Arnold Schwarzenegger
Governor

ATTACHMENT#3
CANDIDATE BUILDING ASSEMBLIES AND CONSTRUCTION PRACTICES REPORT

PIER FINAL PROJECT REPORT

Prepared For:
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Candidate Building Assemblies and Construction Practices

Task 2.4 Report

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Table of Contents

Background 4
Task 2.4 Goal 4
Summary of Approach 4
List Mold and Moisture Problems Using Task 2 Information and Expert Judgment 4
Task 2.1 Literature Review 5
Task 2.2 Water Claims Incidence Database 5
Task 2.3 Building Industry Interviews and Surveys 5
Project Team Experience 6
PAC Member Expertise 6
Problem List 6
Prioritize Problems 6
Establish Baseline Building Assemblies and Practices 10
Figure 1 Baseline Roof and Wall Assembly 10
Figure 2 Baseline Floor Slab 11
Identify Possible Improvements to Baseline 11
Prioritize Improvements 11
Recommend List of Improvements for Laboratory Evaluation 14
Recommend List of Improvements for Demonstration Homes 14
Summary of Results 17
Results of Interviews 17
Results of Literature Review 19

Task 2.4 - Candidate Building Assemblies and Construction Practices

Background

The first technical task of the project was to perform a situation analysis of mold problems and state-of-the-art methods of addressing these problems in the residential new construction market in California. The situation analysis included a literature review (Task 2.1) water claims incidence database development and analysis (Tasks 2.2 and 2.5), building industry interviews and surveys (Task 2.3), and recommended building assemblies and construction practices (Task 2.4). The overall goal of Task 2 was to identify the most challenging mold problems facing California builders and recommend potential solutions for detailed laboratory evaluation and possible use in demonstration homes to be built by the two participating builders. Tasks 2.1 through 2.3 are complete, and Task 2.5 is nearing completion. Results of these tasks are summarized in separate task reports. This report summarizes the results of the Task 2.4 effort.

Task 2.4 Goal

The goal of Task 2.4 was to recommend building assemblies and construction practices for laboratory evaluation and possible use in demonstration homes.

Summary of Approach

Selection of building assemblies and construction practices for laboratory evaluation and demonstration homes is a critical element of the overall project. To achieve the Task 2.4 goals, the project team developed and used a selection process that addressed relevant building problems and prioritized potential solutions to those problems. The selection process combined risk analysis methods with expert engineering judgment to develop the recommended list of building assemblies and construction practices. It used results of information collected in Tasks 2.1 through 2.3 as well as Project Advisory Committee (PAC) member input and expertise and project team members' experience as the basis of final recommendations. Commission staff reviewed the selection process and will review and approve the recommended list prior to commencing Task 3 laboratory evaluations.

The selection process included the following elements:

- List Mold and Moisture Problems Using Task 2 Information and Expert Judgment
- Prioritize Problems
- Establish Baseline Building Assemblies and Practices
- Identify Possible Improvements to Baseline
- Prioritize Improvements
- Recommend List of Improvements for Laboratory Evaluation
- Recommend List of Improvements for Demonstration Homes

List Mold and Moisture Problems Using Task 2 Information and Expert Judgment

The project team used a number of resources to create a targeted list of mold and moisture problems and possible improvements. Resources included:

- Task 2.1 Literature Review
- Task 2.2 Water Claims Database

- Task 2.3 Building Industry Interviews and Surveys
- Project Team Experience
- PAC Member Expertise
- Commission Staff Input

Task 2.1 Literature Review

Task 2.1 literature review analyzed publicly available literature and conducted expert interviews with international building science experts to identify mold and moisture problems and potential solutions. While the literature review intentionally did not focus specifically on California, it was useful in determining a number of common issues confronting the residential building industry in California. A key output of Task 2.1 was a list of problems confronting builders and building owners and a list of potential solutions to these problems. Appendix A lists problems identified in the literature review and potential solutions based on industry expertise.

Task 2.2 Water Claims Incidence Database

Task 2.2 Water Claims Incidence Database focused on determining relationships between water damage claims contained in the California Department of Insurance (CDI) Water Claims Database and other parameters such as rainfall, building location, type, and construction characteristics. CDI does not have a mold claims database. Coupling the water claims database with local weather data for 2001-2003 shows a range of correlations between rainfall and water claims across California counties, weather stations, and climate zones. Water claims are concentrated in 7 counties, and in some cases, show a strong correlation with local rainfall. In other counties and locations, there is little or no correlation between water claims and rainfall. Climate zone did not show a strong correlation with water claims. No other parameters were available in the database or other publicly available databases to allow development of meaningful correlations between building type or other construction characteristic and water damage claims.

Task 2.2 database information was useful to focus attention on specific locations in California that have a history of water damage claims linked to weather-related events as well as other causes. Builders, regulators, and utilities in these areas may derive significant benefit from key information developed in this project. For the purposes of identifying the candidate list under Task 2.4, the database validated the relevance and importance of moisture management and mitigation strategies in the California residential market, including both event-related and design-related strategies.

Task 2.3 Building Industry Interviews and Surveys

Task 2.3 interviews and surveys conducted by the project team built on the national and international interviews and literature search results from Task 2.1. The goal of the Task 2.3 interviews and surveys was to identify problems and potential solutions that are most relevant to California builders. Interviews conducted with California building scientists, builders, mold remediators, and air conditioning industry professionals were intended to corroborate Task 2.1 findings and identify other issues specific to the California building industry. Table 3 shows results of the Task 2.3 interviews. Nearly all of the problems and potential solutions identified in Task 2.3 were also identified in the Task 2.1 literature review. The value of Task 2.3 was to link global moisture and mold problems to California building practices. Task 2.3 results show that California builders face similar challenges as builders in other areas of the country, and nearly all of the moisture management and mitigation strategies developed for other areas or the country may have application in California. Appendix B summarizes results of the interviews and surveys.

Project Team Experience

The project team includes building scientists, two home builders, Title 24 design experts, and a mold remediator. Discussions with team members throughout Task 2 provided insight into both mold problems and possible solutions. Combining project team experience with results of Task 2.1 through 2.3, a preliminary list of candidate building assemblies and construction practices was assembled and reviewed with PAC members and commission staff at the March 2004 PAC Meeting.

PAC Member Expertise

PAC members include several building products manufacturers and suppliers, building scientists, and members of State of California agencies, all with significant expertise in mold problems and solutions. PAC members provided substantial input and feedback to the project team throughout the Task 2 effort, and especially at the March 2004 PAC Meeting. The recommended list and preliminary approach for Task 3 laboratory evaluations reflects guidance from individual PAC members as well as the group.

Problem List

Using Task 2 results, project team experience, and PAC member expertise, the project team created a categorized problem list. The problem list included building materials problems, home system problems, and installation problems. In addition, a number of problems identified during Task 2 were cross-cutting or at a higher level, and were listed as miscellaneous problems.

Prioritize Problems

Table 1 lists mold and moisture problems categorized as either design-driven or event-driven problems. Table 1 also includes values for the criteria for each of the problems used to prioritize the problems. The higher the score, the more likely the problem will be relevant to this project.

The project team prioritized problems listed in Table 1 according to relative risk using engineering judgment applied to a standard risk analysis method. The selected risk analysis method was derived from the failure modes and effects analysis method used in a variety of industries. In accordance with this method, problems were prioritized according to three criteria:

- Frequency (probability of occurrence)
- Severity of consequence
- Probability of Detection

Engineering judgment based on expert opinions from team members and the PAC was used to fill in specific values for all criteria. The highest priority, most challenging problems would be those that have a high frequency of occurrence, a high severity of consequence, and a low probability of detection. For example, roof leaks have a high probability of occurrence sometime during the life of the home. Depending on the type and location of the roof leak, the severity of the problem can range from low to high. Finally, it is often difficult to detect a roof leak, especially if the water drains behind a wall rather than through a ceiling. For these reasons, roof leaks are deemed to be a high priority problem for mold and moisture. On the other hand, unless a toilet overflows when no one is around (an unlikely scenario), even if the probability and severity are potentially high, the event is easily detectable and therefore is not considered a high priority problem for the purposes of this project.

Table 1 - List of Mold and Moisture Problems

Problem	Type	Probability	Severity	Detection	Overall
Framing Materials					
- OSB Sheathing	Event	4	9	8	288
- OSB Flooring	Event	3	9	7	189
- Gypsum Board Panels	Event	3	10	4	120
- Plywood Sheathing	Event	2	6	8	96
- Wood Framing	Event	2	5	9	90
- Plywood Flooring	Event	2	6	7	84
Window Leaks					0
- Inadequate Flashing	Design	5	9	9	405
- Expansion/Contraction Leaks at Seams	Design	8	6	4	192
- Flashing Leaks	Event	3	9	7	189
Door Leaks					0
- Flashing Leaks	Design	5	9	7	315
- Door Sill Leaks	Design	5	9	6	270
Exterior Wall Closets					0
- Exterior Wall Cooling Effect	Design	9	7	4	252
- Stagnant Air	Design	9	5	2	90
Under Sink					0
- Caulking Leaks	Event	7	6	3	126
- Stagnant Air	Design	10	5	2	100
- Plumbing Fitting Leaks	Event	4	8	2	64
- Burst Pipe	Event	2	10	1	20
Inside Wall Cavity					0
- Roof Leaks	Event	8	7	8	448
- Window Leaks	Event	8	6	8	384
- Cool Wall Water Vapor Condensation	Design	2	8	9	144
- Sprinkler Saturation/Capillary Action	Design	1	9	4	36
Slab on Grade					0
- Vapor Retarder Below Sand Soaked Due to Rain	Design	5	8	9	360
- Capillary Action through Cracks	Design	4	6	6	144
- Carpeted	Design	5	8	2	80
- No Vapor Retarder	Design	1	8	9	72
Stucco					0
- No Drainage Channels at Sheathing	Design	3	8	9	216
- No Space to Allow for Air Movement	Design	3	8	9	216
- Stucco Settling Cracks	Event	10	3	4	120
- No Weep Holes (or Plugged Weep	Design	2	8	5	80

Holes)

Table 1 - List of Mold and Moisture Problems (Continued)

Problem	Type	Probability	Severity	Detection	Overall
HVAC System					0
- Water Carryover	Design	2	8	6	96
- Condensate Pan Plugged	Event	2	10	4	80
Bathroom					0
- Plumbing Fitting Leaks	Event	4	7	8	224
- Greenboard	Design	4	7	7	196
- Shower/Tub Surround Caulking Failure	Event	7	5	4	140
- High Humidity/No Ventilation	Design	5	6	4	120
- Stagnant Air Under Cabinet	Design	10	3	2	60
- Toilet Overflow	Event	9	6	1	54
Ceiling					0
- Excessive Cooking Vapor	Event	2	7	5	70
- Cold Room Adjacent to Kitchen	Design	1	8	6	48
Washing Machine					0
- Leak from Upper Floor Installation	Design	7	7	2	98
- Inadequate Ventilation	Design	3	5	5	75
Water Heater					0
- Leak from Second Floor/Attic Installation	Design	9	9	1	81
Improper Drainage Slope					0
- Graded Toward Instead of Away from Home	Design	3	7	3	63
Roof Leaks					0
- Remote assemblies impacted by drainage flow path	Event	9	8	8	576
- Flashing failure	Event	7	8	8	448
- Gutter Backups	Event	5	8	5	200
Cellulose Insulation					0
- Food Source for Mold	Event	7	9	9	567
- Wet-Blown Without Drying before Closing in with Drywall	Design	3	9	9	243

Table 1 - List of Mold and Moisture Problems (Continued)

Problem	Type	Probability	Severity	Detection	Overall
Miscellaneous House Systems					0
- So Tightly Sealed that Trapped Moisture Has Little Opportunity to Dry Out	Design	5	5	7	175
- New Building Materials and Technologies Require More Careful Installation	Design	6	4	7	168
- High Moisture Content Framing Lumber (>19%)	Design	3	8	7	168
- Vinyl Wallpaper	Event	4	6	6	144
- Wicking from Concrete Foundation to Wood Framing	Design	2	8	7	112
- Complicated Roof Designs	Design	9	3	4	108
- No Roof Overhang	Design	6	5	3	90
- Downspouts Terminate too Close to Wall	Design	4	6	2	48
- Mold Spore Intrusion from Redwood Bark Landscape Chips	Design	2	7	3	42
Construction Site					0
- Rooms Painted Before Wallboard is Dry	Event	3	8	8	192
- Site Exposed to Rain after Moisture-sensitive Materials Installed	Event	7	9	3	189
- Walls Closed in Before Wood Framing and Sheathing Dries	Event	2	9	8	144
- Rainwater Accumulates Under Slab above Vapor Retarder	Event	3	8	6	144
- Lumber Unloaded Directly onto the Ground	Event	4	8	3	96

Establish Baseline Building Assemblies and Practices

Baseline building assemblies and construction practices provide the basis of comparison for potential improvements as well as alternatives that may be more susceptible to mold growth in the presence of moisture. The baseline building configuration is based on typical Title 24 construction applicable to most of California's 16 climate zones. Figures 1 and 2 show the baseline configurations for walls, roof, and floors. In climate zones with high heating loads, the only major additional requirement is exterior sheathing insulation.

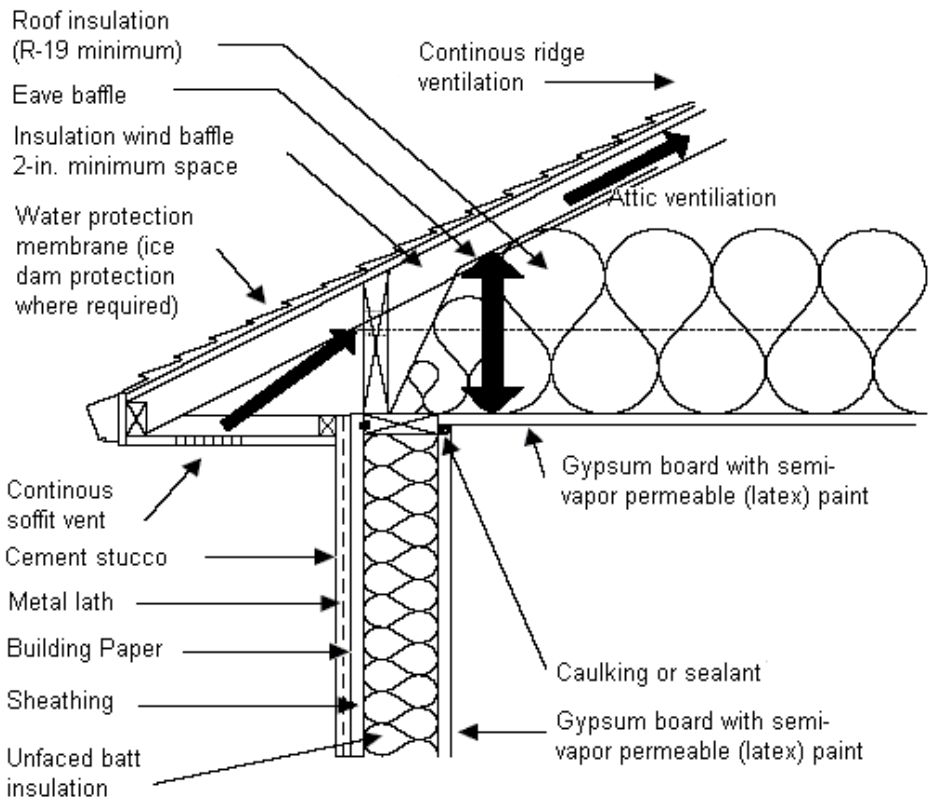

Figure 1 Baseline Roof and Wall Assembly

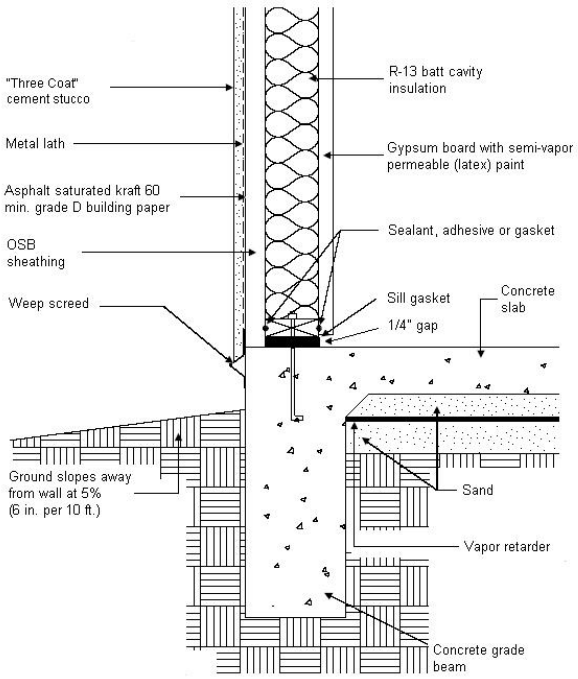

Figure 2 Baseline Floor Slab

Identify Possible Improvements to Baseline

Table 2 shows candidate improvements to the baseline building. The basis for including a candidate improvement was its perceived value in addressing one or more high priority mold and moisture problems.

Prioritize Improvements

Table 2 also shows the relative score of each candidate improvement compared to the baseline. Items in italics have weighted scores lower than baseline. The criteria for the prioritization addressed various aspects of efficacy, cost, commercial availability, and energy impact, all relative to the baseline construction. As with the problem set, engineering judgment based on expert opinions from team members and the PAC was used to fill in specific values for all criteria. Mold resistance and energy impact were weighted by a factor of 3 compared to all other criteria since those two parameters are most important to the success of this project. Candidates with higher weighted scores offer good potential for cost-effective improvements to the baseline. Candidates with lower scores may still warrant further consideration in the project on a case-by-case basis due to a unique value added or difficulty in applying a reasonable quantitative assessment to the improvement.

Table 2 Candidate Building Assemblies and Construction Practices

Assembly or Practice	Problem Type Addressed	Weighted Score
Insulation		
- Polyicocyanurate	Design	14
- Insulated Sheathing	Design	13
- Polystyrene Foam	Design	6
- Radiant Barrier with Airspace	Design	1
- Fiberglass Batt with Fungicide	Design	*(2)*
- Blown in Cellulose Insulation	Design	*(9)*
- Cellulose	Design	*(11)*
Gypsum Board		
- Cement Board	Event	14
- Paper-faced with Fungicide	Event	8
- Fiberglass-backed	Event	3
- Greenboard	Event	0
Housewrap		
- Higher Permeance Nonwoven	Design	18
- Lower Permeance Nonwoven	Design	18
Floor Slab		
- Vapor barrier adjacent to concrete	Design	3
- Compactable fill/vapor barrier	Design	1
- Sand and vapor barrier	Design	0
- No vapor retarder	Design	*(7)*
Sheathing		
- Insulated Concrete Wall	Design	12
- Metal Flashing/Foam Gasket at Foundation	Design	8
- Moisture Content Standards	Design	6
- Cement Board Sheathing	Event	6
- OSB with fungicide coating	Event	3
- Plywood with fungicide coating	Event	3
- Wood studs with fungicide coating	Event	3
- Floor Sheathing with Drainage Channels	Design	3
- "Weak" Vapor Barrier	Design	3
- Wood siding with fungicide coating	Event	1
- Wood studs without fungicide coating	Event	0
- Plywood without fungicide coating	Event	*(1)*
- Wood siding without fungicide coating	Event	*(2)*
- Metal Studs	Event	*(5)*
Window Installation		
- Window installation standards	Design	26
- Multiple Layer Caulking/Counterflashing	Design	18
- Self-Stick Flashing	Design	13
- Pan Flashing	Design	13

Table 2 Candidate Building Assemblies and Construction Practices (Continued)

Assembly or Practice	Problem Type Addressed	Weighted Score
Improved Drainage Planes		
- Window framing	Design	12
- Lapped joints (horizontal)	Design	11
- Lapped joints (vertical)	Design	11
- Roof/wall joints	Design	11
- Secondary Drainage Plane	Design	11
- Corners	Design	10
- Door sills	Design	9
- Complex Structure Flashing Details	Design	9
Stucco		
- With hi/low drainage openings	Design	10
- With Vented Rain Screen	Design	10
- With low drainage openings	Design	8
- 3 Coats	Event	2
- Without hi/low drainage openings	Design	0
- With irrigation (underground sprinklers)	Design	*(8)*
Construction Site		
- Open Storage	Event	8
- Plastic Encasement	Event	6
- Plastic Sheet Cover	Event	3
- Drying	Event	*(12)*
Ventilation		
- Exhaust Only Ventilation	Design	1
- Heat Recovery Ventilation	Design	*(1)*
- Positive Pressure Ventilation	Design	*(2)*
- Ventilation with Dehumidifier	Design	*(2)*

Recommend List of Improvements for Laboratory Evaluation

The list of candidate improvements in Table 2 provided a good starting point for the recommended list of improvements for laboratory evaluation. However, additional factors needed to be considered in the final decision. Numerous organizations and individuals, including several PAC members, have conducted extensive laboratory testing related to moisture on building components, subsystems, and full-scale wall and roof assemblies. For this project to advance the state-of-the-art and provide value to California builders and consumers, it should focus on items and areas that have not been previously tested in the laboratory. Based on discussions with the project team and PAC members, the highest value areas for this project to address are drainage plane design options (especially around windows) and drying time for built up assemblies. This focus will provide defensible, repeatable results that advance the understanding of overall system performance. Components and subsystems have been tested for mold growth and impact of moisture by universities and manufacturers. The recommended focus will build on that testing to provide a better understanding of the behavior of the entire assembly as well as collect unique data on the performance of wall and roof cavities and materials as a part of a complete assembly. This approach also allows flexible configurations and innovative combinations of materials and systems to be tested.

Table 3 summarizes the building assemblies and construction practices for laboratory testing. The list was reviewed and prioritized by the PAC and by Commission staff at a special PAC conference call and through follow-up discussions with the project team and individual PAC members. The list is subject to update and modification as the laboratory test plan (Task 3.1) is developed based on practicality of testing and creation of a suitable set of test protocols.

Recommend List of Improvements for Demonstration Homes

Task 2.4 primarily focused on recommendations for laboratory testing. However, it is also important to incorporate this thinking into recommendations for the demonstration homes. For instance, some of the high value improvements may not be tested in the laboratory under this project because other organizations have already performed definitive testing on the improvement. Other items do not lend themselves well to a laboratory setting. It remains important for Task 5 Builder Guidelines and Title 24 recommendations to have certain of these systems included in the demonstration homes to see the overall impact on the construction process and costs. Items such as construction site drying and ventilation options are better suited to actual installations than a laboratory evaluation. Other items such as fungicidal coatings may undergo limited laboratory testing in this project but warrant further investigation in the field.

A recommended list of improvements for demonstration homes will be developed during Task 3, based on results of laboratory evaluations, coordination with participating manufacturers, and agreement with the participating builders. Table 4 provides a preliminary list of recommended improvements for one or both of the demonstration homes based on interest expressed by participating builders and participating manufacturers. Additional items will be added to this list as Task 3 progresses.

Table 3 List of Building Assemblies and Practices for Laboratory Evaluation

Category	Description of Building Assembly
Window Installation Methods (Highest Priority)	This category will examine different window installation methods to evaluate moisture penetration through the drainage plane. Tests will include medium quality installations to reflect variability in skill levels in the field. Baseline will include vinyl windows, 3 coat stucco.
- ASTM E2112 Method A	Sill flashing; window; jamb flashing; head flashing; weather barrier
- ASTM E2112 Method A1	Weather barrier; sill flashing; window; jamb flashing; head flashing
- ASTM E2112 Method B	Sill flashing; jamb flashing; window; head flashing; weather barrier
- ASTM E2112 Method B1	Weather barrier; sill flashing; jamb flashing; window; head flashing
- CAWM Method A	Similar to ASTM E2112 Method A, different details
- CAWM Method B	Similar to ASTM E2112 Method B, different details
- Silverline	Head flashing over weather barrier
- Marvin	Multiple layers of weather barrier and flashing
- Certainteed	Similar to Method B; extra sill flashing; different sealing details
- Pella	Similar to Method A1; extra sill flashing; different flashing details
- Owens Corning	Felt paper flashing; sealant; no gaps
- One-Coat Stucco	Evaluate joint details at selected windows
Stucco Wall Assemblies (High Priority)	This category will examine different wall assemblies used with stucco to determine the impact of various moisture loading scenarios on stucco drainage planes, wall cavities, and interior finishes.
- High/Low Drainage Openings	Baseline with high/low drainage openings.
- No Drainage	Baseline without weep screed
- Stucco Wrap	Baseline with DuPont Tyvek™ "Stucco Wrap"
- One Coat Insulated Sheathing	Baseline with one coat, insulated sheathing, no drainage channel
- Polystyrene Insulation	Baseline with Dow Styrofoam™ instead of fiberglass insulation
- Cellulose Insulation	Baseline with cellulose instead of fiberglass insulation
- Fungicide in gypsum board	Baseline with USG Humitek™ fungicidal gypsum board
- Fiberglass faced gyp. board	Baseline with GP DensArmor™ gypsum board
- Fungicide on OSB	Baseline with Foster 40-20® fungicidal coating
- High Permeance Housewrap	Baseline with Owens Corning Pinkwrap® house wrap
- High Permeance Housewrap	Baseline with DuPont Tyvek™ house wrap
- Low Permeance Housewrap	Baseline with Dow Styrofoam Weathermate™ house wrap
Concrete Floor Slab (High Priority)	This category will examine the impact of various vapor retarder and fill material locations and options on drying time and pooled water for 4" concrete floor slabs and grade beams.
- Sand, VR	2"Sand; 10 mil polyethylene sheet; soil
- Sand, VR, Sand	2"Sand; 10 mil polyethylene sheet; 2" sand; soil
- Sand, VR, CDF	2" sand; 10 mil polyethylene sheet; 2" compactable, drainable fill; soil
- CDF, VR, Sand	2" compactable, drainable fill; 10 mil polyethylene sheet; 2" sand; soil
- VR, CDF	10 mil polyethylene sheet; 2" compactable, drainable fill; soil
- VR, Sand	10 mil polyethylene sheet; 2" sand; soil
- Sand alone	2" sand; soil
- VR under Grade Beam	2"Sand; 10 mil polyethylene sheet under grade beam; 2" sand; soil,

Table 3 Recommended List of Building Assemblies for Laboratory Evaluation (Continued)

Category	Description of Building Assembly
Innovative Wall Assemblies (Medium Priority)	This category will examine innovative wall assemblies, with focus on insulated concrete forms and structural insulated panels. Experiments are likely to focus on drying time from initial pour.
- ICF	Owens Corning Lite-Form® insulation panels.
- T-Mass	Dow STYROFOAM™ T-MASS™ system
- SIP	Structural insulated panel with OSB
Challenging Interface (Lower Priority)	This category will examine challenging interfaces, especially at the roof and wall joint, to determine the impact of installation practices on moisture penetration. Based on PAC input, only one assembly will be considered for this project.
- Roof/Wall Assembly	Roof/Wall joint at roof flashing, counterflashing, and side wall

Table 4 Preliminary Recommendations for Demonstration Homes

Category	Description of Building Assembly
Construction Site	This category will examine actions at the construction site that address moisture issues during and immediately following construction..
- Construction Site Drying	Dri-Eaz Construction drying process
Fungicides	This category will examine products with fungicidal coatings or impregnated with fungicides to evaluate their initial cost and impact on the overall construction process..
- OSB Coating	Foster 40-20® fungicidal coating on all exterior wall and roof OSB sheathing
- Gypsum Board	USG Humitek™ fungicidal gypsum board on all exterior walls

Appendix A Summary of Task 2.1 Literature Review Results

The objective of Task 2.1 was to provide a preliminary set of recommendations identifying moisture and mold resistant building assemblies and practices for further investigation and application in the Laboratory Evaluation, Demonstration Homes, and Information Product Dissemination tasks. To accomplish this objective, a literature review and interview process was implemented. The interviews with experts in the field provided an up-to-date sampling of the most relevant issues related to moisture intrusion in building assemblies. The literature created a supporting foundation of information detailing background on the moisture intrusion issues cited by the experts in the field, as well as other issues. A total of 16 interviews and 85 literature reviews were completed.

Summary of Results

A set of recommendations emerged from the interview and literature survey process to potentially solve some of these water problems through work in later project tasks. Those recommendations include, but are not limited to:

- Upgrade window (and door) installation techniques, standards and codes to foster proper flashing, etc.
- Improve plumbing systems and installation practices to ensure pressure testing before operation, eliminate punctures by other trades during construction, etc.
- Consider alternatives to, or enhanced means of water intrusion protection for, hygroscopic building materials such as OSB in wall and roof assemblies. Likewise consider alternatives to mold food sources, e.g., substitute fiberglass paper for cellulose on drywall.
- Evaluate proper placement of vapor barriers in wall assemblies, including “smart” vapor barriers, to inhibit water vapor transport but allow drying under saturated air conditions and new home humidity pulldown.
- Produce a builders’ manual to check during construction for known anomalies leading to water intrusion. Likewise, produce a manual for homeowners to properly maintain a residence to prevent moisture intrusion and mold growth.

Results of Interviews

Major water intrusion issues cited in interviews include:

- Bulk Water --
  Improper lot grading and/or settling create slopes toward foundations and allow water to intrude into slabs, crawlspaces or basements; irrigation systems overspray water and repeatedly wet foundations and walls; and roof downspouts are inadequately separated away from homes and deposit water near foundations instead of to a properly sloped grade.
- Roof Eaves --
  Roof eaves lack sufficient extensions outward and permit rain, especially wind driven rain, to soak exterior porous (brick, stucco, wood, etc.) facades.
- Vapor Barriers --
  Barriers are sometimes incorrectly applied or of the wrong type, depending on climate, and allow moisture to be trapped or build up in walls. Walls need to be able to breathe.

- Window Detailing in Wall and Roof Penetrations --
    - Builders and subcontractors lack sufficient training for proper installation of windows (and flashing).
    - Building codes lack standardized window installation practices.
    - Standards are non-existent for installation of building membranes and flashings with windows.
    - Standards for windows, building membranes, and flashing are outdated (post WW-II ASTM standards) and need to be modernized.
    - Trade organizations for fenestration, building membranes, and flashing are needed to foster these training, standard, and code activities.
- Plumbing --
    - Fittings are not always pressure tested before sealing and can leak undetected for some time behind walls.
    - Piping is often punctured by other trades during construction and can leak undetected for some time behind walls.
    - Alternative, more robust systems are needed to help remedy these plumbing leaks issues.
- Interior Moisture/HVAC --
    - Houses are too tight for natural ventilation to be effective. Mechanical outside air (OA) ventilation is needed.
    - Architects and engineers need to be educated on ventilation issues and mechanical ventilation options.
    - Oriented Strand Board (OSB) is often gets wet during construction and then is not adequately dried before wall and roof construction is completed.
    - Some newer paints have much less tolerance to mold growth than paints manufactured 20-25 years ago.
    - DHW heaters, AC coils/drain pans, and ductwork, are placed in attics where leaks can go unnoticed for some time until after substantial damage is done.
    - Baths and kitchens do not have properly sized exhaust fans that run until moisture levels are reduced to desired humidity levels. Fan operation needs to be automated (based on humidity level) to remove the human factor. Most of these fans are too noisy and people are annoyed and limit their operation.
    - Wet spray cellulose, if used, Is not allowed to dry sufficiently. Moisture content needs to be checked before closing drywall.
    - Moisture content in wood framing is often to high before closing in the walls. Moisture content needs to be checked before closing drywall and should not be higher than 19%.
- Miscellaneous
    - An homeowners' manual needs to be developed that would address some of the maintenance issues that could prevent mold incidences over the life of a house.
    - A builders' manual needs to be developed that offers a "systems approach" to ensuring quality and managing risk during construction. For example, utilizing a series of checkpoints established by extensive litigation and failure analysis background, specially trained inspectors can check for specific, known anomalies in the building assemblies at greatest risk of water damage and mold formation.
    - Construction sequencing is a clear issue with poor scheduling leading to unprotected building materials getting soaked with rain/snow on the job site.
    - Elastomeric paints for stucco to limit cracking and water intrusion need to be utilized.

Results of Literature Review

Many of the pieces of literature cited established the methods by which moisture travels:

- Pressure differential
- Temperature differential
- Capillary action
- Spills/leaks
- Diffusion

Other literature detailed the points at which traveling moisture intrudes into buildings and its assemblies. The following moisture intrusions problem areas were mentioned frequently in the literature. Common moisture intrusion points are:

- Penetrations in walls and roofs: windows, doors, skylights, piping through walls, ductwork through walls and ceilings
- Roofs with improper installation of flashing, or gutters not working properly
- Surface or ground water pooling from improper grading, irrigation system overspray, and improper placement of downspouts.
- Interior moisture buildup due to over crowding, improper exhaust venting (bathrooms, kitchen, and laundry), too low of a cooling temperature set point, inadequate removal of moisture (insufficient dehumidification).
- Attic/crawlspace moisture from leaky HVAC ducts, condensation on cooler surfaces, improper ventilation of attic/crawl spaces.
- Improperly installed vapor and air barriers. Proper placement of air barriers is important to allow building assemblies to dry out.
- Infiltration of moist air when leaky HVAC ducts cause pressure differentials, leading to outside air being drawn in to building, and oversized air conditioning equipment leading to short cycling that reduces the AC equipment ability to dehumidify.

Potential solutions that were cited for moisture problems are:

- Use materials that are not prone to moisture build-up and mold formation.
- Provide proper air barrier placement for the building assembly to dry out.
- Provide eaves with at least 18 inches overhang, and do not start siding within 8 inches of the ground/soil.
- Increase the cooling set point temperature, and allow the air to flow around the entire space (well mixed conditions). Furniture can block airflow to corners, leading to cold spots and moisture condensation on cooler, dark surfaces. Provide supplemental dehumidification in addition to air conditioning.
- Make sure that flashing is properly installed everywhere, particularly at doors and windows.
- Venting of crawlspaces depends on climate: hot humid climates do not necessarily benefit from natural ventilation of crawlspaces.

Appendix B Summary of Task 2.3 Interviews and Surveys

In February and March of 2004, a series of telephone interviews were conducted to gain specific, qualitative information about the incidence and nature of water damage and mold problems in California homes. The purpose of this task was to obtain detailed information on insurance adjustor, builder, and mold remediator experience with mold and home building assemblies, and to provide data to assess California benefits of improved building assemblies. The interviews were a follow-up effort to provide a California focus to the initial, broad-based findings through interviews and literature search conducted under Task 2.1. The interviews focused on professionals in four areas of expertise: Insurance Claims Adjusters, Mold Remediation Professionals; Air Conditioning Repair and Maintenance Contractors; and Home Builders. Names of interview candidates were obtained through a variety of methods, including referrals by other professionals, individuals with prior contact about the project, cold calls to companies, and lists available on the Internet.

The findings of interviews and surveys sent by email essentially confirmed the preliminary interviews and literature search conducted in Task 2.1; and gave some estimates of relationships between water intrusion and resulting mold damage. The insurance claims adjusters and remediation experts identified catastrophic problems resulting from equipment, appliance, and fixture failure as being the most common source of moisture resulting in mold problems. Further, they estimated about 20 to 40% of such occurrences also had mold issues. There was no specific type of building assembly identified with a higher propensity for moisture problems.

Air conditioning specialists were in two groups: Those who dealt with day-to-day cleaning; and those who specialized in mold. The cleaning firms did not seem to have the knowledge and consistency in their approach to accurately assess the extent of moisture and mold problems occurring from air conditioning sources. Mold specialists lacked broad knowledge about the extent of the problem, since they primarily were called after a problem had been identified.

California builders were unanimous in pointing to worker error and quality control as the dominant causative factors for both exterior and interior sources of moisture in new homes. Specific questions about stucco revealed the belief that application methods had evolved to a level of consistency which, when adhered to, essentially eliminated problems with moisture collection by allowing proper drainage.