.com).

Aerated flooring systems using the new, plastic-dome matrix system are similar to raised-floor systems, but use structural thermoplastic domes made from recycled polypropylene to create a large void space beneath the building's first-floor concrete floor slab. This novel design results in minimal resistance to sub-slab airflow. Each structural dome interlocks with its neighbors to create a permanent self-supporting formwork and moisture barrier. The arch geometry of the plastic domes results in a sturdy foundation using less concrete volume and puts the concrete under compression instead of tension.

Compared to traditional perforated pipe and gravel methane mitigation systems, plastic-dome matrix systems typically use less concrete for floor slab completion and improve methane collection and venting by eliminating sub-slab gravel that impedes airflow in traditional systems. Compared to traditional raised-floor systems, plastic domes provide equal structural integrity and result in similar, but less expensive, large interconnected sub-slab void space.

Plastic-dome matrix forms can be used to accommodate a range of site conditions, including low-bearing capacity soils, expansive soils, predicted settlement, and bridging over utilities. These forms can be part of an effective system to mitigate soil gas containing methane, radon, and/or volatile organic compounds (VOCs).

**Testing and Inspection**

Testing for proper operation of plastic-dome matrix active-mitigation systems can be evaluated by simple measurements of the vent riser vacuum levels and airflow rates, whereas traditional mitigation systems may require vacuum field extension tests, which are more complex. Prior to pouring the concrete floor slab over the mitigation system, the elements of the aeration system normally require formal inspection.

For inspection, plastic-dome matrix systems include three elements that must be evaluated prior to concrete placement (the subgrade, the plastic-dome forms, and steel reinforcement). By contrast, traditional sub-slab systems include inspection of at least six elements (the subgrade, perforated/slotted pipe, gravel quality and placement, sand/geotextile quality and placement, impermeable membrane installation, and steel reinforcement).

**Installation**

Aerated flooring system materials using the plastic-dome matrix system are manufactured to ISO 9001:2000 standards and can be installed by hand with high cost-efficiency. On average, two laborers can set 1,500 square feet of these forms in approximately one hour. One pallet of delivered, plastic-dome forms can replace the transport of approximately seven trucks of gravel or fill to perform mitigation of the same coverage area. Based on project magnitude, using the plastic-dome forms instead of hauling gravel and fill can also greatly reduce on-site construction related traffic. After plastic-dome forms have been installed, steel reinforcement is placed directly on the forms, and, after the system has been inspected, a concrete floor slab is poured and conventionally finished.

The under-slab void space created by the plastic-dome formwork can also provide options for utility, conduit, and pipe installation resulting in faster and more cost-effective construction. Plastic-dome matrix systems can be used to create temporary stormwater detention storage volume...
beneath development streets and sidewalks for storm water management. Using plastic-dome elements as part of building construction can also help activate and assign credits to U.S. Green Building Council Leadership in Energy and Environmental Design (LEED)-certified buildings.

**Case Study: Plastic-Dome Matrix Aeration System in Arizona**

Expanding business in fast-growing cities has led to unique site selections for commercial development in order to match consumer demand. In Tempe, AZ, for example, a former industrial parcel and landfill near the intersection of Highway Loops 101 and 202 is now an expanding multi-million-dollar shopping, restaurant, and entertainment center.

As with most former landfill sites containing municipal, agricultural, industrial, and construction wastes, the site in Tempe includes large tracts of land that are underutilized and are, therefore, attractive for commercial redevelopment. Besides being cost-effective, reuse of the former landfill also reduces development pressure on nearby undeveloped property. Development challenges at the former landfill include the management and remediation of fluids and/or gases from contaminated soils and the potential for subsidence as subsurface waste decomposes.

At the site in Tempe, significant soil cleanup was performed by removing contaminated soils as part of site remediation. Field investigation results nevertheless indicate the remaining soils can emit low concentrations of methane, requiring developers to implement mitigation systems to prevent methane intrusion into new structures being developed on-site. Instead of traditional mitigation systems, new developments at the entertainment center in Tempe are opting to use new plastic-dome matrix technology to control methane mitigation.

A new 20,000-square-foot building at the site includes a plastic-dome matrix beneath the west and central portions of the building, and a traditional gravel layer beneath the east foundation of the building. Vacuum test results at this building allow air pressure losses and sub-slab air exchange rates for aerated floor and traditional mitigation systems to be compared. A radon fan was temporarily installed on a central riser pipe (RP-1) while all other riser pipes and inlets were capped. Airflow was measured at RP-1 and vacuum was measured at all locations. The air inlet pipes were then uncapped and their flow rates measured. Comparative results are presented in Table 1, demonstrating the better air flow performance of the sub-floor plastic-dome matrix system over the traditional, sub-floor gravel layer.

Air inlets IP-7 and IP-8 installed in the gravel bed on the east side of the building have significantly lower vacuum levels than the plastic-dome matrix aerated-floor inlets (IP-1 through IP-6), indicating greater airflow resistance through the gravel bed than through the plastic-dome matrix's void space. Flow measurements with each inlet uncapped indicate the inlet pipes installed in the gravel bed area (IP-7 and IP-8) have, as expected, lower airflow than the aerated floor inlets.

**Post-Tensioned Slabs**

One-way and two-way post-tensioned floor slabs are frequently used (often with piers or piles) for lower-bearing capacity soils, to bridge over weak areas, or areas expected to be prone to settlement. Traditional grade beam construction divides the building sub-slab into many isolated areas that are complex to vent. Post-tensioned slabs having large, easily

<table>
<thead>
<tr>
<th>Pipe Description</th>
<th>Building Location</th>
<th>Vacuum (in.)</th>
<th>Flow Rates (cfm)</th>
</tr>
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<tbody>
<tr>
<td>RP-1</td>
<td>Central</td>
<td>-1.525</td>
<td>288.85</td>
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<tr>
<td>RP-2</td>
<td>Central</td>
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<td>West</td>
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<tr>
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<td>Central</td>
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<td>Central</td>
<td>-0.120</td>
<td>50.61</td>
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<td>Central</td>
<td>-0.123</td>
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<td>IP-6</td>
<td>Central</td>
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<td>44.94</td>
</tr>
<tr>
<td>IP-7</td>
<td>East</td>
<td>-0.064</td>
<td>9.16</td>
</tr>
<tr>
<td>IP-8</td>
<td>East</td>
<td>-0.050</td>
<td>no measured flow</td>
</tr>
</tbody>
</table>

*Note: Vacuum measurement in inches water column, a non-SI unit for pressure measurement.*
ventilated, sub-slab void space for soil gas mitigation can be easily constructed by combining the Cupolex plastic-dome forms with another recycled thermoplastic element from the same manufacturer, called Pontex. Pontex is used in slab design as a reinforced internal rib to create one or two directional structural slabs. The channels thus created provide support of post-tensioning cables, as shown in the photo of the framework used for a methane mitigation system in Colorado on the first page of this article.

Conclusion
Commercial site redevelopers facing the challenge of sub-surface migration of gases, such as methane, radon, and VOCs can benefit from site redevelopment incorporating a new plastic-dome matrix technology (Cupolex) as an effective, efficient, and “green” engineering control method for those gases. Specific attributes of the plastic-dome matrix technology for mitigation of sub-surface methane and other gases include: ease of system assembly, sustainable component manufacture from recycled thermoplastic, increased aeration efficiency over traditional gravel sub-slab systems, cost-effective construction, reduced long-term operating costs, simpler construction inspections, and simpler operational testing methods. In addition, with the plastic-dome matrix system, the sub-slab aeration space can, in appropriate settings, serve as a reservoir for stormwater management.

Deran Pursoo, Dave Folkes, and Ted Kuehster are all with Geosyntec Consultants. E-mail: DPursoo@geosyntec.com.

Disclaimer:
The authors and their organization have no affiliation with neither the technology supplier company Pontarolo Engineering nor the Cupolex product.