Relationship of Total Solar Reflectance to the Visual Appearance and Color Intensity of Asphalt Shingles

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Introduction:

Rising energy prices and the finite capacity of the existing electrical energy infrastructure is increasing interest in finding new ways to improve building energy efficiency and to reduce peak electrical energy demand. Preferably these improvements can be achieved with minimal disruption to the economy and without adversely impacting key product performance features such as: esthetics, utility, ease of use, and cost of ownership.

One building component receiving considerable attention is the roof. In steep slope dwellings, many designers and owners have relied on the wide variety of styles, appearance, and colors provided by asphalt shingles to meet their needs cost effectively. Homeowners often choose asphalt shingles to create or complement a specific design theme and increase the curb appeal of their dwelling, which ultimately enhances its value. It is desirable that asphalt shingle manufacturers be able to continue to provide these wide varieties of choice, but with more energy efficient shingle designs.

An approach to improve the roofing system energy efficiency is to reduce the amount of solar energy absorbed by the roofing material and transferred into the structure, thereby decreasing the cooling burden on the dwelling. One way this can be accomplished is by increasing the total solar reflectance of the exposed surface of the shingles. White materials reflect broadly across the visible spectrum, while dark materials absorb more broadly in the same region. All else being equal whiter roofs have higher total solar reflectance than darker. However, consumer preference, as evidenced by the sales of granule colors (and hence asphalt shingle colors) indicate that many consumers prefer darker, richer shingle colors to white. This raises the question as to what can be achieved with those colors in between the light and dark extremes.

> *Can one achieve higher reflectance asphalt shingles while still maintaining a range of color choices which will be acceptable to consumers?*

Conceptually this is possible by taking advantage of the large infrared (IR) component of the solar spectrum. This IR band constitutes approximately half of the solar energy reaching the earth's surface, but it is outside of the range which the human eye can detect (the visible spectrum). By increasing the IR reflectance of roofing materials while still allowing them to selectively absorb in the visible spectrum to provide color, non-white shingles with higher total solar reflectance values can be developed. However, some level of absorption is still necessary to achieve color. The practical balancc is to determine how much the total solar reflectance can be increased before the loss of color intensity causes the shingle appearance to become unacceptable to the consumer.

Discussion and Results:

This study attempts to address this question by looking at how the visual appearance changes for three different color blend designs of shingles as the total solar reflectance is increased. This was accomplished by varying the type (standard or higher solar reflectance) and color of roofing granules used to produce the shingle. Traditional roofing granules, such as those available from 3M Company, come in a wide variety of vivid colors including dark browns and blacks. 3M also has recently introduced a new line of granules that are specifically designed to have a high total solar reflectance while still providing a suitable range of colors. However, in visual appearance these high reflectance granules are lighter and more pastel in color than the standard line of granule colors. As a baseline for comparison a standard shingle for each of these three designs was created incorporating only the standard line of granules. The baseline shingle designs chosen for this study are intended to be composite facsimiles of the more popular shingles currently available from a variety of asphalt roofing manufacturers – they are of our own creation and do not exactly duplicate any existing commercial shingle. The three generic designs are a blend of colors which result in what we will refer to as: a standard black shingle, a standard tan shingle and a standard grey or weathered wood type shingle. All of the shingles used in this study were produced on the shingle pilot plant facility at 3M.

Using these three standard shingles as baseline visual references, new shingles were created to be as close in appearance to their respective base shingle as possible but with total solar reflectance targets of 20%, 25%, and 30% (see Table 1). It should be noted that although some of the shingles in Table 1 have reflectance values 1 or 2 units above their target value that it is anticipated that normal variability in both the granule and shingle production processes will require a shingle to be designed with a reflectance value slightly higher than a required minimum, such as the EPA's Energy Star® criteria of 25% for initial steep slope roofing. The baseline standard shingle reflectance values were all below 15%. In order to achieve these higher reflectance values while still maintaining some resemblance to the appearance and color of the baseline shingles it was necessary to use the new higher reflectance granules, and at the 30% level a large percentage of white granules. Table 1 lists the shingles and their respective total solar reflectance values as measured with a Device and Services Solar Spectrum Reflectometer Model SSR using a method similar to ASTM C1549. As a rough numerical quantification of the difference in color intensity and appearance a Hunter Labscan instrument was used to determine the delta L* (1976 CIE L*a*b* Color Space) between the various shingle samples and their respective baseline standard shingles. L* is a measure of the lightness of an object on a scale from 0 to 100 with 100 being completely white and 0 completely black. The delta L* is a measure of the difference in lightness between two objects with a positive delta value indicating a more white object. As an object becomes increasingly lighter on the L* scale it tends to lose intensity in color on the other scales (a* is the red/green axis and b* is the yellow/blue axis in the L*a*b* color space).

Table 1: Shingle Reflectance and Average L Difference from the Respective Standard Shingle*

Shingle	**Total Solar Reflectance (%)**	**Average ΔL* value**
Standard Tan	14	n/a
20% TSR Tan	20	3.1
25% TSR Tan	27	7.5
30% TSR Tan	30	16.0
Standard Grey	9	n/a
20% TSR Grey	21	7.0
25% TSR Grey	26	16.5
30% TSR Grey	31	24.0
Standard Black	4	n/a
20% TSR Black	23	20.7
25% TSR Black	27	28.7
30% TSR Black	31	37.3

The delta L* results indicate an increase in the whiteness of a shingle as reflectance is increased. Furthermore, the darker the standard baseline shingle was to begin with, the lower its initial reflectance, and as a result a more significant loss of color was required in order to raise the reflectance to the targeted values. This can be seen by the 20 unit L* increase for the 20% black shingle versus only a 3 unit L* increase for the 20% tan shingle. But how important are these difference to the visual appearance? This is a rather subjective question that can be best addressed by physically looking at the different shingles.

The following figures provide an illustration of the degree to which shingle reflectance can be increased while still maintaining an appreciable amount of color. It should be noted that although every attempt was made to provide images that accurately reflect the actual daylight appearance of these shingles they will vary depending on the type of monitor or printer used. The images are placed in order of increasing total solar reflectance from left to right. There is an appreciable lightening and loss of color intensity as the reflectance is increased; however at 20% and 25% reflectance a definite non-white shingle was clearly obtained. At 30% reflectance, however, essentially only a white shingle was achieved. A small amount of color is visible in the 30% shingles when viewed up close but from ground level a roof with this little color will appear to be off white at best.

Figure 1: Tan Shingle Series *(Targeted Solar Reflectance)*

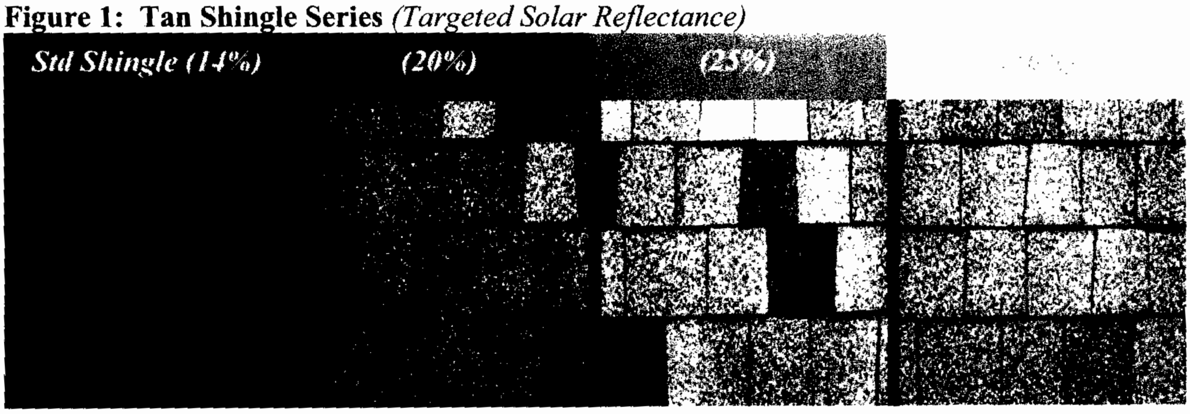


Figure 2: Grey Shingle Series: *(Targeted Solar Reflectance)*

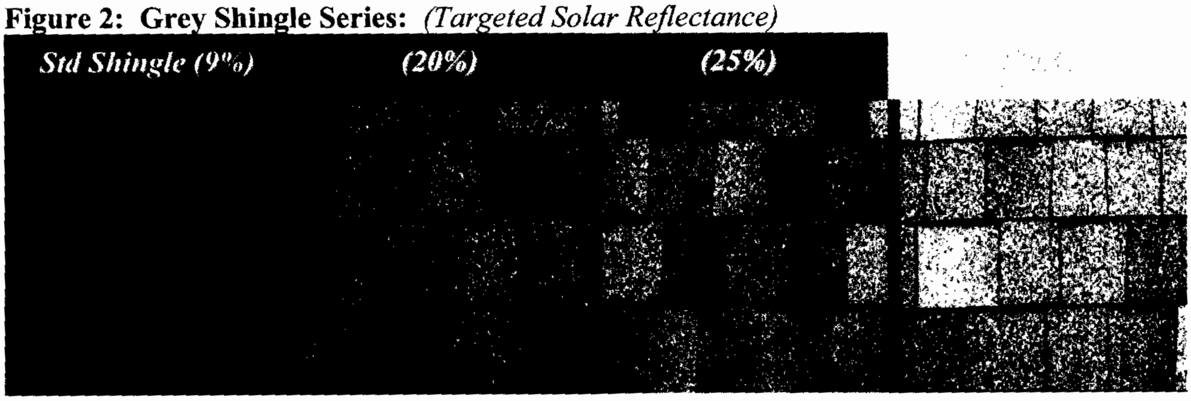
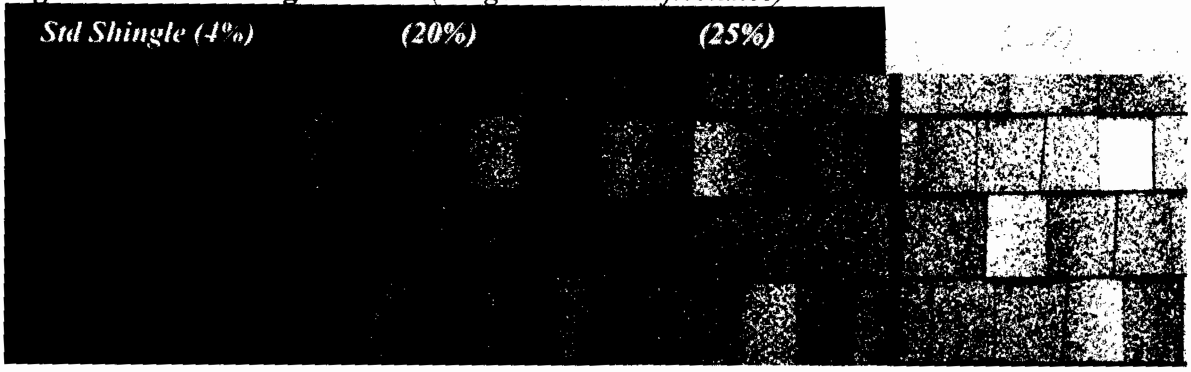


Figure 3: Black Shingle Series: *(Targeted Solar Reflectance)*



Conclusions:

Typically non-white asphalt shingles have total solar reflectance values of less than 15%. Current white asphalt shingle roofs are capable of achieving reflectance values of around 30%. However, homeowners generally do not consider white shingles on a steep slope residential roof to be an acceptable choice. They demand a selection of colors and styles that will enhance the appearance and maintain the value of their home. Nonetheless, there is increasing awareness of the importance of conserving energy and growing interest in products that can deliver improved energy efficiency without sacrificing the performance of their primary functions. For residential steep slope roofing, this means improving the total solar reflectance without compromising weather-ability, appearance or cost effectiveness.

In this study we looked at the possibilities of using new high reflectance granules to design colorful high reflectance asphalt shingles. To cover a wide range of different shingle color blend designs three different color types were evaluated (tan, grey, black) with respect to the impact on color intensity and appearance as solar reflectance was increased.

It was found that at 20% total solar reflectance a mixture of the new high reflectance granules and standard roofing granules could be used, which helped to minimize the loss of color intensity.

To achieve the 25% reflectance level, we found we needed to exclusively employ the high reflectance granules. However, with the exception of the black series, we found the shingles still retained significant color and though somewhat more pastel in appearance, still continued to resemble the original baseline shingle.

At the 30% reflectance level we found there is little flexibility to add color even with the new high reflectance granules. Aesthetics are certainly subjective to individual perceptions and personal preferences, but it is anticipated that most observers would contend these 30% reflectance shingles have minimal remaining resemblance to their popular standard shingle counterparts.