SLAB-ON-GRADE UNDERLAYMENT

LITERATURE SEARCH AND INDUSTRY SURVEY RESULTS

Prepared by CGEA Board Members

JULY 2007

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INTRODUCTION

For quite some time, geotechnical engineers have provided language in their reports that relate to curing of concrete slabs-on-grade, e.g. a sand cushion; mitigation of moisture transmission through the concrete slab-on-grade, e.g. a moisture vapor retarder/barrier; as well as a capillary break. To develop an understanding of the industry practice, a committee was assembled at CGEA's April 2005 annual meeting in Kauai, Hawaii to look into the relationship between the geotechnical engineering profession and current concrete slab-on-grade construction practices, specifically with regard to slab underlayment elements.

In the weeks following the annual meeting a simple questionnaire was developed and a total of seven member firms offered samples of their recommendations for slab underlayment treatment. In reviewing the practice of member firms representing both northern and southern California, there was no clear consensus regarding the recommendations that geotechnical engineers should provide relative to slab-on-grade construction. Based on the interest shown by the member firms, the Board of Directors of CGEA decided to perform a comprehensive search of the related literature.

The literature search was completed just before the CGEA's April 2006 annual meeting in Ojai, California. Based on the results of this literature search and the limited number of the participants in the original survey, the Board decided to extend the survey to all member firms. In October 2006, a questionnaire was sent to all member firms. A total of 50 individuals from 39 member and one non-member firms responded to this questionnaire. The results were summarized in series of tables and together with a summary of literature search conducted earlier were presented in the CGEA's April 2007 annual meeting in San Francisco, California. This presentation followed by a roundtable discussion by the conference participants. Further, a portion of attendees, who did not get a chance to participate in the October 2006 survey, contributed their comments to the database.

The following presents the results of the literature search conducted on the subject as well as the results of survey participated by 70 individuals from 58 companies in northern and southern California.

RESEARCH

Vapor Retarder/Vapor Proof Membrane

ACI Manual of Concrete Practice, 2006, Part 5, Design of Slabs on Grade, ACI 360R-92, Chapter 9 Reducing the Effects of Slab Shrinkage and Curling, 9.8 Subgrade and vapor barriers.

The information provided includes the following:

- Vapor barriers in direct contact with the slab are discouraged because they increase slab curling as explained below.

- Vapor barrier design should receive the same attention as the design of a roof membrane. The barrier should be covered with at least 3 inches of fine granular material to provide a permeable, absorptive base directly under the slab. However, using 6 inches or more of this material over the barrier will improve constructability and minimize damage.

- If the subgrade is kept moist by groundwater or if the slab is placed on a wet subgrade, then this will increase upward curl.

ACI Manual of Concrete Practice, 2006, Part 5, Guide for Concrete Floor and Slab Construction, ACI 302.1R-04, Chapter 3 Design Considerations, 3.2.3 Moisture protection.

Under this heading, considerable guidance is provided, including the following selected information:

- Proper moisture protection is essential for any slab-on-ground where the floor will be covered by moisture-sensitive flooring materials such as vinyl, linoleum, wood, carpet………… or environment exist, such as humidity-controlled or refrigerated rooms.

- A vapor retarder is a material that is intended to minimize the transmission of moisture upward through the slab from sources below. The performance requirements for plastic vapor retarder materials in contact with soil or granular fill under concrete slabs are listed in ASTM E1745. It is generally recognized that a vapor retarder should have a permeance (water vapor transmission rate) of less than 0.3 perms, as determined by ASTM E96.

- Although conventional polyethylene film with a thickness of as little as 6 mils has been used, the committee strongly recommends that the material be in compliance with ASTM E 1745 and that the thickness be no less than 10 mils.

- A number of vapor retarder materials have been incorrectly referred to and used by designers as vapor barriers. True vapor barriers are products that have a permeance (water vapor transmission rating) of 0.00 perms when tested in accordance with ASTM E96.

- The decision to locate the vapor retarder or barrier in direct contact with the slab or beneath a layer of granular fill should be made on a case-by-case basis. For moisture sensitive floor covering materials and environments, placing concrete in direct contact with the vapor retarder or barrier eliminates the potential for water from sources such as rain, saw-cutting, curing, cleaning, or compaction to become trapped within the fill course.

- The anticipated benefits and risks associated with the specified location of the vapor retarder should be reviewed with all appropriate parties before construction. Figure 3.1 can be used to assist this evaluation. (Include Fig. 3.1)

ACI Manual of Concrete Practice, 2006, Part 3, Requirements for Residential Concrete Construction and Commentary, ACI 332-04, Chapter 8 Slabs-On-Ground, 8.1 Design.

No mention is made of a vapor retarder or vapor proof membrane; however, Commentary R8.1 states in part "In addition, refer to the International Residential Code for applicable requirements concerning vapor retarder, granular base drainage, waterproofing, and damp-proofing requirements."

ACI Manual of Concrete Practice, 2006, Part 3, Guide to Residential Cast-in-Place Concrete Construction, ACI 332R-84, Chapter 9 Concrete Slab Construction 9.2 Site Preparation, 9.2.2 Vapor Barriers.

This section states "Vapor barriers are waterproof membranes of 4 to 6 mil (0.10 to 0.15 mm) polyethylene or roofing paper. They should be resistant to deterioration as well as to puncture by construction traffic."

Additionally, the ACI Manual further states "Vapor barriers should be overlapped 6 inches (150 mm) and sealed at the joints and should be carefully fitted and sealed around all slab openings."

2003 International Residential Code for One- and Two-Family Dwellings, R506, Concrete Floors (On Ground), 506.2.3 Vapor Retarder.

This document states a 6-mil polyethylene or approved vapor retarder with joints lapped not less than 6 inches shall be placed between the concrete floor slab and the base course or the prepared subgrade where no base exists.

Exception; The vapor retarder may be omitted:

1. From garages, utility buildings and other unheated accessory structures.
2. From driveways, walks, patios and other flatwork not likely to be enclosed and heated at a later date.
3. Where approved by the building official, based on local site conditions.

The Portland Cement Association (PCA) EB001.13T, Design and Control of Concrete Mixtures, Chapter 9 Placing and Finishing Concrete.

This section includes the following statement "A vapor barrier should be placed under all concrete floors on ground that are likely to receive an impermeable floor finish or be used for any purpose where the passage of water vapor through the floor is undesirable."

Post-Tensioning Institute – Design and Construction of Post-Tensioned Slabs-on-Ground, Third Edition, 2004, Ch. 9 Installation and Field Procedures, 9.2 Moisture Barrier.

This document states in part "A moisture barrier may be placed over the subgrade material after the beams are formed. When specified, the moisture barrier shall be taped adequately to provide a continuous moisture barrier under the entire slab."

Post Tensioning Institute – Frequently Asked Questions: Slab-on-Ground Construction, July 2001, Issue No. 3.

"Based on comments that were received, the consensus opinion of specialists in the design and construction of post-tensioned slabs-on-ground is that a vapor retarder be placed beneath all post-tensioned slab-on-ground foundations used for residential applications and that the retarder be placed on top of the leveling sand"

Post-Tensioning Institute – Construction and Maintenance Procedures Manual for Post-Tensioned Slab-On-Ground Construction May 2006, Chapter 4 Building Pad Preparation, Section: 4.3 *Vapor Barrier*.

This document states in part "A plastic vapor barrier or vapor retarder may be placed over the prepared subgrade material, if required by the engineer's drawings or geotechnical report. When required, the vapor barrier should be lapped to provide a continuous sheet under the entire slab."

ASTM E1643 Standard Practice for Installation of Water Vapor Retarders Used in Contact with Earth or Granular Fill Under Concrete Slabs.

This standard provides guidance *on installing* flexible, prefabricated sheet membranes in contact with earth or granular fill used as vapor retarders under concrete slabs. ASTM E1643 references ACI 302.1R Guide for Concrete Floor and Slab Construction (which has been superseded by ACI 3021R.04, effective March 23, 2004). In its Appendices, ASTM E1643 advises the Architect to "….plan the organization and coordination of drawings and specifications so that graphic, dimensional, and descriptive information on subgrade, granular base, vapor retarder, and protection course, if any, appears in only one place." And further, to paraphrase, architectural drawings are the preferred location for graphic depictions and dimensions of the granular base and protection course, but structural drawings are sometimes used. To continue paraphrasing, specifications for base, vapor retarder, and protection course should be in the section on concrete. ASTM E1643 references the geotechnical discipline by describing that "the geotechnical survey includes comprehensive and reliable information on subsurface water table levels and the hydrology of geological strata as well as historical data on surface flooding and hydrology." It further states that "Soils with comparably higher clay contents are particularly troublesome because the relatively high capillary action within the clay allows moisture to rise under the slab." All of the information in the Appendices is noted to be "non-mandatory information."

ASTM E1745 Standard Specification for Plastic Water Vapor Retarders Used in Contact with Soil or Granular Fill under Concrete Slabs.

This specification covers flexible, preformed materials to be used as vapor retarders and defines vapor retarder (formerly vapor barrier) as “a material or construction that impedes the transmission of water vapor under specified conditions.” Classifications of vapor retarders are further defined by the parameters of (1) water vapor permeance, (2) tensile strength and (3) puncture resistance. It should be noted that all three classes have the **same** water vapor permeance value of 0.3 perms. The differences are with respect to tensile strength and puncture resistance where Class A has the highest values and Class C has the lowest values.

<u>Capillary Break</u>

ACI Manual of Concrete Practice, 2006, Part 5, Design of Slabs on Grade, ACI 360R-92, Chapter 3 Soil Support Systems for Slabs On Grade.

This chapter discusses the various soil types that may be encountered referencing the Unified Soil Classification System and that typical slab-on-grade construction may involve a base course and a subbase course beneath the slab depending on the supporting value of the subgrade materials. No mention is made of a capillary break.

ACI Manual of Concrete Practice, 2006, Part 5, Guide for Concrete Floor and Slab Construction, ACI 302.1R-04, Chapter 3 Design Considerations, 3.2 Slabs-on-ground, 3.2.1 Required Design Elements.

This section states in part: The following items should be specified in the contract documents by the designer: base and subbase materials, preparation requirements, and vapor retarder, if required.

ACI Manual of Concrete Practice, 2006, Part 3, Requirements for Residential Concrete Construction and Commentary, an ACI Standard, ACI 332-04, Chapter 8 Slabs-On-Ground 8*.2.2 Base*.

This section states that a 4-inch-thick base course consisting of clean graded sand, gravel, crushed stone, or crushed blast-furnace slag passing a 2-inch sieve shall be placed on the prepared subgrade when the slab is below grade.

ACI Manual of Concrete Practice, 2006, Part 3, Guide to Residential Cast-in-Place Concrete Construction, ACI 332R-84, Chapter 9 Concrete Slab Construction, 9.2, Site Preparation, 9.2.1 Subgrade and Drainage.

This section states that where the bearing or grade is not uniform, especially in clay or other cohesive soils, it is desirable to fill at least the top 4 inches with gravel, crushed stone or sand subbase. Fill coarse enough to be retained on a No. 4 sieve is widely used when it is desirable to interrupt capillarity between the slab and the soil.

2003 International Residential Code for One- and Two-Family Dwellings, R506, Concrete Floors (On Ground), 506.2.2 Base.

This section states that a 4-inch-thick base course of clean graded sand, gravel, crushed stone or crushed blast-furnace slag passing a 2-inch sieve shall be placed on the prepared subgrade when the slab is below grade.

The Portland Cement Association (PCA) EB001.13T, Design and Control of Concrete Mixtures.

This section states that many of the moisture problems associated with enclosed slabs on ground (floors) can be "minimized or eliminated" by the following five treatments: (1) sloping landscaping away from buildings, (2) using a 4-inch granular subbase to form a capillary break between the soil and the slab, (3) providing drainage for the granular subbase to prevent water from collecting under the slab, (4) installing foundation drain tile, and (5) installing a vapor barrier. Continue to provide appropriate recommendations for commercial slab-on-grade elements.

Post-Tensioning Institute - Design and Construction of Post-Tensioned Slabs-on-Ground, Third Edition, 2004.

This document makes no reference to a capillary break.

Post-Tensioning Institute – Construction and Maintenance Procedures Manual for Post-Tensioned Slab-On-Ground Construction October, 1998, Chapter 4 Building Pad Preparation.

No mention is made of a capillary break in this document.

Sand Above/Below Vapor Retarder

ACI Manual of Concrete Practice, 2006, Part 5, Design of Slabs on Grade, ACI 360R-92, Chapter 9 Reducing the Effects of Slab Shrinkage and Curling, Para. 9.8 Subgrade and vapor barriers.

The information provided includes the following:

- Vapor barriers in direct contact with the slab are discouraged because they increase slab curling.

- The barrier should be covered with at least 3 inches of fine granular material to provide a permeable, absorptive base directly under the slab.

- If polyethylene is required only to serve as a slip sheet to reduce friction between the slab and subgrade, and the subgrade is to remain dry, then the polyethylene can be installed without a stone and sand cover.

ACI Manual of Concrete Practice, 2006, Part 5, Guide for Concrete Floor and Slab Construction, ACI 302.1R-04, Chapter 3 Design Considerations, 3.2.3 Moisture protection.

This section states in part:

The decision to locate the vapor retarder or barrier in direct contact with the slab or beneath a layer of granular fill should be made on a case-by-case basis. For moisture sensitive floor covering materials and environments, placing concrete in direct contact with the vapor retarder or barrier eliminates the potential for water from sources such as rain, saw-cutting, curing, cleaning, or compaction to become trapped within the fill course.

ACI Manual of Concrete Practice, 2006, Part 3, Requirements for Residential Concrete Construction and Commentary, ACI 332-04, Chapter 8 Slabs-On-Ground, 8.1 Design.

No mention is made of a vapor retarder or vapor proof membrane, however, Commentary R8.1 states in part “In addition, refer to the International Residential Code for applicable requirements concerning vapor retarder, granular base drainage, waterproofing, and damp-proofing requirements.”

ACI Manual of Concrete Practice, 2006, Part 3, Guide to Residential Cast-in-Place Concrete Construction, ACI 332R-84, Chapter 9 Concrete Slab Construction 9.2 Site Preparation, 9.2.2 Vapor Barriers.

This section states in part “To minimize the drying shrinkage cracking that may occur in a thin slab over a vapor barrier, a 2- to 3-inch layer of damp sand over the vapor barrier has sometimes been used. However, some regard it as impractical because care must be taken to avoid mixing the sand blanket into the concrete during placement.”

2003 International Residential Code for One- and Two-Family Dwellings, R506, Concrete Floors (On Ground), 506.2.3 Vapor Retarder.

This document states a 6-mil polyethylene or approved vapor retarder with joints lapped not less than 6 inches shall be placed between the concrete floor slab and the base course or the prepared subgrade where no base exists.

The Portland Cement Association (PCA) EB001.13T, Design and Control of Concrete Mixtures, p. 108.

This document states in part relative to “vapor barriers directly under concrete”, a 3-inch-thick sand layer may be placed over the vapor barrier.

The Portland Cement Association (PCA) EB075, Concrete Floors on Ground, p.16 “Granular Layers over Vapor Barriers or Retarders”.

This document provides a flow-chart as a guide as to where to place the retarder: Case 1- No retarder required (to be used when there is no vapor sensitive floor covering); Case 2 – Retarder directly below slab (to be used when there is a vapor sensitive floor covering and/or when the slab will be placed with the roof membrane in place); Case 3 – Retarder placed below dry granular sand blanket (to be used in humidity controlled environments with either a low w/c ratio concrete or when the slabs will be paved with the roof membrane in place.

Post-Tensioning Institute – Design and Construction of Post-Tensioned Slabs-on-Ground, Third Edition, 2004, Ch. 8 Note, Plans and Tolerances, Figure 8.2, Section 1.

This figure illustrates that concrete is placed directly over the "continuous moisture barrier" which is placed directly over a sand cushion over the subgrade.

Post-Tensioning Institute, Construction and Maintenance Procedures Manual for Post-Tensioned Slab-On-Ground Construction October, 1998, Chapter 4 Building Pad, 4.4 Leveling Base.

This document states in part "If a vapor barrier is also required, the layer may be placed on top of, in between or below it, depending on the recommendations of the engineer or the geotechnical report."

Post-Tensioning Institute – Construction and Maintenance Procedures Manual for Post-Tensioned Slab-On-Ground Construction May 2006, Chapter 4 Building Pad Preparation, Section: 4.4 Leveling Base.

Section 4.4 states that: "If a vapor retarder is required it should always be placed on top of the leveling base material for ribbed foundations, but may be placed below the leveling base for uniform thickness foundations provided that special attention is given to the method of concrete placement to ensure that the leveling base material is not displaced."

Slab Design (Maximum Water/Cement Ratio)

The Portland Cement Association (PCA) EB001.13T, Design and Control of Concrete Mixtures, p. 108.

This document discusses water-cement ratio in conjunction with the use of vapor barriers as follows. "If concrete is placed directly on a vapor barrier, the water-cement ratio should be low (0.45 or less)."

Post-Tensioning Institute – Construction and Maintenance Procedures Manual for Post-Tensioned Slab-On-Ground Construction October, 1998, Chapter 7.0 Concrete, 7.1 Materials.

This document states in part "The water/cement ratio, entrained air content and use of fly ash and other additives should be recommended by the ready mix concrete supply company and approved by the engineer."

The other references reviewed do not provide guidance, recommendations or specifications for maximum water/cement ratio. The Uniform Building Code and the International Building Code, however, do provide guidelines on the maximum water-cement ratio if the concrete is to be in contact with sulfate concentrations of various degrees.

SURVEY

As stated earlier, a total of 70 individuals from 57 member and one non-member firms responded to our October 2006 questionnaire. Approximately 51 percent of the respondents were from Northern California and 49 percent from Southern California. The results are provided in Tables 1 through 5. The following presents a brief summary of our interpretation of the results. Please note that in interpreting and reporting the results in the following sections the results are rounded to the nearest 5 percent, where appropriate.

Vapor Retarder/Vapor Proof Membrane

Please refer to Tables 1A and 1B.

- No major trend in the use of vapor retarder/vapor proof membrane could be detected between Northern and Southern California respondents

- 85 percent of Northern California and 95 percent of Southern California respondents ALWAYS recommend to place vapor retarder membrane below the slabs.

- 5 percent of the Northern California respondents NEVER recommend to place vapor retarder/vapor proof membrane below the slabs.

- 85 percent of those who responded to membrane thickness question recommend 10 mil vapor retarder membranes; one company recommends 2 layers of the same.

- 5 percent of the respondents indicated that they require a perm rate or water vapor transmission rate (WVTR) for the membrane.

Capillary Break

Please refer to Tables 2A and 2B.

- 80 percent of Northern California respondents and 45 percent of Southern California respondents ALWAYS recommend a layer of capillary break material.

- 20 percent of Northern California respondents and 30 percent of Southern California respondents SOMETIMES recommend a layer of capillary break material.

- 50 percent of the respondents recommend ¾” rock.

- Of those who recommend a capillary break layer, 75 percent recommend a 4 inch thick layer (The recommended capillary break thicknesses range from 2-6 inches).

Sand Below Vapor Retarder

Please refer to Tables 3A and 3B.

- 80 percent the Northern California respondent NEVER recommend a sand layer below the vapor retarder.

- 40 percent of the Southern California respondents ALWAYS recommend a sand layer below the vapor retarder while 50 percent SOMETIMES recommend the same.

- 80 percent of those who recommend sand below vapor retarder in Southern California recommend 2 inches of clean sand (The recommended sand thicknesses range from 1-4 inches).

Sand Above Vapor Retarder

Please refer to Tables 4A and 4B.

- 55 percent of Northern California respondents and 70 percent of Southern California respondents ALWAYS recommend a layer of sand above the vapor retarder.

- 30 percent of Northern California respondents and 15 percent of Southern California respondents NEVER recommend a layer of sand above the vapor retarder.

- 70 percent of those responded recommend 2 inches of clean sand (The recommended sand thicknesses range from 1-3 inches).

Slab Design (Thickness and Maximum Water/Cement Ratio)

Please refer to Tables 5a and 5B.

- 60 percent of the Northern California respondents and 70 percent of Southern California respondents ALWAYS provide recommendations for slab thickness.

- 25 percent of the respondents SOMETIMES provide recommendations for slab thickness.

- 75 percent the Northern California survey participants and 70 percent of Southern California survey participants who responded to thickness question specify 4-inch slab thickness.

DISCUSSION

The design and construction process involves a collaboration of disciplines to produce a set of documents that ultimately results in the installation of a residential or non-residential slab-on-grade. Most of the disciplines involved, e.g. architectural, structural and civil engineering, provide drawings and specification documents that guide the contractor to build the slab-on-grade. The plans and specifications include illustrations and assembly instructions based on calculations performed with references to codes and various documents. The geotechnical contribution to this set of documents is a report wherein the engineer describes the process by which data was obtained, a description of the analyses performed as well as recommendations for the design and construction of the project, which in the case of a building or residence, typically includes a slab-on-grade. The geotechnical information rarely appears on the plans and specifications in any form except by reference in the same manner as the referencing of codes. Just as Caltrans specifications are referred to in the pavement construction portion of the plans, the geotechnical report is referenced in the structural notes, in illustrations of drainage elements as well as in grading plans.

While the committee did not trace the origin of when it became common to discuss slab underlayment in geotechnical reports (one CGEA's 2007 San Francisco annual conference participant remembered that as early as 1963, when he entered the profession, these recommendations were being routinely provided by his firm), most of us would agree it is fairly common today to see discussion of these elements if not recommendations for what these elements consist of, and in some cases, why they are needed. In doing the research to prepare this document, it is apparent that neither geotechnical engineering academics nor geotechnical engineering profession has been the source for slab underlayment design, code requirements, or guidance for construction.

As it is not the intent of this document to direct the geotechnical engineering profession in California regarding how to run their practices, it does seem prudent to acknowledge that slab underlayment is not under the purview of the geotechnical engineer. In researching where reference is made to slab underlayment, it is clear to this committee that organizations such as the American Concrete Institute (ACI), the Portland Cement Association, the American Society of Testing and Materials (ASTM) and the Post-Tensioning Institute (PTI) and the International Residential Code for One- and Two-Family Dwellings are the main contributors to the design and construction practices associated with slab underlayment.

RECOMMENDATIONS

The practice of providing at least some information regarding slab underlayment in geotechnical engineering reports has clearly been in our profession for some time (for more than 44 years). As practices in California differ from north to south and from coastal to inland areas, one set of recommendations regarding slab underlayment likely does not apply. However, when geotechnical engineering reports do provide language for slab underlayment, the reports should include sufficient references to ACI, PCA, ASTM, PTI and the International Residential Code.

While it does not yet appear to be common place in our reports, the committee feels strongly that geotechnical engineering reports should include a statement that we are not experts in the field of moisture vapor transmission. Furthermore, the report should advise that if moisture vapor transmission is a concern to the facility owner, the appropriate experts should be consulted to develop the proper design and construction elements relative to moisture vapor transmission through slabs-on-grade for the particular project.

The committee suggests a similar statement in our reports as follows:

"[Firm's Name] does not practice in the field of moisture vapor transmission evaluation/mitigation. Therefore, we recommend that a qualified person/firm be engaged/consulted with to evaluate the general and specific moisture vapor transmission paths and any impact on the proposed construction. This person/firm should provide recommendations for mitigation of potential adverse impact of moisture vapor transmission on various components of the structure as deemed appropriate."

REFERENCES

ACI Manual of Concrete Practice, 2006, Part 5, Design of Slabs on Grade, ACI 360R-92

ACI Manual of Concrete Practice, 2006, Part 5, Guide for Concrete Floor and Slab Construction, ACI 302.1R-04

ACI Manual of Concrete Practice, 2006, Part 3, Requirements for Residential Concrete Construction and Commentary, ACI 332-04

ACI Manual of Concrete Practice, 2006, Part 3, Guide to Residential Cast-in-Place Concrete Construction, ACI 332R-84

ASTM E1643 Standard Practice for Installation of Water Vapor Retarders Used in Contact with Earth or Granular Fill Under Concrete Slabs

ASTM E1745 Standard Specification for Plastic Water Vapor Retarders Used in Contact with Soil or Granular Fill under Concrete Slabs

2003 International Residential Code for One- and Two-Family Dwellings, R506, Concrete Floors (On Ground)

Portland Cement Association (PCA) EB001.13T, Design and Control of Concrete Mixtures

Portland Cement Association (PCA) EB075, Concrete Floors on Ground

Post-Tensioning Institute – Design and Construction of Post-Tensioned Slabs-on-Ground, Third Edition, 2004

Post-Tensioning Institute – Construction and Maintenance Procedures Manual for Post-Tensioned Slab-On-Ground Construction May, 2006

Post-Tensioning Institute – Frequently Asked Questions, Slab-on-Ground Construction, July 2001

TABLE 1A
Vapor Retarder Recommendation Practice In Northern California

	Recommendation			Specification		
Respondent	**Always**	**Sometimes**	**Never**	**Thickness**	**Permeance**	**ASTM**
1	X			10		
2		X				
3	X			10		
4	X					X
5	X			10		1643
6	X			10		
7		X		15		
8	X			10		
9	X			1745	1745	1745
10	X			10		
11	X			10		
12	X			10		X
13	X			10		
14	X			10		
15	X			10		
16		X		10		
17	X			10		
18		X		10		
19	X			10		
20	X			10		1643
21	X			10		
22	X					
23			X			
24			X			
25	X			10		
26	X			10		
27	X					
28		X		10		
29	X			10		X
30	X			10		
31	X			10		1745
32	X			10		
33	X			10		
34	X					
35	X			10		X
36	X			10		

Table 1B

Vapor Retarder Recommendation Practice in Southern California

	Recommendation			Specification		
Respondent	**Always**	**Sometimes**	**Never**	**Thickness, in**	**Permeance**	**ASTM**
1	X			10		
2	X			2x10		
3	X			10		X
4	X			10		
5	X			10		
6	X					
7	X			15	WVTR	X
8	X					
9	X					
10	X			10		
11	X			10		
12	X			10		
13		X				
14	X			6		
15	X			15		1745
16	x			10		
17	X			10		
18	X			10		
19	X			10		
20	X			10		
21	X			10		
22	X			10		
23	X			10	Max 0.04	1643
24		X		10		
25	X			10	0.05	
26	X			10		
27	X			6		
28	X					X
29	X			10		
30	X			10		
31	X			10		
32	X			10		
33	X			10		
34	X			15		X

Table 2A
Capillary Break Recommendation Practice in Northern California

	Recommendation			Specification	
Respondent	**Always**	**Sometimes**	**Never**	**Material**	**Thickness, in**
1	X			Rock	4
2	X			¾ rock	
3	X			¾ rock	4
4		X		¾ rock	4
5	X			¾ rock	4
6	X			¾ rock	4
7	X			¾ rock	4
8	X			Class 2	4
9		X		Sand or Rock	4
10	X			¾ rock	4
11	X			¾ rock	4
12		X		Class 2	4
13	X			¾ rock	4
14		X		1 rock	4
15	X			¾ rock	6
16	X			Aggregate Base	6
17	X			-	6
18	X			¾ rock	4
19	X			Caltrans	2
20	X			¾ rock	4
21	X			1 rock	4
22	X			¾ rock	4
23	X			¾ rock	4
24	X			¾ rock	4
25		X		¾ rock	4
26	X			Gravel	4
27			X	¾ gravel	4
28		X			
29	X			¾ rock	6
30	X				4
31	X			1 rock	6
32		X			
33	X			¾ rock	4
34	X				4
35	X				4
36	X			SE 30	

Table 2B
Capillary Break Recommendation Practice in Southern California

	Recommendation			Specification	
Respondent	**Always**	**Sometimes**	**Never**	**Material**	**Thickness, in**
1		X		SE 30	2
2	X			¾ rock	4
3		X		Rock	6
4	X	X		¾ rock	4
5	X				
6	X				
7			X		
8			X		
9		X			
10			X		
11			X		
12		X		Clean sand	2
13				¾ rock	2
14		X	X		
15			X		
16			X	¾ rock	4
17	X			CAB	4
18	X			Clean sand	2
19	X			¾ rock	4
20	X			Sand	2
21	X			¾ rock	4
22	X			Sand or Gravel	4
23		X		¾ rock	4 - 6
24	X			¾ rock	4 - 6
25		X		Clean sand	4
26		X		Rock	4
27					
28		X			
29		X		¾ gravel	4
30			X		
31	X				4
32	X			Clean sand	4
33	X			SE 30	4
34	X			½ rock	4

Table 3A

Sand Placement Below Vapor Retarder Recommendation Practice in Northern California

	Recommendation			Specification	
Respondent	**Always**	**Sometimes**	**Never**	**Type**	**Thickness, in**
1	X			Sand	4
2			X		
3			X		
4			X		
5			X		
6			X		
7			X		
8			X		
9			X		
10			X		
11			X	Clean sand	1
12			X		
13			X		
14			X		
15			X		
16			X		
17			X		
18			X		
19	X			Clean sand	1
20			X		
21			X		
22			X		
23			X		
24			X		
25		X			
26			X		
27		X			
28			X		
29			X		
30			X		
31		X		Clean sand	2
32			X		
33			X		
34			X		
35	X			Clean gravel	4
36	X			SE 30	2 - 4

Table 3B
Sand Placement Below Vapor Retarder Recommendation Practice in Southern California

	Recommendation			Specification	
Respondent	**Always**	**Sometimes**	**Never**	**Type**	**Thickness, in**
1		X		SE 30	2
2		X		Clean sand	3
3	X			SE30	4
4			X		
5	X			SE30	2
6	X				
7			X		
8	X				2
9	X				
10	X			Clean sand	2
11			X		
12	X			Clean sand	2
13		X		SE30	2
14		X			2
15		X			
16		X			
17	X			Clean sand	2
18					
19		X			2
20	X				1
21			X		
22	X			Clean sand	2
23		X		SE30	1 - 2
24		X		Clean sand	2
25		X		SE 30	2 – 4
26	X			Clean sand	2
27		X			4
28		X			
29	X			SE 30	2
30		X		% fines < 8	2
31			X		
32		X		Clean sand	2
33		X		SE 30	2
34			X		

Table 4A

Sand Placement Above Vapor Retarder Recommendation Practice in Northern California

	Recommendation			Specification	
Respondent	**Always**	**Sometimes**	**Never**	**Type**	**Thickness, in**
1	X			Sand	1
2		X			2
3	X				2
4		X		SE30	1 ½
5	X			Fine sand	1
6	X			Clean sand	2
7			X	ACI	2
8			X		
9		X		ASTM C 33	2
10	X			Clean sand	1
11	X			Clean sand	1
12	X			ACI	2
13	X			Washed sand	1
14			X		
15			X		
16			X		
17	X			Clean sand	2
18		X		Clean sand	2
19	X			Clean sand	1
20			X		
21	X				1
22			X		
23			X		
24			X		
25			X		
26	X				2
27	X				
28		X		Clean sand	2
29	X			SE 30	2
30	X				2
31		X		< 3% pass #200	2
32	X				
33	X				2
34	X				2
35	X			Clean sand	1
36		X		SE 30	2

Table 4B
Sand Placement Above Vapor Retarder Recommendation Practice in Southern California

	Recommendation			Specification	
Respondent	**Always**	**Sometimes**	**Never**	**Type**	**Thickness, in**
1	X			Clean Sand	2
2	X			Clean Sand	3
3			X		
4	X				2
5	X			SE30	1
6	X				
7			X		
8	X				2
9	X				
10	X			Clean sand	2
11		X		Clean sand	
12	X			Clean sand	2
13			X		
14		X			2
15	X				1
16	X			Clean sand	2
17	X			Clean sand	2
18	X			Clean sand	2
19	X			Clean sand	1
20	X				1
21	X			Clean sand	2
22	X			Clean sand	2
23			X		
24		X		Clean sand	2
25		X		SE 30	2 – 4
26	X			Clean sand	2
27	X			Concrete sand	4
28	X				
29	X			sand	2
30	X			% fines < 8	2
31		X			2
32		X		Clean sand	2
33	X				2
34			X		

Table 5A

Slab Design Recommendation Practice in Northern California

	Recommendation			Specification	
Respondent	**Always**	**Sometimes**	**Never**	**Thickness, in**	**w/c Ratio**
1	X			3.5	
2	X			5	<0.45
3			X		
4			X		
5	X			4	<0.48
6		X		4	
7		X			5" slump
8	X			6	
9	X			4	0.5
10	X			4	0.5
11	X			4	0.5
12	X			4	0.5
13			X		
14			X		
15	X			4	
16	X			4	
17		X		4	
18	X			5	
19	X			3.5	
20		X		4	0.45
21		X		4	
22	X			4	
23	X			4	
24	X			4	
25	X			8	0.5
26			X		
27		X			
28		X		4	
29	X			4 - 6	0.45
30		X		5	0.45
31	X			4	0.45
32	X				
33	X			4	
34		X		4	
35	X			4	4" slump
36	X			4	

Table 5B
Slab Design Recommendation Practice in Southern California

	Recommendation			Specification	
Respondent	**Always**	**Sometimes**	**Never**	**Thickness, in**	**w/c Ratio**
1	X			4	CBC
2	X			5	0.45
3	X			4.5	0.45
4		X		4	0.45
5	X			5	CBC
6	X				
7			X		
8		X		5	
9	X			4	
10	X			4	5”slump
11		X		4	4”slump
12	X			4	CBC
13	X			3.5	
14		X		4	CBC
15		X		5	CBC
16	X			4	CBC
17	X			4	
18		X		4	
19	X			4	0.45
20		X		5	
21	X			4	0.45
22	X			4	Sulfate
23	X			5	CBC/Green Book
24	X			5	
25		X		4	CBC
26	X			4	
27	X			4	4” slump
28	X				
29	X			4	
30			X		
31			X		
32	X			4	
33	X			4 - 5	0.47
34	X			5	CBC