EFFECT OF RADIANT BARRIER TECHNOLOGY ON SUMMER ATTIC HEAT LOAD IN SOUTH TEXAS

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ABSTRACT

The objective of the study was to experimentally evaluate the performance of radiant barriers in single-family occupied housing units in South Texas. Ceiling heat fluxes, attic air temperatures, indoor air temperatures, ambient air temperatures, roof temperatures, and solar radiation were measured. Results of the radiant barrier experiment using two side-by-side 600 ft^2 units are presented. Attic fiberglass insulation of nominal R-11 was installed in the two apartments when the units were last remodeled in 1974. The test houses responded similarly to weather variations, that is, attic temperature and heat flux profiles were similar in magnitude prior to the retrofit. Residents of the housing units were asked to set the thermostats at 76°F. Data were analyzed for periods of time which had the greatest attic temperatures (11 a.m. - 11 p.m.) and for which the indoor temperature differences were less than 1 percent. The results showed that radiant barriers reduced ceiling heat loads (on daily basis) by an average of 60 percent.

INTRODUCTION

Radiant barriers are used to decrease the transfer of infrared radiation from the attic deck space to the top of the insulation on the attic floor. Such barriers are thin aluminum sheets which have at least one low-emissivity surface (less than 0.05). A barrier may be applied in the attic space of a residence by facing the low emissivity surface toward the air space. Radiation blockage results in a reduction in the amount of ceiling heat gain into the conditioned space.

Radiant barriers may be installed in three configurations. The "horizontal radiant barrier" (HRB) places the radiant barrier on top of the ceiling joists. If the radiant barrier has only one reflective side, then this side faces up towards the air space. The "truss radiant barrier" (TRB) consists of a radiant barrier stapled to the rafters which support the roof deck. Hence, an extra air space is created between the barrier and the roof deck. If the radiant barrier has only one low emissivity side, it can face either the deck or the space beneath the barrier without making much difference. It has been recommended that the low emissivity surface face the lower air space so that dust accumulation will not represent a major problem. The "draped radiant barrier" (DRB) staples the radiant barrier directly to the roof deck thus avoiding the formation of a new air space. This configuration is the least common for retrofits because it is difficult to drape the barrier around the rafters. However, this last configuration is the most widely used in new constructions.

Results from radiant barrier experiments are usually given in terms of heat flux reduction from or to the attic through the ceiling. This refers to the amount of heat prevented from entering the conditioned space during summer time (or the amount of heat prevented from escaping from the conditioned space during the winter time). The percent heat flux reduction is given by

$$Reduction = \frac{\int_T q''_{control} - \int_T q''_{retrofit}}{\int_T q''_{control}} x100$$

Equation (1)

where,

$q''_{control}$ = Ceiling heat flux from the control attic [$Btu/hr\text{-}ft^2$].
$q''_{retrofit}$ = Ceiling heat flux from the retrofit attic [$Btu/hr\text{-}ft^2$].
T = Testing period used in the integration.

Percent heat flux reduction is a measure of radiant barrier effectiveness. Increased reduction constitutes increased effectiveness.

The South Texas area is one of abundant sunshine, high and sustained winds from the gulf coast, and high humidity. The more sunshine an area receives, the more attractive radiant barriers become because radiant barriers have the potential to lower the heat transfer which is driven by the solar loads on roof surfaces. On hot summer days, the roof of a residence absorbs solar radiation at a higher rate than is dissipated through conduction (to the attic interior) and convection (to the outside air), thus creating a rise in energy flow into the attic and hence an increase in attic temperature. During a typical afternoon, attic temperature may reach 110°F to 130°F. At peak times (when outdoor temperatures are hottest), more than 40 percent of the energy which enters the conditioned space through the ceiling is the direct result of radiant energy from the attic deck. Because of its low emissivity, a radiant barrier placed facing the attic air space can prevent as much as 95 percent of the infrared radiation from the attic deck from being transferred to the top of the attic insulation. This radiation blockage reduces the amount of energy gained by the conditioned space through the ceiling.

EXPERIMENTAL SET-UP

The radiant barrier experiment was conducted in two side-by-side housing units in the Texas A&M University-Kingsville (formerly Texas A&I University) Married Student Housing Complex. The one-bedroom units were selected based on resident interest and similarity of energy consumption patterns over the past year. Energy consumption data were obtained through the local utility company (Central Power and Light, CPL). Each unit was approximately 600 ft^2 and were mirror images of one another (Fig 1). Each unit was equipped with electric driven A/C units and was independently metered by CPL. The ridge line ran east to west in both houses. No shade was cast on the units from any direction. The units had slab-on-grade foundations with floor tile and the walls were constructed of concrete blocks. The units were last remodeled in 1974 and insulation with nominal R-11 was installed in the attics (dust accumulation and other impurities have decreased the resistance of this insulation). The units shared a brown shingle, pitched roof and the attics were open between units. The housing units were labeled "D" and "C", with unit D to be used as a control house.

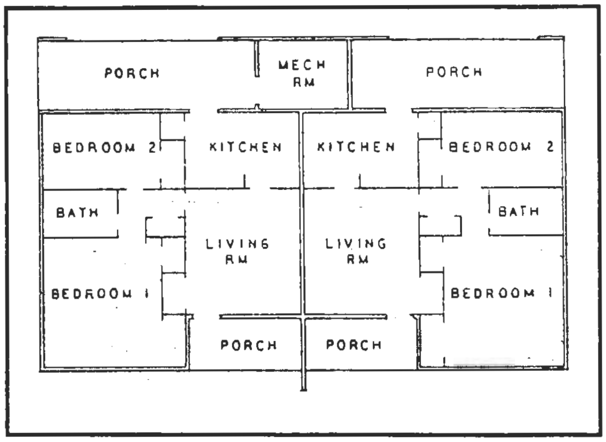

Figure 1. Houses Layout

INSTRUMENTATION

Each house was instrumented with 11 sensors including Type T thermocouples (three each along the peak of the attic, along the bottom of the attic, and inside the housing unit), and two heat flux meters 4 in. x 4 in. x 3/32 in. with calibration traceable to NIST standards. In addition, thermocouples were utilized to monitor ambient air temperature and roof shingle temperature, and solar radiation was recorded using a pyranometer with calibration also traceable to NIST standards. All data were recorded by means of a data logger. The data were collected at one minute intervals and integrated every hour. These values were stored in a microcomputer.

BASELINE CALIBRATION

The housing units were monitored for two weeks prior to the placement of the radiant barriers. This served as baseline information and was used to evaluate similarities in heat flux and indoor and attic air temperatures. The second week of the calibration phase was plagued with unseasonably wet and cool weather and it was therefore ruled out as an adequate baseline model. The week of May 29-June 4 was therefore selected as the calibration period. It was found that both houses were similar in their dynamic response to heat (Fig. 2 - Fig. 4). The average attic temperature difference was calculated to be 0.14 percent (Fig. 2). The residents of the housing units were asked to set their thermostats at 76°F. Due to the human factors involved (cooking, bathing, opening of doors and windows), the inside temperature difference ranged from 0.05 percent to 2.81 percent (Fig. 3).

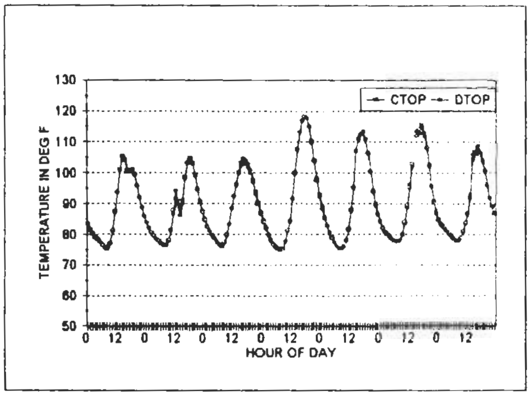

Figure. 2. Pre-Retrofit Attic Air Temperatures

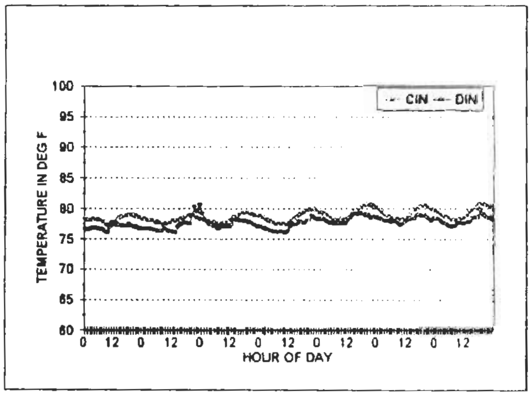

Figure 3. Pre-Retrofit Indoor Air Temperatures

Temperature percent difference was calculated by:

$$\%TemperatureDifference = ((TD - TC)/TD)x10$$

Equation (2)

where,
TD = Temperature Apartment D
TC = Temperature Apartment C

To accurately represent the effectiveness of radiant barriers, only that data which were collected when inside temperature differences were less than 1 percent were used. The average heat flux difference for the calibration period was 10.4 percent, with average heat flux into house C being greater than the average heat flux into house D. This was especially evident during the peak periods (11 a.m. - 11 p.m.) when attic temperatures were the highest. Attic temperatures ranged up to 118°F and shingle temperature reached as high as 149°F during peak periods.

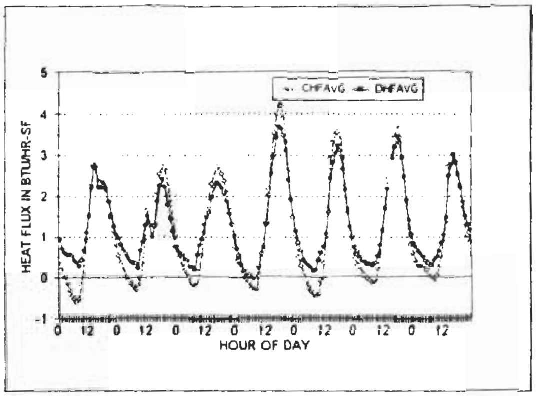

Figure 4. Pre-Retrofit Ceiling Heat Fluxes

RESULTS

House C was retrofitted with horizontal and truss radiant barriers[1] on June 23 and data continued to be collected until August 31, 1993. Horizontal radiant barriers were implemented due to the open structure of the attic area which allowed radiant heat from house D to enter into house C. House D remained as the control house for the experiment.

The week of August 7-August 13 was selected as the data comparison period due to the relative similarities in attic temperatures as compared to those of the calibration period. Attic temperatures ranged up to 119°F (Fig. 5) and shingle temperature reached as high as 141°F during peak periods. Inside temperatures were almost identical for this time period (Fig. 6).

The data gathered during this period clearly indicated a significant decrease in heat flux into the apartment with radiant barriers (Fig. 7). Average heat flux difference increased to 49.7 percent with heat flux into house D surpassing that into house C (Fig. 8). When the initial 10.4 percent heat flux difference into house C is accounted for, overall heat flux percent difference was calculated to be 60.1 percent.

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[1] Innovative Insulation Inc., Super R Brand

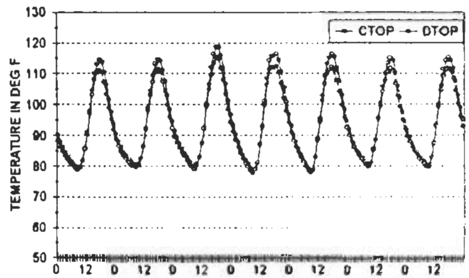

Figure 5. Post-Retrofit Attic Air Temperatures (measured above the radiant barrier)

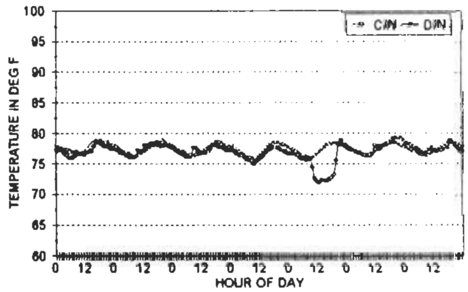

Figure 6. Post-Retrofit Indoor Air Temperatures

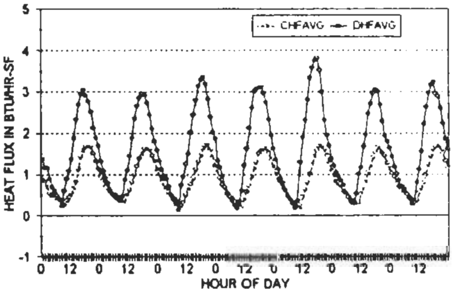

Figure 7. Post Retrofit Ceiling Heat Fluxes

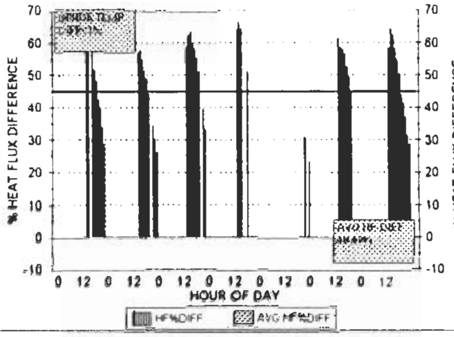

Figure 8. Post Retrofit Ceiling Heat Flux Differences.

SUMMARY AND CONCLUSIONS

Radiant barrier experiments were conducted for a period of three months on two well calibrated single-family apartments in South Texas. The test apartments responded similarly to weather conditions during the calibration period. Attic temperature differences averaged 0.14 percent. Data were analyzed for time periods when inside temperature differences were less than 1 percent and when attic temperatures were at their peak. The average heat flux difference for the calibration period was 10.4 percent, with more heat flowing into the apartment which was to be retrofitted with radiant barriers. Horizontal and truss radiant barriers were then installed and data were collected and analyzed. It was found that ceiling heat flux difference was increased to 49.7 percent after the installation of radiant barriers (with more heat flux into the apartment without radiant barriers) for a total heat flux difference of 60.1 percent

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