SPECIFICATION AND APPLICATION OF VOID SPACES BELOW CONCRETE FOUNDATIONS

by
The Structural Committee

of
The Foundation Performance Association

www.foundationperformance.org

Houston, Texas

Document # FPA-SC-11-0

ISSUE HISTORY (Some internal committee issues omitted)

Rev #	Date	Description	Subcommittee Chair	Subcommittee Members
A	22 Jun 05	Issued for Committee Review	Michael Skoller	Mike Turner Ron Kelm Mohamed Moussaoui Al Maceiras Mari Mes Jim Austin Karl Breckon
Z	18 Jul 07	Issued for FPA Peer Review		
BB	26 Oct 07	Issued for Committee Review		
0	11 Nov 07	Issued for Website Publication		

PREFACE

This document was written by the Structural Committee's FPA-SC-11 ad hoc subcommittee and has been peer reviewed by the Foundation Performance Association (FPA). This document is published as FPA-SC-11 Revision 0 (or, FPA-SC-11-0) and is made freely available to the public at www.foundationperformance.org so all may have access to the information. To ensure this document remains as current as possible, it may be periodically updated under the same document number but with higher revision numbers such at 1, 2, etc.

The Structural Committee is a permanent committee of the Foundation Performance Association. At the time of writing this document, the Structural Committee was chaired by Ron Kelm and 25 to 35 members were active on the committee. The committee sanctioned this paper and formed a subcommittee to write this document. The subcommittee chair and members are listed on the cover sheet of this document and are considered this document's co-authors.

Suggestions for improvement of this document should be directed to the current chair of the Structural Committee. If sufficient comments are received to warrant a revision, the committee may form a new subcommittee to revise this document. If the revised document successfully passes FPA peer review, it will be published on the FPA website and the previous revision will be deleted.

The intended audiences for the use of this document are engineers, architects, builders, foundation contractors, owners, and others that may be involved in the design of foundations that are located in the southeast region of the state of Texas, and primarily within the City of Houston and its surrounding metropolitan area. However, much of the information discussed may also apply to other geographical areas with Expansive Soils.

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GLOSSARY

- **Carton Forms** are shoring elements designed to provide a Void Space between Expansive Soils and foundation systems, while providing a temporary support formwork for the weight of concrete and construction loads during placement until the concrete sets to the point that it can span between its permanent supports. See section 2.0 for additional information.

- **Expansive Soils** per 2006 International 1Building Code [1] Section 1802.3.2 and 2006 International Residential Code [2] Section R403.1.8. are "Soils meeting all four of the following provisions shall be considered expansive, except that tests to show compliance with Items 1, 2 and 3 shall not be required if the test prescribed in item 4 is conducted:
    1. Plasticity Index (PI) of 15 or greater, determined in accordance with ASTM D 4318.
    2. More than 10 percent of the soil particles pass a No. 200 sieve (75 μm), determined in accordance with ASTM D 422.
    3. More than 10 percent of the soil particles are less than 5 micrometers in size, determined in accordance with ASTM D 422.
    4. Expansion Index greater than 20, determined in accordance with ASTM D 4829."

- **Heave** is the upward movement of an underlying supporting soil stratum due to the addition of water to an unsaturated Expansive Soil within the moisture active zone. When moisture is added to the soil, expansion occurs within the structure of the soil, and the corresponding area of the foundation and Superstructure move upward. Heave most commonly occurs within clayey soils with an available moisture source.

- **Plasticity Index (PI)** is the numeric difference between the liquid limit and the plastic limit. It is a scale used to measure the potential for volume change for Expansive Soils. Soil with a PI less than 15 is considered non-expansive, soil with a PI between 15 and 30 are considered to be moderately expansive, and soil with a PI above 30 is considered highly expansive.

- **Potential Upward Movement (PUM)** is the potential amount of upward movement of the site-specific soils directly below the foundation. PUM is typically provided in geotechnical reports and is based on moisture changes from dry to saturated conditions as well as in-situ to saturated conditions. Common methods for determining PUM include the use of suction tests, swell tests, and the potential vertical rise (PVR) method.

- **Slab Area** is the portion of a Structural Slab spanning between the grade beams and/or piers.

- **Soil Retainers** are sheets placed vertically adjacent to the degradable voids under the grade beams and are used to resist the lateral soil pressures that can invade the voided space during and after construction. Soil Retainers are typically comprised of HDPE (high density polyethylene) or other materials that are non-degradable and are not adversely affected by moisture.

- **Structural Slab,** as defined for this paper, is a foundation system consisting of a structural reinforced concrete slab with Carton Forms that create a space that separates the slab from the surface soils. A slab is designated as a Structural Slab when the slab is designed to span between reinforced concrete grade beams that are supported entirely by deep support systems or piers if the slab is unstiffened, i.e. a foundation of uniform thickness. Deep support systems are foundations having deep components such as drilled piers or piles that extend below the moisture active zone of the soils. Deep support systems function to limit the vertical movements of the building by providing support in a non-active soil stratum. For further details, see Document No. FPA-SC-01, *Foundation Design Options for Residential and Other Low-Rise Buildings on Expansive Soils* [4].

- **Superstructure** is comprised of building components above the foundation such as the structural framing and the architectural coverings for the floor, walls, ceilings, and roof.

- **Void Spaces** are gaps designed to provide an intended buffer zone or clearance between Expansive Soils and a concrete foundation in order that Heave can occur without imposing detrimental uplift pressures to the foundation.

- **Void Space System** is the complete assembly and use of components specified by the foundation design engineer in order to create the designed Void Space.

- **Wax Coated** describes a process that is used to coat only the exterior liner surface of corrugated Carton Forms. This process will temporarily help maintain structural integrity should the forms come in contact with excessive moisture during foundation construction.

- **Wax Impregnated** describes the result of a process that saturates (with wax) individual papers used to manufacture Carton Forms. *Fully* Wax Impregnated describes the result of a manufacturing process where all paper components (e.g., liners and mediums) are Wax Impregnated. This process allows the Carton Forms to maintain some structural integrity should the forms come in contact with water during foundation construction. Fully Wax Impregnated paper is highly resistant to initial moisture contact, is not biodegradable, and holds its shape when wet with no imposed load.

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1.0 INTRODUCTION

The need for this document was prompted by a concern in the industry about the effectiveness of Void Space Systems in isolating foundations from Expansive Soils. Void Space Systems are designed to provide an intended buffer zone or clearance between Expansive Soils and a concrete foundation system, while providing a support formwork for the weight of concrete and construction loads during placement until the concrete has sufficient strength to span between supports. At sites where Expansive Soil below the foundation has the potential to swell, Void Space Systems are designed to isolate the foundation from Heave of the underlying soil.

The scope of this document is to provide guidance in the design, specification, and installation of Void Space Systems under residential and other low-rise building foundations, typically called lightly loaded foundations, which are founded on Expansive Soils. These buildings may include but are not necessarily limited to houses, garages, apartment and condominium buildings, restaurants, schools, churches, and other similar structures.

Void Space Systems have been used for decades. The intent has been to provide an intended buffer zone or clearance beneath the foundation for the Expansive Soils to Heave into without applying detrimental upward pressure to the bottom of the foundation. In the mid-1990’s, however, members of the Foundation Performance Association and others in the structural, geotechnical and forensic community in the Houston Texas area discovered some foundations designed with Void Spaces beneath ***only*** the grade beams had experienced damaging movement. The general consensus in the Houston Texas area at that time was that the presence of the Carton Forms allowed water to accumulate below the foundation, causing Heave. Most concerned professionals concluded that it might be better to simply eliminate the use of Void Spaces that were used only below the grade beams.

Until the mid-1990’s it was customary to use Void Spaces below grade beams but not below the Slab Area. Since that time many engineers have specified that Void Spaces be installed under the Slab Area only when designing a Structural Slab with Void Space. Presently, some performance problems associated with foundations isolated from Expansive Soils using Void Spaces continue. This document was written to help clarify possible causes of foundation problems and present a guideline for the use of Void Space Systems under foundations in an effort to improve future performance.

This committee recommends in this document to eliminate utilizing Void Spaces under grade beams only. The two alternatives recommended in this document are: 1) Void Space Systems under Slab Areas only and 2) Void Space Systems under both Slab Areas and grade beams.

Section 2 of this paper provides detailed definitions of Void Space System materials. Section 3 discusses the design of Void Space Systems along with the advantages and disadvantages of various void material types. Section 4 presents specifications for materials used to create Void

Spaces. Section 5 discusses the handling and installation of Void Space Systems. References may be found in Section 6.

2.0 VOID SPACE SYSTEM TYPES

Several Void Space System types are discussed below. See Section 4.0 for material specifications.

2.1 DEGRADABLE VOID SPACE (CARTON FORM) SYSTEMS

The type of Carton Forms most commonly used are degradable forms constructed of a corrugated paper product arranged in an open cell configuration. The exterior surface of the Carton Forms may be Wax Coated to temporarily resist moisture from the weather, soil, and/or wet concrete. These forms are typically designed to gradually absorb ground moisture and lose strength over a period of time, leaving a Void Space between the Expansive Soils and the foundation.

If the soil below the foundation expands, the soil can then Heave into the space provided by the Carton Forms without lifting or deforming the foundation. Course fill material under Carton Forms should not be used because a capillary break may occur preventing moisture migration to the degradable Carton Forms.

Only degradable Void Space (Carton Form) Systems should be used under Slab Areas.

2.2 COLLAPSIBLE VOID SPACE SYSTEMS

Collapsible Void Space Systems incorporate a non-degradable material designed to collapse under Heave pressures (from the soil below) greater than the foundation and Superstructure dead loads, but *not* collapse during foundation make-up and placement. Collapsible Void Space Systems may be constructed of plastic, Wax Impregnated corrugated paper, or other materials resistant to moisture but designed to collapse under the pressure of swelling soils.

Collapsible Void Space Systems should not be used under Slab Areas. The combination of the dead load plus sustained live load and inherent stiffness of the typical Slab Area is not sufficient to collapse this type of material and would thereby transfer the uplift forces through the non-collapsed Void Space Systems to the above Slab Area.

2.3 NON-COLLAPSIBLE VOID SPACE SYSTEMS

Non-collapsible Void Space Systems incorporate material designed to maintain its original structural integrity throughout the life of the foundation. This type of system provides a built-in Void Space. Materials may be comprised of Fully Wax Impregnated corrugated paper products, Styrofoam, plastics or other non-degradable products. See section 4.4 for an example.

Non-Collapsible Void Space Systems should not be used under Slab Areas. This is because the combination of operational loads and inherent stiffness of the typical Slab Area is not sufficient to collapse this system and thereby allows transfer of uplift forces through the non-collapsible support structure of the Void Space Systems to the above Slab Area.

3.0 DESIGN OF VOID SPACE SYSTEMS

This section includes the design of Void Spaces under various load criteria in conjunction with the Void Space System material type (see Section 2.0 for definitions). This section also includes some advantages and disadvantages of Void Space Systems under slabs, under grade beams, and around piers.

Carton Forms under foundations typically support uncured concrete during construction, creating a Void Space that isolates the foundation from the underlying soil. The depth of the Void Space, which has been known to range from two to twenty-four inches (2"-24"), is a function of the PUM of the underlying soils. Typically, deeper Void Spaces are associated with more Expansive Soil. The geotechnical engineer should specify the net depth of the Void Space and the PUM. In the case of collapsible Void Space Systems, the net depth is the non-collapsed depth minus the collapsed depth. In the case of non-collapsible Void Space Systems, the net depth is increased appropriately to provide the same net Void Space volume.

When using Carton Forms under the Slab Area, Void Spaces under the grade beams should also be used when the uplift forces of the Expansive Soils are predicted to be greater than the dead plus sustained live loads of the foundation and Superstructure that are transferred to the grade beams.

3.1 VOID SPACE (CARTON FORM) SYSTEMS UNDER SLAB AREAS

Only degradable Void Space (Carton Form) Systems should be used under Slab Areas. The advantages, disadvantages and comments on the use of Carton Forms under Slab Areas are addressed in Table 3.1-1, below. In order for the Carton Forms to degrade, the contractor shall ensure that no subgrade capillary breaks, such as gravel, plastic sheathing, and fill debris, exist below the Void Space.

TABLE 3.1-1 VOID SPACE UNDER SLAB AREAS		
ADVANTAGES	**DISADVANTAGES**	**COMMENTS**
1. A Slab Area with Void Space below allows Expansive Soils to swell into the Void Space, thereby reducing the risk of foundation Heave. 2. Slab Areas that are elevated above the surrounding grade are less affected by surface water prior to concrete placement. 3. Allows the construction of Slab Areas on sites with inadequately compacted, untested soil or other soil conditions that may not be suitable to support the construction of grade-supported foundations.	1. Creates a path for water to migrate below the slab, particularly when the bottom of the Void Space is near or below adjacent grade (e.g. in carport or garage foundations). 2. When paper products are utilized, termites may be attracted to Carton Forms as a limited food source. 3. Usually increases cost of the design and construction. 4. Concrete may enter the Carton Form during placement if grade stakes (commonly used to set the elevation of the slab) are driven through the Carton Forms.	1. Only Degradable Void Space (Carton Form) Systems should be used under Slab Areas. 2. Collapsible and Non-Collapsible Void Space Systems should not be used under Slab Areas. The combination of the dead plus sustained live loads of the foundation and Superstructure and inherent stiffness of the typical Slab Area is not sufficient to collapse this type of material and thereby causes transfer of the uplift forces through the non-collapsed Void Space Systems to the above Slab Area This may cause foundation uplift. 3. Installation of expendable cover sheets such as ¼” hardboard directly above Slab Area Carton Forms may facilitate construction by effectively supporting concentrated loads during construction. 4. Improper Carton Form installation can result in a void height that is inadequate to provide for anticipated soil expansion. 5. Current moisture content of upper soil needs to be considered. Wet soil conditions may compromise the load carrying capacity of degradable Carton Forms prior to concrete placement. 6. Carton Forms can be treated to resist mold and termites.

3.2 VOID SPACE SYSTEMS UNDER GRADE BEAMS

For a Slab Area designed with a degradable Void Space (Carton Form) material, Void Space Systems under the grade beams will typically be required if the uplift forces from the soil, applied to the area of the grade beams in contact with the soil, are greater than the dead load plus sustained live load of the foundation and Superstructure. Swell pressures from Expansive Soils may exceed several thousand pounds per square foot while the dead load plus sustained live load of the Foundation and Superstructure are typically only several hundred pounds per square foot.

As explained in Section 1.0, *Void Spaces under the grade beams should only be used when Carton Forms are also used under the Slab Area***.** Advantages, disadvantages and comments of utilizing Carton Forms under grade beams are addressed in Table 3.2-1, below.

TABLE 3.2-1	**VOID SPACE SYSTEMS UNDER GRADE BEAMS**	
ADVANTAGES	**DISADVANTAGES**	**COMMENTS**
1. Allows total isolation of the upper foundation soffit (i.e., the underside of the Slab Area and grade beams) from the active soils. 2. If a sufficient Void Space is maintained under the foundation, and the deeply supported foundations are founded sufficiently below the moisture active zone, then Potential Upward Movement of the foundation will be reduced or eliminated.	1. The bottoms of the beams are typically placed below grade and therefore allow water to collect in the Void Space. 2. Usually prolongs the installation time. 3. Usually increases cost of the design and construction. 4. Due to inclement weather conditions, the entire foundation makeup may need to be removed in order to replace damaged or wet Carton Forms.	1. Improper Carton Form installation can result in void height or width that is insufficient to provide for anticipated soil expansion. 2. In order to eliminate the need for Void Spaces under the grade beams, the geotechnical engineer must determine the uplift pressures of the soils and therefore will have to perform additional testing and engineering 3. The geotechnical engineer should include recommendations in the geotechnical report considering the possibility that water may collect in the Void Space. 4. Polyethylene sheathing (normally used for the vapor retarder) should be used on *both* sides of interior *and* exterior grade beams to reduce the adhesion forces that add to the design uplift forces at the bottom of the grade beams. Corrugated plastic sheets from 1/8” to 1/2” in thickness can also achieve the smooth sides against the soil. 5. Unless the Carton Forms are Fully Wax Impregnated, Carton Forms should not be used after becoming wet. Fully Wax Impregnated Carton Forms may be used after complete drying and it has been determined that the carton forms will support the necessary loads.

3.3 DESIGN CONSIDERATIONS

Following are miscellaneous considerations for the design of Void Space Systems.

3.3.1 Earth-Formed Beams

If the foundation design engineer desires earth-formed grade beams without a Void Space below the grade beams, the following design procedure should be considered:

a) Determine the maximum uplift forces of the soil and compare the capacity of the grade beams with that force applied to the bottom of the grade beams. If the dead load on the beam is equal to or greater than the uplift force, no additional design is necessary. If the uplift force is greater, the grade beams need to be designed for this upward force minus the dead load, and the piers should then be designed for the proper depth below the moisture active zone to resist this uplift.

b) There are two uplift forces to be considered: bearing on the bottom of the grade beams and side friction between the soil and sides of the beam. One method of determining these forces is to provide swell tests to determine the surcharge needed for zero swell and use the shear capacity of the soil for the side friction. The actual determination of these forces is not in the scope of this document.

c) It would be a reasonable assumption that, if the above items were accounted for and the actual forces are the same or lower than assumed, Void Space would not be necessary under the grade beams.

The following sections present comments on the design of Void Space Systems:

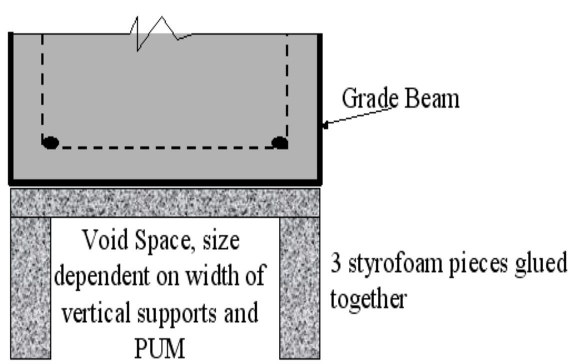
3.3.2 Degradable Carton Forms (under Slab Areas, grade beams, and pier caps)

The collapsed or degraded height of the Carton Form materials is important for the design of the gross vertical height of the Void Space. The gross vertical height of the Void Space should include the collapsed or deformed height plus the required Void Space height dictated by the geotechnical engineer.

3.3.3 Collapsible Void Space Materials (under grade beams only)

The Void Space height dictated by the geotechnical engineer should be increased by the collapsed height of the Void Space material.

3.3.4 Non-Collapsible Void Space Materials (under grade beams only)



When using Non-Collapsible Void Space materials, the excavated Void Space prior to installation should be large enough to compensate for the volume of the permanent Void Space material (see Figure at right). The net volume of the Void Space should be sufficient to accept the heaving soils. The Void Space material in contact with the soil should be able to support the wet weight of the concrete grade beams above but should not be able to support the dead plus sustained live loads of the foundation and Superstructure.

3.4 DESIGN LOADS

All Void Space System products shall be capable of supporting the construction loads until the concrete sets and becomes self-supporting while maintaining the design Void Space (between the soil and the concrete) as indicated on the foundation design drawings. In addition to the weight of the wet concrete construction loads include, as a minimum, personnel and equipment during the construction process and the concentrated loads from reinforcing steel chairs.

The following load specifications as shown in Table 3.4-1 should be given to the Carton Form supplier:

TABLE 3.4-1	REQUIRED DESIGN LOADS FOR VOID SPACE SYSTEMS			
		VOID SPACE SYSTEM MATERIAL TYPE[1]		
			NON-DEGRADABLE	
CRITERION	CONDITION[1, 3]	DEGRADABLE	COLLAPSIBLE[2]	NON-COLLAPSIBLE
Minimum *Initial* Ultimate Uniform Load Collapse Pressure (as shipped, dry) [PSF]	Slabs with t ≤12” thick Slabs with t > 12” Beams with d ≤ 36” Beams with d > 36”	600 456 + 12t 1000 568 + 12d	Do not use Do not use 600 168 + 12d	Do not use Do not use 600 168 + 12d
Maximum *Initial* Ultimate Uniform Collapse Pressure (as shipped, dry) [PSF]	Slabs with t ≤12” thick Slabs with t > 12” Beams with d ≤ 36” Beams with d > 36”	1500 1356 + 12t 1500 1068 + 12d	Do not use Do not use 1000 568 + 12d	Do not use Do not use No limit No limit
Maximum *Final* Ultimate Uniform Collapse Pressure (at 100% humidity for 7 days) [PSF]	Slabs with t ≤12” thick Slabs with t > 12” Beams with d ≤ 36” Beams with d > 36”	12t 12t 12d 12d	Do not use Do not use 1000 568 + 12d	Do not use Do not use No limit No limit

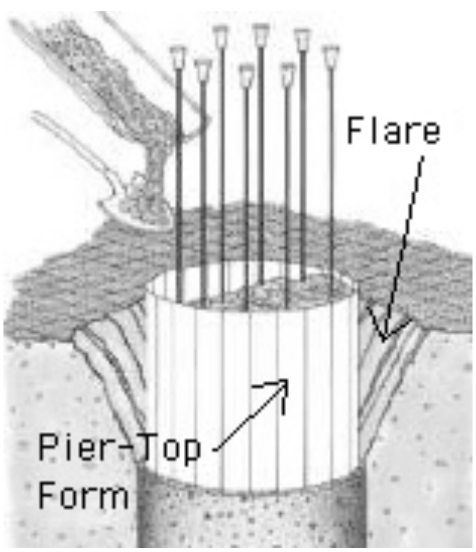
Notes:
1. t = slab thickness [inches]; d = grade beam depth [inches], measured from the top of the slab to the bottom of the beam
2. The foundation design engineer should verify the maximum ultimate collapse pressure.
3. The slab values should also be used for pier caps.

3.5 FORMS AROUND THE TOPS OF THE PIERS

In order to reduce the uplift pressures on pier shafts, the top two-foot portion of each drilled pier may be formed to the specified shaft diameter. The advantages, disadvantages and comments of using forms around the tops of piers are shown in Table 3.5-1, below.

TABLE 3.5-1 FORMS AROUND THE TOPS OF THE PIERS		
ADVANTAGES	**DISADVANTAGES**	**COMMENTS**
1. By eliminating the flair at the top of the pier, the contact area between the soils and the pier will be reduced, thereby reducing potential uplift pressures. 2. By eliminating the flair at the top of the pier, concrete waste is eliminated.	1. Additional cost of materials. 2. Additional labor to install.	1. If pier-top forms are not specified, then the uplift pressures on the flair should be accounted for in the uplift design calculations. 2. Available in 2-foot long sections. 3. Forms around the top of piers are typically used when the elevation at the top of the pier is near the ground surface.

Figures showing the application of forms at the top of piers are given below:



Forms around the upper 2 feet of piers eliminate flaring

The intersection of the grade beam and pier correctly isolated by using a pre-manufactured, non-field cut, cemented Carton Form with a curved, radial, vertically supported edge adjacent to pier.

Piers within uniform thickness Structural Slabs are correctly isolated from the soils by using a pre-manufactured, non-field cut, cemented Carton Form with a curved, radial, vertically supported edge adjacent to pier.

3.6 DESIGN PROCEDURE

Following is an example procedure to design a Void Space System:

a) A geotechnical investigation and report should be in accordance with the requirements of Document No. FPA-SC-04, *Recommended Practice for Geotechnical Explorations and Reports* and / or other guidelines acceptable to the foundation design engineer.

b) The foundation design engineer decides whether or not to utilize a Void Space System based on recommendations from the geotechnical report and discussions with the client.

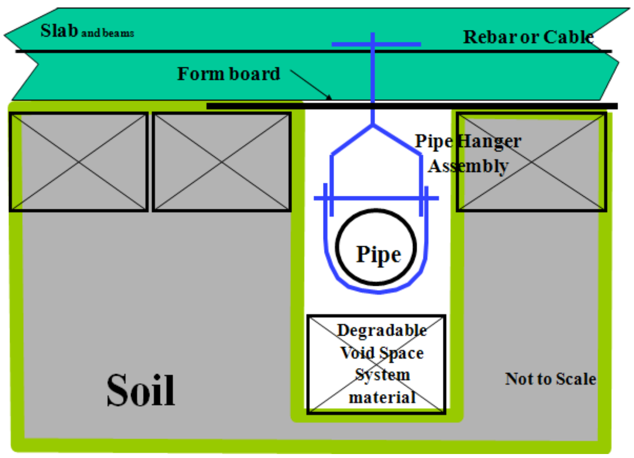
c) The geotechnical report shall include recommendations needed by the foundation design engineer to design the Void Space System, in particular the net height of Void Space (PUM) required below the bottom of the slab and grade beams.

d) The foundation design engineer specifies the Void Space height and Void Space System on the design drawings and / or specifications based on recommendations of the net height of Void Space (PUM) recommended by the geotechnical engineer.

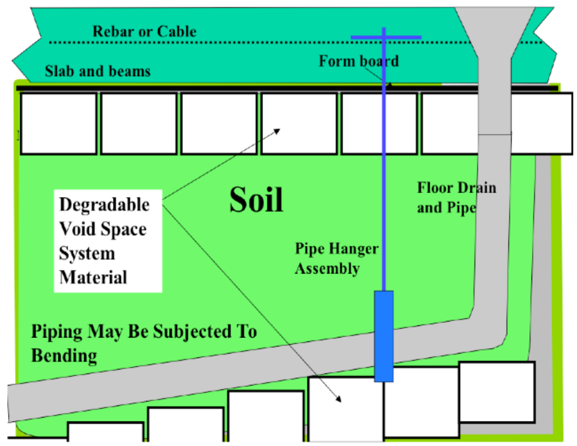
3.7 CONSIDERATIONS FOR UNDER-SLAB UTILITIES

Under slab utilities must be carefully designed for locations where a considerable Void Space may develop between the slab and the soil. Expansive Soils should not support under slab utilities below a Structural Slab. Under slab piping must remain stationary with respect to the slab. The distance between the slab and the buried utilities may change as the soil moisture changes. These changes could cause the utility lines to disconnect, start leaking or otherwise fail. Industry experience indicates that such under slab problems (costly to repair) tend to develop frequently for locations with PUM values over 4 inches. There are various methods to accommodate such differential movement by using designs that allow the utilities to adjust to the changing conditions. The piping design beneath the foundation must take into consideration the differential movement between the interior stationary piping and the soil outside the foundation, and any associated bending stresses.

The following illustrations serve as an example a designer may follow to reduce the likelihood of such utility failures:



Under Floor Piping –Front Detail



Under Floor Piping – Side Detail

4.0 SPECIFICATIONS FOR VOID SPACE MATERIALS

The following specifications are to be provided by the purchaser (e.g., general or foundation contractor) to the Void Space material supplier and / or manufacturer.

4.1 SPECIFICATIONS FOR ALL VOID SPACE MATERIAL TYPES

Following are some general specifications applicable to all types of Void Space materials:

a) Unless otherwise shown or specified, design, place, and maintain Void Spaces between cast-in-place concrete and the soil in compliance with the American Concrete Institute Standard *Guide to Formwork for Concrete*, ACI 347 (Table 4.1 and the reference number 4.12) [3] and / or Ziverts, G. J., *A Study of Cardboard Voids for Prestressed Concrete Box Slabs*, PCI Journal, V. 9, No. 3, 1964, pp. 66-93, and V. 9, No. 4, pp. 33-68 [6].

b) Manufacturer should submit product data sheets and test information for the Void Space materials and Soil Retainers, if applicable, to the foundation design engineer who then verifies compliance with the specifications.

c) Void Space materials shall be designed by the manufacturer to support all vertical and lateral loads that might be applied until such loads can be supported by the concrete structure. These loads include, but are not limited to, live load, dead load, weight of moving equipment, effects of the concrete drop, vibration, and other concrete placement loads, ambient temperature, and vertical and lateral soil pressures.

d) The contractor shall maintain the Void Space materials prior to concrete placement.

e) Soil Retainers are placed at the sides of Void Space forms to resist soil intrusion during the construction process that may compromise the Void Space. See photographs below for examples of Soil Retainer installation. During the design life of the foundation, the lateral forces of Expansive Soil can be greater than these Soil Retainers are able to resist. Therefore, the amount of Void Space under the grade beams should be designed to accept this potential lateral soil expansion. See figures below for examples of Soil Retainers.

Figures showing two applications of Soil Retainers are given below:

Example of a high-density polyethylene (HDPE) Soil Retainer manufactured of materials that are not adversely affected by moisture.

Example of Soil Retainers adjacent to Carton Forms placed under grade beams

4.2 DEGRADABLE VOID SPACE (CARTON FORM) MATERIALS

Differences in climate, use, or site conditions may affect the selection of Void Space (Carton Form) material properties, including strength and moisture response. Following are considerations for specifying degradable Void Space materials:

a) The Carton Form components should be constructed of corrugated fiberboard liners and mediums that are laminated with moisture resistant adhesive. *F*ully Wax-Impregnated corrugated fiberboard is not acceptable as a degradable Void Space material due to resistance to deterioration.

b) The interior construction of the Void Space material should be of a uniform, cellular configuration.

c) If the product employs Wax Impregnation, the soil bearing area should *not* be Wax Impregnated to ensure that the intended strength loss occurs.

d) Degradable Carton Forms should be the product of a manufacturer engaged in the commercial production of Carton Forms.

e) Carton Form products may be treated with registered Environmental Protection Agency (EPA) biocides and fungicides that resist mold, mildew, spore infestation, and pests.

f) Types of degradable corrugated paper shall be either plain paper, plain paper with water-resistant adhesive, or Wax Impregnated medium paper as detailed below:

1) **Plain Paper** has no moisture resistance and is used in low moisture and low humidity environments. This type of paper employs regular adhesive and no wax or chemical water repellant. This fully degradable paper is extremely susceptible to moisture and, once wetted, cannot be used.

2) **Plain Paper with Water-resistant Adhesive** has some moisture resistance and is used in low-to-average moisture environments. This type of water-resistant paper has no wax or chemical water repellant. This fully biodegradable paper is susceptible to moisture and will maintain its shape when lightly wetted if there is no imposed load and, once wetted, cannot be used.

3) **Wax Impregnated Medium Paper and Wax Coated Exterior Paper** has some moisture resistance and is used in average-to-moist conditions in areas with moderate humidity. This corrugated paper medium is Wax Impregnated and is made with water-resistant adhesive. This partially biodegradable paper holds its shape when wet, with no imposed load and, this product cannot be used once wetted.

4.3 COLLAPSIBLE VOIDS (UNDER GRADE BEAMS ONLY)

a) Materials may be comprised of fully Wax Impregnated corrugated paper product, plastic, or other non-degradable products. The net volume of the collapsed Void Space should be sufficient to accept the heaving soils. The Void Space materials should collapse under the combined weight of the foundation and Superstructure above, but should be sufficiently stiff to withstand the weight of the foundation and associated construction loads during concrete placement.

b) Collapsible Carton Forms should be the product of a manufacturer engaged in the commercial production of Carton Forms.

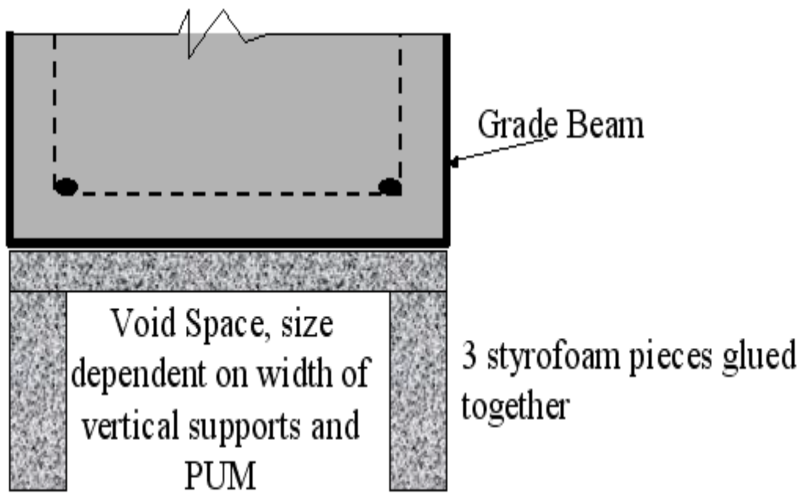
c) Carton Form products may be treated with registered Environmental Protection Agency (EPA) biocides and fungicides that resist mold, mildew, spore infestation and pests.

d) Fully Wax Impregnated corrugated Carton Forms are resistant to deterioration in strength due to moisture and are *not* considered to be biodegradable.

4.4 NON-COLLAPSIBLE VOID SYSTEMS (UNDER GRADE BEAMS ONLY)

Non-collapsible Void Space Systems are intended to permanently remain intact under the grade beams.

An example of a non-collapsible Void Space System is shown below:



4.5 TRAPEZOIDAL CARTON FORMS

Trapezoidal Carton Forms *should not* be specified for the reasons that follow:

a) This shape is designed to form concrete Soil Retainers at the sides of Void Space below a cast-in-place concrete grade beam or wall, but the intended result is difficult to achieve, and therefore may be inappropriate for use as a Void Space System.

b) These retainers are designed to resist lateral pressures from the expanding soil on the concrete grade beam or wall, but the result is seldom achieved due to the concrete on the sides of the Void Space lacking reinforcement and sufficient thickness into the intended retainer area. In practice, this may result in locations that are devoid of concrete.

c) There is also evidence that under certain conditions trapezoidal Carton Forms do not perform as intended due to the lack of sufficient interior vertical supports [5].

See results of installed trapezoidal Carton Form in the two photos below:

Photos showing examples of trapezoidal Carton Forms that lack continuous concrete to function as a Soil Retainer at the bottom of grade beams

4.6 TESTING REQUIREMENTS

An independent testing laboratory shall qualify the strength of every "unique Void Space material". A "unique Void Space material" is defined as a system having a different height, geometry, application, structure, composition, or coating. In order for a Void Space System to be considered acceptable under this document, it shall be tested by an independent laboratory in accordance with the following minimum requirements:

a) There shall be a minimum of three (3) test samples, randomly selected by the independent laboratory.

b) The test samples shall have a minimum length equal to twice the depth of the test sample.

c) The test samples shall have a repetitive cell pattern of at least two adjacent cells in each horizontal direction.

d) The test pressure at failure shall be the pressure where either the deflection increases without additional pressure, or the total vertical deformation exceeds 5% of the original vertical dimension of the Void Space materials.

e) The test pressure at failure applied to each sample shall be within plus or minus 10% of the stated average failure pressure of all the samples.

f) The test pressure shall be uniformly applied to the test sample.

4.7 SUBMITTALS

As a minimum for each Void Space System being supplied, the following shall be provided to the foundation design engineer for review:

a) Product data sheets describing properties such as, but not limited to, geometry, dimensions, materials, coatings, and test results.

b) If requested, certified laboratory test data.

5.0 HANDLING AND INSTALLATION OF VOID SPACE SYSTEMS

This section provides considerations for onsite protection, quality control, and installation concerns of Void Space Systems.

5.1 ONSITE VOID SPACE SYSTEMS PROTECTION

Following are recommendations for proper onsite protection of Void Space materials to help ensure performance as designed:

a) Store Void Space materials in accordance with manufacturer's recommendations.

b) Store degradable Void Space Systems and accessories on an elevated area, not directly in contact with the ground.

c) Onsite Void Space System materials shall be protected against the elements as applicable and other means of damage prior to installation, preferably in an enclosed transport trailer or other storage container.

d) Do not install or use water sensitive Void Space materials that have been damaged.

5.2 INSTALLATION

Care should be given during the installation of the Void Space material in order to ensure that it is installed according to the manufacturer's recommendations. Below are some specific guidelines:

a) Assemble knockdown (unassembled) products as recommended by the manufacturer to develop designed strengths.

b) Degradable Carton Forms should have access to moisture in order to properly deteriorate. The degradable Carton Forms should not be wrapped in polyethylene. In addition, a moisture retarder (polyethylene) should not be used below degradable Carton Forms because this may *not* allow deterioration from the subgrade below.

c) Place a protective covering over Void Space Systems as necessary to distribute working load, bridge small gaps, and protect the materials from puncture and other damage during concrete placement. A protective fiberboard may be used on top of all Void Space Systems, which helps distribute concentrated construction loads from rebar bolsters, personnel, etc. Protective fiberboard less than 1/8" may curl and is not recommended. Plywood or OSB board is not recommended because of the possibility of termite infestation. See below photo showing placement of fiberboard coverings.

Protective fiberboard sheets being placed over Carton Forms

d) The foundation design engineer should be assigned an active roll in the construction procedures to ensure that Void Space Systems are installed per the specifications during construction.

e) Use end caps to seal exposed ends adjacent to pier locations.

f) Use seam pads, polyethylene sheeting, or protective fiberboard to cover open joints to prevent concrete intrusion.

g) Protect degradable Void Space (Carton Form) Systems from moisture. Replace wet or damaged materials before placing concrete.

h) Ensure that there is positive drainage away from the foundation.

i) Void Space Systems should be properly placed and anchored to prevent displacement or flotation during placement of concrete.

j) It is acceptable to place moisture retarder over the top of the Carton Forms. Collapsible Void Systems may be wrapped with a moisture retarder as long as the entrapped air has a method of escaping prior to concrete placement.

k) Following are installation comments and concerns of Void Space Systems:

- Selection of paper type
- Void Space System minimum and maximum strength (psf)
- Pre-manufactured Void Space System eliminates field cutting
- Fiberboard protection for Void Space System
- Minimize openings to prevent concrete from flowing into Void Space System
- Concentrated loads on Void Space Systems such as from rebar chairs
- Moisture retarder in wrong location
- Onsite weather protection
- Size of concrete pour
- Labor force (size and skill level)
- Weather conditions
- Insufficient soil moisture for degradable Void Space System

6.0 REFERENCES

1. 2006 International Building Code, International Code Council

2. 2006 International Residential Code, International Code Council

3. American Concrete Institute Standard *Guide to Formwork for Concrete*, ACI 347 (Table 4.1 and the reference number 4.12)

4. Foundation Performance Association, Document No. FPA-SC-01-0, *Foundation Design Options for Residential and Other Low-Rise Buildings on Expansive Soils*, 30 June 2004.

5. Isbell, David K., *Performance Of Cardboard Carton Forms*, presented to the Foundation Performance Association on 21 February 2001.

6. Ziverts, G. J., *A Study of Cardboard Voids for Prestressed Concrete Box Slabs*, PCI Journal, V. 9, No. 3, 1964, pp. 66-93, and V. 9, No. 4, pp. 33-68