Asphalt Shingles - Thermal Cracking

INTRODUCTION

A typical residential roof surface experiences extreme changes in temperature. Those changes in temperature cause all materials on a roof to expand and contract.

Like any other material, asphalt shingles are susceptible to thermal movement. Adverse effects due to thermal movement in asphalt shingles is nearly inescapable due to the inherent physical properties of asphalt shingles, aging, and extreme cyclic temperature changes of a typical roof.

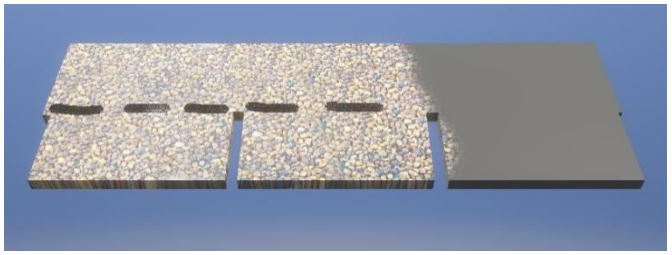
This document provides background information that is needed to understand the issues related to thermal cracking in asphalt shingles. To understand the problem, it is necessary to grasp the following related subject matter:

TABLE CONTENTS

1. The Anatomy of an Asphalt Shingles

The fabrication of a roof shingle starts with a base mat. The mat is typically composed of cross-woven fiberglass fibers that holds the asphalt together.

The mat is saturated with asphalt. Small granules are applied to the top surface of the shingle while the asphalt is still hot. A sealant strip of adhesive is applied to the center of the shingle.

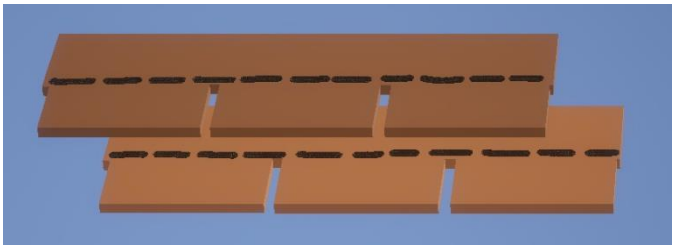


2. The Sealant Strip

The sealant strip is designed to activate when the shingles are in contact with each other and heated during a typical warm summer day. The adhesive of the sealant strip bonds the upper and lower shingles together forming larger sections of connected shingles.

The sealant strip helps to keep the shingles together. The adhesive holds down the leading edge of the upper shingle. The image below shows an upper shingle held slightly above the final placement.

When the upper shingle is placed over the lower shingle the sealant come in contact with the underside of the top shingle just above the leading edge. The first warm day activates the adhesive making a strong connection.



As shingles age, the adhesives break-down. Eventually, many older roofs become unsealed as the adhesives become ineffective.

There are many things that can prevent good sealing between shingles such as: dirt, winter installation, inadequate storage, or a manufacturing defect.

3. Thermal Movements

Most all building materials will:

a) expand with increased temperature
b) contract with decreased temperature.

In order to prevent damage to the materials or connections, many types of expansion joints are used within the building industry. A good example of an expansion joint can be found at the end of a bridge. A steel bridge must be allowed to expand or contract otherwise internal stresses will cause problems within the bridge structure or damage the end conditions.

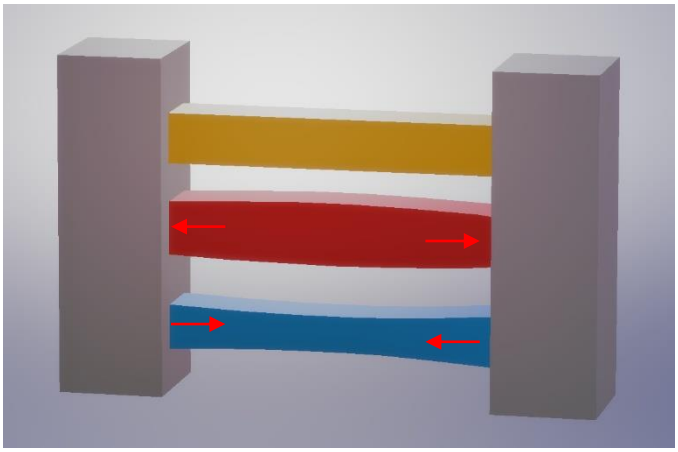
Thermal movements can be calculated. The coefficient of thermal expansion is a material property that represents the percentage change in the length of a material per degree of temperature change.

4. Internal Stresses Due to End Restraint

If a material is held tight at the ends and a temperature change is experienced the member will develop internal stresses as it tries to contract or expand.

The image below shows three identical square beams connected between two immovable posts.

- The top member (gold) is at a neutral temperature.
- The middle (red) member is heated. It wants to expand. It pushes on the end conditions.
- The bottom member (blue) is cooled. It wants to shrink. It pulls on the end conditions.



5. Thermal Effects in Asphalt Shingles

Shingles are not left on a roof and free to expand and contract with temperature changes.

- They are nailed to a wood surface that has a different coefficient of expansion.
- Shingles are also connected to each other with the adhesive.

Therefore, internal stresses are created in roof shingles with day-to-day changes in temperature.

There is a mixture of movement and internal stresses that are ever changing with daily and seasonal temperature changes.

6. Estimating Thermal Movements

The coefficient of thermal expansion is a material property that can be obtained by testing. Asphalt shingles have a coefficient of thermal expansion in the range of 0.0001 in/in/F. Other materials have different values.

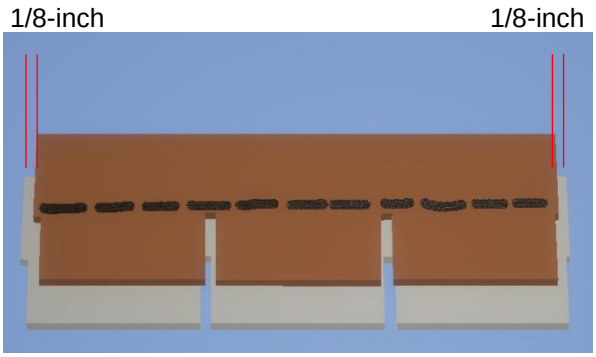
Asphalt shingles experience significant changes in temperature. On a hot summer day, a residential roof can reach extreme temperatures of 150 degrees which is enough to get a light burn if touched with a bare hand. At night is may drop down in the 60's. Therefore, daily temperature change can be as much as 150 – 60 = 90 degrees.

During a cold winter day in Minnesota the temperatures may plunge to -30 or -40 Fahrenheit. Therefore, the seasonal temperature change can be as much as 150 – (-30) = 180 degree.

Assuming a shingle is installed during a summer day, the day-to-day expansion and contraction of a 36-inch long shingle would be approximately:

(0.0001 in/in/F) x (36-inches) x (70 degrees) = 0.25 inches

Therefore, a typical shingle, if left on a roof and allowed to expand and contract without restraint, might see a change in length of 0.25 inches on a typical day. (Or 1/8-inch on each side)



7. Asphalt Shingle Aging

A roof surface is a harsh environment. As asphalt shingles age, the volatiles are released, and some amount of shrinkage is expected.

Asphalt shingles also become more brittle with age. Material become more brittle with colder temperatures.

With time the sealant becomes weaker. Many older roofs lose the adhesion of the sealant strip.

8. Shingle Installation Patterns

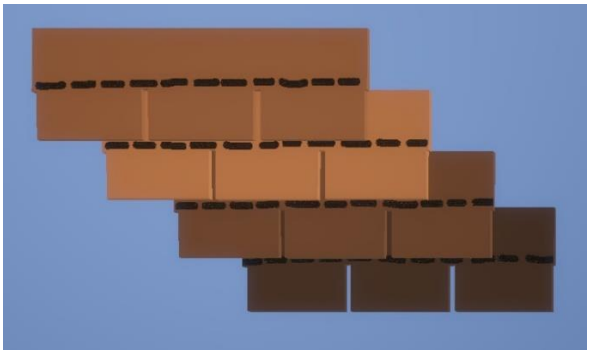
There are basically two ways of installing shingles

1. The Diagonal Method
2. Vertical Racking Method

Each use a 6-inch offset. The two methods produce different internal forces causing different effects of cracking. Each is explained below.

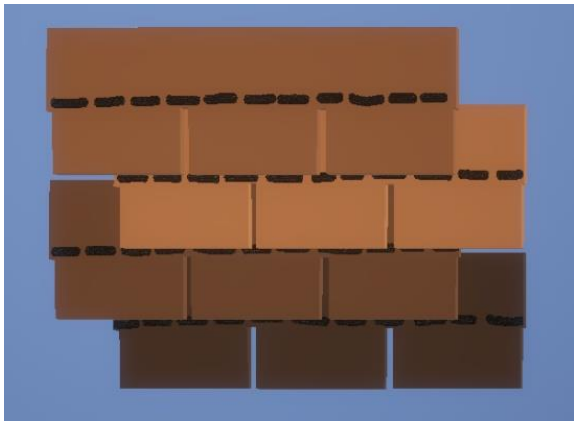
9. Diagonal Method

The shingles are offset from each other consecutively with each row creating a larger section of connected shingles that form a diagonal shape.



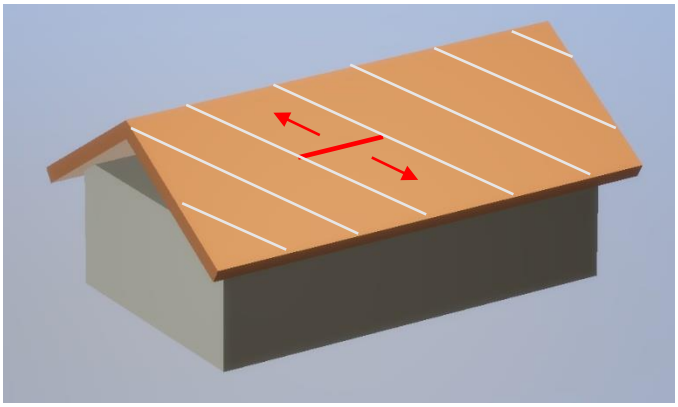
10. Vertical Racking Method

The shingles are offset from each other in a straight column creating a larger section of connected shingles that form a vertical shape.



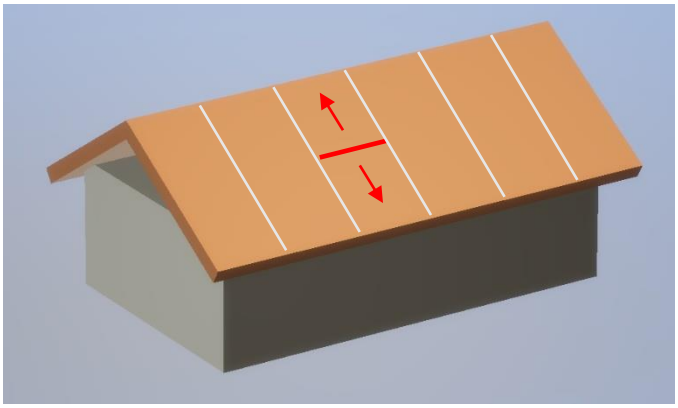
11. Diagonal Method – Horizontal Cracks

The diagonal method creates diagonal sections of shingles that are rigidly attached to each other. The edge boundaries are shown below. As the larger diagonal sections try to contract, they are resisted by each other. Horizontal cracks will form as the materials try to pull apart from each other. Or the shingle adhesive strip will let loose.



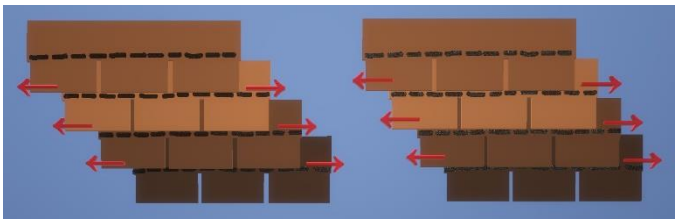
12. Vertical Racking Method – Horizontal Cracks

The vertical racking method creates vertical sections of shingles that are rigidly attached to each other. The edge boundaries are shown below. The effects are the same. Horizontal cracks are formed to relieve stresses.



13. Diagonal Method – Diagonal Cracks

The image below shows shingles installed using the diagonal method. The sections are pulled apart to show the forces between the sections.

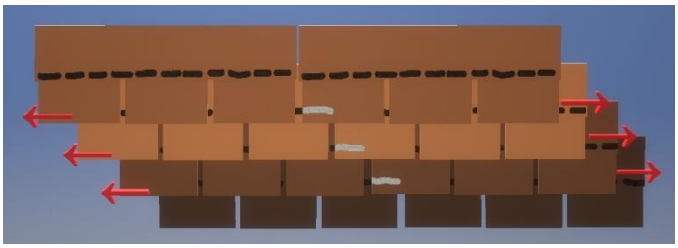


The shingles in a **diagonal** section are held tight together with long lines of adhesive. The red arrows indicate the tension forces that develop as the shingles shrink. There are two effects that occur when the shingles contract:

1. sealant failure
2. tearing

The sealant fails at the joint allowing the two sections to move apart. The white lines indicate unsealed corners of the shingles.

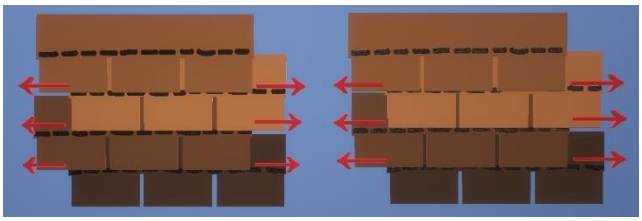
The unsealed edges are at the butt-joint of the two sections and form a **diagonal** pattern running up the slope of the roof.



If the sealant is stronger than the shingle, the shingles tear creating curved tears at the corners. The tearing runs along an arc to release the two sections.

14. Vertical Racking Method – Vertical Cracks

The image below shows shingles installed using the vertical racking method. The sections are pulled apart to show the forces between the sections.

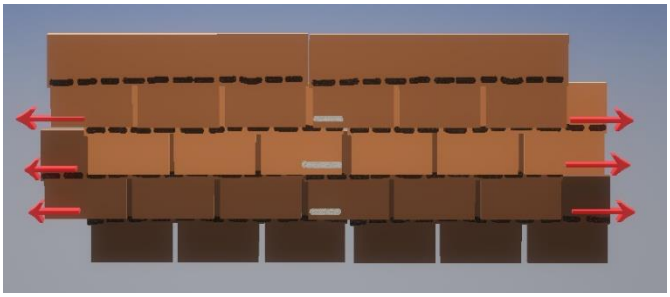


The shingles in a **column** section are held tight together with long lines of adhesive. The red arrows indicate the tension forces that develop as the shingles shrink. There are two effects that occur when the shingles contract:

1. sealant failure
2. tearing

The sealant fails at the joint allowing the two sections to move apart. The white lines indicate unsealed corners of the shingles.

The unsealed edges are at the butt-joint of the two sections and form a **vertical** pattern running up the slope of the roof.



If the sealant is stronger than the shingle, the shingles tear vertically.

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