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January 16, 2004

To: Chris Scruton (CEC)
From: Steve Wiel
Subject: **Cool Roof Colored Materials**: Quarterly Progress Report for Fourth Quarter 2003
CC: Hashem Akbari, Paul Berdahl, Andre Desjarlais, Bill Miller, Ronnen Levinson

A summary of the status of Tasks and Deliverables as of December 31, 2003 is presented in Attachment 1.

HIGHLIGHTS

- Three homes in Cavalli Hills, Fair Oaks, CA are instrumented for demonstrating cool colored materials in concrete tile and painted metal roofing.
- Evans Construction retracted its offer to provide two additional homes in Cavalli Hills for field testing asphalt shingle roofs. We initiated contacts to establish a second demonstration site for demonstrating cool colored asphalt shingles, and are negotiating a second demonstration site with Four Seasons Construction Co.
- We discussed with our industrial partners development of initial prototype cool roofing materials. Several samples have been developed and measured. Recent efforts have focused on (a) cool glazes for clay tiles, (b) cool acrylic coatings for concrete tiles, and (c) coatings for granules.
- We visited MonierLifetile (manufacturing concrete roof tiles) at Lathrop, CA.
- Task 2.4.2 "Develop a Computer Program for Optimal Design of Cool Coatings" was started in November 1, 2003.
- On November 24 and 25, Berdahl and Akbari traveled to Ennis Texas and met with 3M and Elk R&D staff (at Elk Head Quarter).
- We have completed the preparation and optical measurements of tints (mixtures with white) of all pigments, and are using this data to develop a model predicting the performance of mixtures.

Tasks

1.1 Attend Kick-Off Meeting

This Task is completed.

1.2 Describe Synergistic Projects
This Task is completed.

2.1 Establish the Project Advisory Committee (PAC)
This Task is completed. Peter Turnbull of PG&E and Greg Ander of SCE were invited (and accepted) to join the PAC.

2.2 Software Standardization
(No activity.)

2.3 PAC Meetings
(No activity.)

2.4 Development of Cool Colored Coatings

2.4.1 Identify and Characterize Pigments with High Solar Reflectance
We noted that some of our single-pigment films (e.g., titanium white, synthetic iron oxide black) had very low transmittance in parts of the solar spectrum, reducing the accuracy of our computed Kubekla-Munk scattering and absorption coefficients. Hence, we diluted these single-pigment paints with clear binder dilutions to prepare films with lower pigment volume concentration and higher transmittance. We also prepared diluted films of pure carbon black pigments for the same purpose. (Our prior measurements on bone black should be similar, but bone black is a mixture of carbon black and other components of bone, especially calcium hydroxylapatite [$Ca_5(PO_4)3OH$].)

Several industrial partners reviewed our draft paper on pigment characterization. We revised our paper to (a) better account for measurement errors, including those stemming from the limitations of our spectrometer's integrating sphere; and (b) elaborate on some of the physical features (e.g., absorptance spectra) observed in the pigments. We continue to revise our pigment characterization draft paper, and expect to finalize the paper in January 2004.

We have completed the preparation and optical measurements of tints (mixtures with white) of all pigments, and are using this data to develop a model predicting the performance of mixtures.

We compared our measurements for the scattering strength S of conventional white titanium dioxide pigment with theoretical estimates from the published literature. Theory gives S-values of about 11±1 per micrometer (times the pigment volume concentration), for the center of the visible spectrum at 550 nm. These theoretical estimates are based on the Mie theory for light scattering from spherical particles, together with a simple model of multiple scattering effects in white coatings. We find good order-of-magnitude agreement with our measurements, which is in contrast with many of the older studies of this issue.

2.4.2 Develop a Computer Program for Optimal Design of Cool Coatings
We have started this task by assembling various algorithms developed under Task 2.4.1.

2.4.3 Develop a Database of Cool-Colored Pigments
We continued discussing methods to amend the database. We have contacted a few manufacturers for similar data. We forwarded data to our partners and responded to partners' questions and comments.

2.5 Development of Prototype Cool-Colored Roofing Materials

2.5.1 Review of Roofing Materials Manufacturing Methods

On October 1, 2003, Berdahl, Levinson, and Akbari visited the MonierLifetile plant at Lathrop, CA (near Modesto). A new section will be added to the "Roofing Materials Manufacturing Methods" report to cover concrete tiles. We are still working to arrange a visit to a cedar shake roof-manufacturing plant.

2.5.2 Design Innovative Methods for Application of Cool Coatings to Roofing Materials

We met (and held conference calls) with several of our industrial partners to plan production of prototype cool granules, shingles, and tiles. We agreed upon an iterative process in which LBNL suggests a coating design, receives a prototype fabricated by the industrial partner, and characterizes the spectral optical properties of the prototype. Our initial designs have focused on producing materials with a high reflectance white or metallic undercoat covered by a dark pigment with low near-infrared absorptance. We have received prototype granules and shingles from two partners, and prototype tiles from two partners. Based on characterizations of these early prototypes, LBNL has suggested techniques for improving the reflectance of the undercoatings.

We continue to work with tile, granule, and shingle manufacturers to develop cooler products, focusing this quarter on (a) cool glazes for clay tiles, (b) cool acrylic coatings for concrete tiles, and (c) coatings for granules. Glaze samples must be fired prior to characterization because the optical properties of a glaze change when fired in a kiln (peak temperature of about 1050 °C). This presents a challenge, because the clear substrates (e.g., quartz) that can survive such high temperatures have lower coefficients of thermal expansion than do the glazes, which would make the glaze or substrate crack during firing. We have taken the first step in characterizing glazes by measuring the solar spectral reflectance of a series of white tiles coated with glazes containing increasing concentrations of pigments (e.g., 0.5%, 1%, 2%, 4%, and 6%) for about 20 Ferro ceramic colors. We will use these "concentration ladders" to determine the scattering and absorption coefficients of the glazes.

We suggested some modifications to prototypical coatings for granules and concrete tiles that had been developed and tested earlier in this project; these modified coatings are being prepared by our industrial partners. We are also in the process of measuring the solar reflectance of some heterogeneously coated asphalt shingles received from an industrial partner. We are using a Monte-Carlo technique to determine the reflectance of these non-uniform shingles. That is, we measure the reflectance of each shingle at many locations until the average reflectance changes very slowly with each additional measurement.

On November 24 and 25, Berdahl and Akbari traveled to Ennis Texas and met with 3M and Elk R&D staff (at Elk Head Quarter). During the meeting, 3M and Elk updated the LBNL project team on their recent progress for development of cool colored shingles.

2.5.3 Accelerated Weathering Testing

(No activity.)

2.6 Field-Testing and Product Useful Life Testing

We visited Cavalli Hills on October 27- 30, 2003 and instrumented three of four houses for monitoring the temperatures and the heat flow from attics having roofs with and without Cool Roof Color Materials (CRCMs). Mike Evans and the Sacramento Land &

Home real estate agent, Steve Burke, have sold all 12 homes in the Cavalli Hills subdivision located in Fair Oaks, CA, and six of the homes just broke ground in October 03. Evans will not provide homes for field testing shingles because the homeowners prefer tile or painted metal shake roofs. Efforts are in progress to establish a second demonstration site for testing asphalt shingles with and without colored cool pigments.

The Roof Tile Institute (RTI) and its affiliate members installed clay and concrete tile on the steep-slope attic assembly on the Envelope Systems Research Apparatus.

2.6.1 Building Energy-Use Measurements at California Demonstration Sites

ORNL personnel installed temperature, relative humidity, pyranometer and heat flow instruments in the attics and roofs of three demonstration homes. Each house had a plastic electrical conduit run from the attic, down within the exterior wall and terminated adjacent the house's power panel. Interconnecting wires were pulled through the conduit, connected to the instruments and clearly labeled and documented for future hookup to data loggers. ORNL personnel and Wim Bos of SMUD verified the sensor signals. Boss showed air temperature measures for some of the thermocouples to be within about 0.5°F of measurement made using a Fluke temperature indicator. The weather station and data loggers were not installed because stucco must first be applied to the exterior walls of the homes. Tentative plans are to complete all setups once Evans Construction has the fourth house in the dry, which he forecasts occurring in February 04.

Dynamic Roofing installed what is termed an 80% lay of the Hanson concrete tile on the two A Style homes. They will install trim tile to complete the job after other crews have applied stucco to the insulated concrete form walls of the homes. The concrete tiles are the model H409 Hacienda low profile with dark brown color. Joe Riley of American Roof Tile Coatings has prepared CRCM paint and is ready to apply a topcoat finish to one of the two installed tile roofs. The CRCM topcoat will boost the reflectance of the tile from about 25% to almost 45%. Inclement weather has prevented Riley from applying the topcoat finish with cool pigments to one of the two installed tile roofs. Riley is scheduled to complete the work in February 04 while ORNL personnel are at the demonstration site.

W. Miller showed Dynamic Roofing and Rinkydink Builders the location of the thermocouples (Fig. 1) and asked them to give Wim Boss of SMUD advanced notice so he can quickly visit the site and assist the crews with the attachment of the thermocouples. Akbari and Miller discussed surface attachment techniques and agreed on an approach that will not disturb the thermal characteristics of the roof surface. A special epoxy that is UV resistant will be used by Wim Boss to glue the thermocouple and about 1 inch of wire to the top of the brown colored tile. Afterward the attached thermocouple will be painted brown so the surface will have similar reflectance and emittance properties as the rest of the tile surface. Because painted metal is very thin, the underside temperature is an accurate measure of the surface temperature of the roof. Therefore these thermocouples are glued and taped to the underside of the metal shake roof.

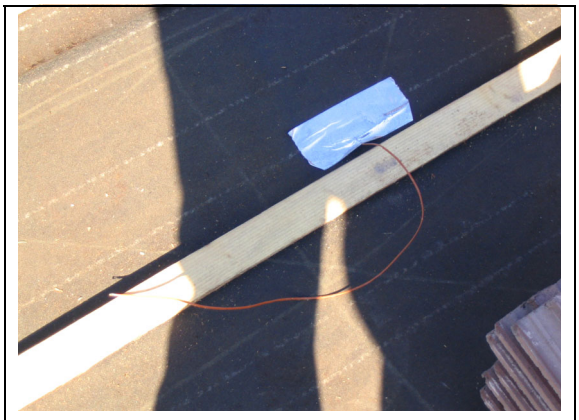


Fig. 1. Tip of thermocouple wire to be threaded to the top of the upper tile.

Rinkydink Builders installed painted aluminum shakes on one of two C style houses being field tested in Cavalli Hills. The color of the aluminum shake is walnut brown and it contains no cool colored pigments. Solar reflectance of the walnut brown is about 0.08. The aluminum shingles for the second C style house will have Custom-Bilt Metals "musket brown" color and have cool colored pigments. Solar reflectance of the musket brown is about 0.31, almost a factor of 4 greater that the standard walnut brown. The second C style home is under construction, and ORNL personnel are scheduled to visit Cavalli Hills the third week in February to complete setup of the data loggers for the first three homes and to run wiring for the second C style house.

While in Sacramento, W. Miller met with the real estate agent, Steve Burke, who is working with Evans Construction to sell the homes. Miller requested the opportunity for Wim Bos (SMUD representative) and himself to meet each of the four homeowners participating in our CRCM project so they would be comfortable when personnel visit to check instruments, do indoor blower door testing and make thermal scans of the exterior of their homes. Miller showed Burke a brochure prepared for Evans (see Attachment 2) and handed him a signed Memorandum of Understanding. Burke was both agreeable and very excited about the project; he asked for and received additional copies of the brochure.

Evans Construction and the Sacramento Land & Home realtor, Steve Burke, sold all 12 homes in the Cavalli Hills subdivision. Original plans called for six homes to be built next year, but because of unexpected demand Evans accelerated his building and will complete all twelve homes for occupancy by March 04 (Figure 2). Our project calls for demonstrating six homes. Two C style homes in Cavalli Hills have metal roofs with and without colored cool pigments; two A style houses have tile roofs. However, Evans retracted his offer to provide two additional homes in Cavalli Hills with asphalt shingle roofs. Evans is looking for other sites to support our initiative; however, we have made contacts through SMUD to establish a second demonstration site for testing homes with asphalt shingles. A Memorandum of Understanding was forwarded to the Four Seasons Construction Co. for review to possibly work with ORNL and SMUD in demonstrating CRCMs in asphalt shingles. A 40 house subdivision in the suburbs of Sacramento has several lots available for conducting side-by-side field testing.

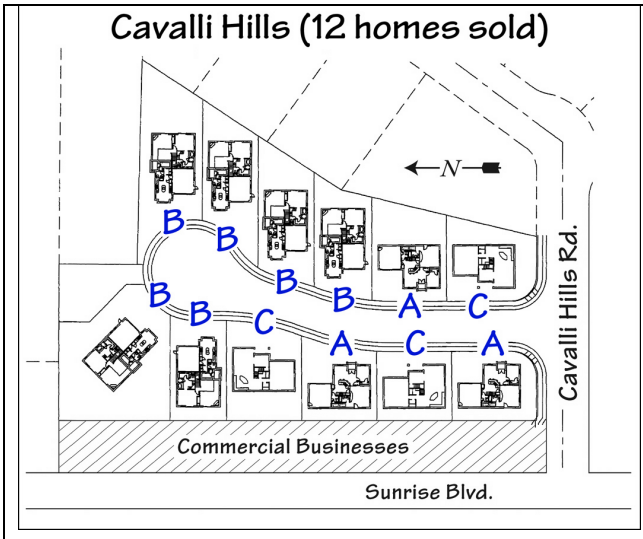


Figure 2. Footprint of A, B and C style homes built by Evans Construction.

2.6.2 Materials Testing at Weathering Farms in California

ORNL received concrete tile samples from the Shepherd Color Company, which they made for MonierLife Tile. Samples are being recalled for measurement of reflectance and emittance.

2.6.3 Steep-slope Assembly Testing at ORNL

ORNL requested and received from MonierLifetile, Hanson, MCA and Eagle about 1-1/2 squares of tiles for placement on the ESRA. The previous metal roofs and plywood deck were removed from the existing steep-slope assembly and 5/8-in OSB attached with a 30-lb felt paper cover. Richard Olson of the Roof Tile Institute (RTI), David Faulkner of Polyfoam Products, Danny Cornwell, consultant to the western states roofing contractors

association, Philip Dregger and John Goveia both of Technical Roof Services and Jerry Vandewater of MonierLife Tile installed clay and concrete tile on the steep-slope attic assembly on Nov 15, 03. The type of tile, manufacturer of the tile, the application used to fasten the tile and surface coverage per test lane are listed below.

Lane	Type of Tile	Manufacturer	Application	Weight	Roof Surface	
1	Clay "S"	MCA	Direct Deck	850 lbs	48”	by 17'
2	Concrete Medium	Hanson	Direct Deck	675 lbs	48”	by 17'
3	Concrete Medium	MonierLife Tile	Direct Deck w/foam	628 lbs	48”	by 17'
4	Concrete Flat	MonierLife Tile	Counter Batten	700 lbs	48”	by 17'
5	Concrete "S"	Eagle	Batten	640 lbs	57 ½”	by 17'
6	Asphalt Shingle	Proprietary	Direct Deck	50 lbs	54 ½”	by 17’

Parapets made from treated 2’ by 4’ lumber and channel flashing were installed between the lanes of clay and concrete tile to eliminate any airflow from underneath the tile to another test lane. All tiles whether direct nailed or installed on battens have a shallow channel for venting heat away from the roof deck. ORNL will measure the temperatures and heat flows just underneath the tile for direct nailed, batten and counter-batten tile systems and will compare the results to a top-of-the-line asphalt shingle.

ORNL recently learned that the Lafarge Roofing Technical Center has developed and validated a computer code that predicts condensation, temperature and heat flow within the air channel seen in batten and counter-batten roof construction. Lafarge wants to validate the code against field data acquired in the U.S. Hence, a white paper was forwarded to the Lafarge Center to begin negotiating collaborative work. It makes good sense to work together and validate the Lafarge code against field data acquired at the demonstration sites and the fully instrumented attic test stand. Once validated, we would use the code to develop correlations for the heat transfer occurring in direct nailed, batten and counter-batten constructions and implement the correlations in AtticSim for determining the cost of energy savings for vented roofs in different climates.

2.6.4 Product Useful Life Testing
(No activity.)

2.7 Technology transfer and market plan

2.7.1 Technology Transfer
The project team submitted an abstract to ACEEE 2004.

Akbari gave two presentations on colored cool roofs and heat-island technologies in a building-energy-efficiency workshop in Kuwait

2.7.2 Market Plan
(No activity.)

2.7.3 Title 24 Code Revisions
Revisions to Title 24 were approved by CEC on November 5, 2003. The new revisions would make cool roofs a prescriptive requirement for low-sloped non-residential buildings. The new standards will be in effect on January 1, 2004.

Management Issues

- None.

Attachment 1

Project Tasks and Schedules (*Approved on May 16, 2002*)

Task	Task Title and Deliverables	Plan Start Date	Actual Start Date	Plan Finish Date	Actual Finish Date	% Completion as of 012/31/2003
1	**Preliminary Activities**					
1.1	Attend Kick Off Meeting *Deliverables:* • Written documentation of meeting agreements and all pertinent information (**Completed**) • Initial schedule for the Project Advisory Committee meetings (**Completed**) • Initial schedule for the Critical Project Reviews (**Completed**)	5/16/02	5/16/02	6/1/02	6/10/02	100%
1.2	Describe Synergistic Projects *Deliverables:* • A list of relevant on-going projects at LBNL and ORNL (**Completed**)	5/1/02	2/1/02	5/1/02	5/1/02	100%
1.3	Identify Required Permits	N/A		N/A		
1.4	Obtain Required Permits	N/A		N/A		
1.5	Prepare Production Readiness Plan	N/A		N/A		
2	**Technical Tasks**					
2.1	Establish the project advisory committee *Deliverables:* • Proposed Initial PAC Organization Membership List (**Completed**) • Final Initial PAC Organization Membership List • PAC Meeting Schedule (**Completed)** • Letters of Acceptance	6/1/02	5/17/02	9/1/02		100%
2.2	Software standardization *Deliverables:* • When applicable, all reports will include additional file formats that will be necessary to transfer deliverables to the CEC • When applicable, all reports will include lists of the computer platforms, operating systems and software required to review upcoming software deliverables	N/A		N/A		

Project Tasks and Schedules (contd.)

Task	Task Title and Deliverables	Plan Start Date	Actual Start Date	Plan Finish Date	Actual Finish Date	% Completion as of 012/31/2003
2.3	PAC meetings *Deliverables:* • Draft PAC meeting agenda(s) with back-up materials for agenda itemsFinal PAC meeting agenda(s) with back-up materials for agenda items Schedule of Critical Project ReviewsDraft PAC Meeting Summaries • Final PAC Meeting Summaries	9/1/02	6/1/02	6/1/05		50% (3/6)
2.4	Development of cool colored coatings					
2.4.1	Identify and Characterize Pigments with High Solar Reflectance *Deliverables:* • Pigment Characterization Data Report	6/1/02	6/1/02	12/1/04		~ 70%
2.4.2	Develop a Computer Program for Optimal Design of Cool Coatings *Deliverables:* • Computer Program	11/1/03	11/1/03	12/1/04		< 2%
2.4.3	Develop a Database of Cool-Colored Pigments *Deliverables:* • Electronic-format Pigment Database	6/1/03	7/1/03	6/1/05		~ 10%
2.5	Development of prototype cool-colored roofing materials					
2.5.1	Review of Roofing Materials Manufacturing Methods *Deliverables:* • Methods of Fabrication and Coloring Report	6/1/02	6/1/02	6/1/03		~ 95%
2.5.2	Design Innovative Methods for Application of Cool Coatings to Roofing Materials *Deliverables:* • Summary Coating Report • Prototype Performance Report	6/1/02	6/1/02	12/1/04		~ 30%
2.5.3	Accelerated Weathering Testing *Deliverables:* • Accelerated Weathering Testing Report	11/1/02	10/1/02	6/1/05		<5%

Project Tasks and Schedules (contd.)

Task	Task Title	Plan Start Date	Actual Start Date	Plan Finish Date	Actual Finish Date	% Completion as of 012/31/2003
2.6	Field-testing and product useful life testing					
2.6.1	Building Energy-Use Measurements at California Demonstration Sites *Deliverables:* • Demonstration Site Test Plan • Test Site Report	6/1/02	9/1/02	10/1/05		35%
2.6.2	Materials Testing at Weathering Farms in California *Deliverables:* • Weathering Studies Report	6/1/02	10/1/02	10/1/05		35%
2.6.3	Steep-slope Assembly Testing at ORNL *Deliverables:* • Whole-Building Energy Model Validation Presentation at the Pacific Coast Builders ConferenceSteep Slope Assembly Test Report	6/1/02	10/1/02	10/1/05		25%
2.6.4	Product Useful Life Testing *Deliverables:* • Solar Reflectance Test Report	5/1/04		6/1/05		
2.7	Technology transfer and market plan					
2.7.1	Technology Transfer *Deliverables:* • Publication of results in industry magazines and refereed journal articles • Participation in buildings products exhibition, such as the PCBC Brochure summarizing research results and characterizing the benefits of cool colored roofing materials	6/1/03	6/1/02	6/1/05		~ 5%
2.7.2	Market Plan *Deliverables:* • Market Plan(s)	5/1/05		6/1/05		
2.7.3	Title 24 Code Revisions *Deliverables:* • Document coordination with Cool Roofs Rating Council in monthly progress reports • Title 24 Database	6/1/02	5/16/02	6/1/05		~ 5%

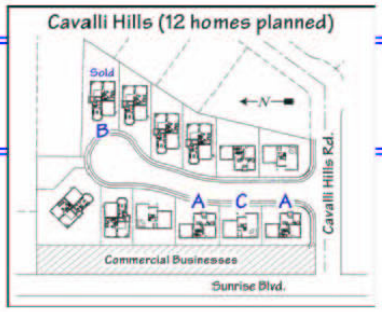
Project Tasks and Schedules (contd.)

Task	Task Title	Plan Start Date	Actual Start Date	Plan Finish Date	Actual Finish Date	% Completion as of 012/31/2003
VII	Critical Project Review(s) *Deliverables:* • Minutes of the CPR meeting					
XII (C)	Monthly Progress Reports *Deliverables:* • Monthly Progress Reports	6/1/02	6/1/02	6/1/05		53% (19/36)
XII (D)	Final Report *Deliverables:* • Final Report Outline • Final Report	3/1/05		10/1/05		
	Final Meeting *Deliverables:* • Minutes of the CPR meeting	10/15/05		10/31/05		

Attachment 2

Mike Evans Building Energy Efficient Homes For You

Evans Construction
EL Dorado Hills, CA 95762
Phone (916) 939 1854
Fax (916) 939 3419

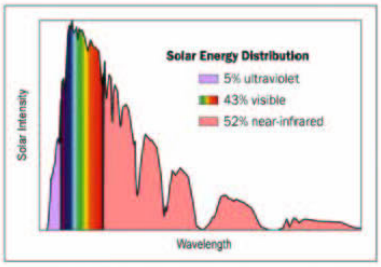


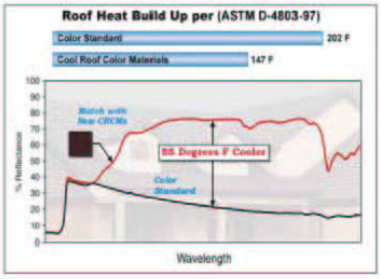
COOL ROOF COLOR MATERIALS (CRCMs)

Most painted roofs today have a reflectance of about 10-20%, but special paint made using Cool Roof Color Materials can give you a much higher reflectance of almost 60%. A roof covered by this special paint absorbs less solar energy and can save nearly 20% of your air conditioning costs.

FERRO Corp. and the Shepherd Color Company developed the Cool Roof Color Materials to look dark in color even though they reflect most of the sun's energy.

How can these dark roofs reflect as much or more energy than a white roof? The sun's radiation consists of ultraviolet, visible, and infrared energy. Our eyes can only see the visible region. The visible light that is reflected from an object determines the color of that object. White roofs reflect most of the visible light (which mixes together to look white to our eyes), but over half of the sun's energy is contained in the infrared region, which isn't visible to our eyes. Because we can't see this energy, we can reflect it away from the roof without changing the roof's color.





Advantages of Cool Roof Color Materials

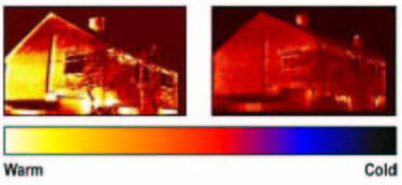
- Better fade resistance than standard colors
- Reflect more sunlight and stay cooler
- Lower utility bill for cooling the house
- Architectural appeal

Insulated Concrete Form Walls

Oak Ridge National Laboratory and the Florida Solar Research Center independently proved that insulated concrete form wall construction reduces seasonal cooling energy. These walls save energy in two ways. First they have a higher thermal resistance (R-value) than many other types of walls. Second, they tend to store energy, so that regular day and night temperature swings can help cool the house in summer and warm the house in winter.

Special Testing

The Sacramento Municipal Utility District is working with Evans Construction because they want to collect thermal performance data for insulated concrete form walls in Sacramento. The California Energy commission and two national laboratories, Oak Ridge National Lab and Lawrence Berkeley National Lab, are interested in knowing the performance of the Cool Roof Color Materials. So it makes good sense to work together in one project. Oak Ridge will make thermal scans of the roofs and walls. In these scans, cold surfaces show as black while the hottest surfaces are orange, red or white in color. The house with ICF walls on the right show lower wall temperatures than the frame construction house on the left, and therefore has lower heat losses.



Air leakage affects the thermal performance of a home, and can account for 30% or more of your home's utility bill. Oak Ridge will conduct blower door and duct testing to determine the natural infiltration rate of the house and duct system. Uncontrolled air leakage can result in high fuel bills and moisture damage.

SMUD • Dave Bisbee, Adv. Tech. • (916) 732-6409 ORNL • Dr. William Miller • (865) 574-2013 LBNL • Dr. Hashem Akbari • (510) 486-4287

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