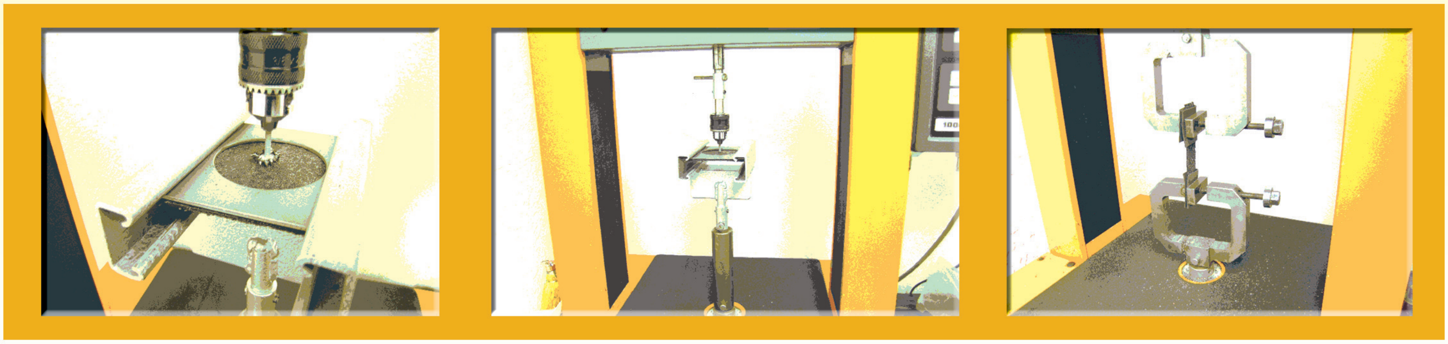
Performance Attributes of Fiberglass Shingles



By Jim D. Koontz, RRC, PE

Introduction

Fiberglass shingles have dominated the market for steep-sloped roofs in the United States for many years. The predominant use of fiberglass shingles occurs on residential structures, multifamily housing units, and many commercial buildings. Satisfactory performance of fiberglass shingles during wind events is an extremely important factor in the protection of property. Successful performance of shingles is a combined function of proper manufacture and installation.

The past 30 years have presented many opportunities to examine numerous shingle losses due to wind events. For the most part, fiberglass shingles have performed well. In many cases, however, it is clear that improperly manufactured or installed shingles have prematurely failed (*Photo 1*). Some shingles, even when properly manufactured or installed, have failed at relatively low wind speeds.

Purpose

The purpose of this research is to examine fiberglass shingle physical properties and workmanship factors that may contribute to shingle failure during wind events. Failure of shingles below the required minimum wind speeds of the governing building code is of particular importance.

Background

In the early 1990s, the performance of fiberglass shingles came into question. Numerous cases of fiberglass shingles splitting, independent of external factors, were reported (*Photo 2*). The shingles would split on the exposed face of the roof in both horizontal and vertical directions. Splitting occurred predominantly on western and southern exposures.

The causes of the splitting were widely debated and resulted in the publication of

Photo 1 – Shingle failure. Note high placement of nails.

Photo 2 – Shingle splitting.

numerous technical articles on the subject. The causes of the splitting were attributed to poor ventilation, workmanship, and in some cases, poor quality of manufacture. Eventually, through research, splitting was found to be related to thermal cycling and the physical properties of the shingles. The earliest article on this subject was published in *Western Roofing*, May/June 1990.[1]

Standards

One physical property that was identified as a factor in the shingle splitting was the "tear strength" of the shingles. Tear strength is a physical property of fiberglass shingles listed under American Society for Testing and Materials (ASTM) Standard D 3462,[2] "Asphalt Shingles Made from Glass Felt and Surfaced with Mineral Granules." The minimum tear resistance listed under this standard is 1,700.0 g.

The test method for tear strength is contained within ASTM D 1922,[3] "Propagation Tear Resistance of Plastic Film and Thin Sheeting by Pendulum Method." The tear strength test utilizes a pendulum device that is based upon quality control procedures initially developed by the textile industry. Within the roofing industry, the test procedure is commonly referred to as the Elmendorf Tear Test. One conclusion with regard to a factor contributing to splitting is that shingles with a higher tear resistance are less likely to split. In this regard, there has been some improvement within the industry. Some manufacturers tout the tear resistance of their products, and in various marketing literature state, "Bring on your Elmendorf." Regardless of the debate over splitting, tear resistance is an important physical property that helps to describe the performance of shingles.

In addition to tear strength, fiberglass shingles complying with ASTM Standard D 3462 must pass a fastener pull-through test. Sufficient fastener pull-through resistance values provide some assurance that shingles will stay in place during expected wind events. This test provides a simple measurement of complex mechanical effects that relate to the shingles' resistance to wind. It requires a minimum pull-through amount of a fastener for both one and two layers of shingle material. One layer is required to have a pull-through resistance of 20.0 lbf, and two layers are required to have a pull-through resistance of 30.0 lbf.

Under ASTM D 3462, fiberglass shingles must also meet other physical property requirements, including a minimum net mass of the reinforcement material. Under Table 2 of ASTM D 3462, a net mass of 1.35 lbs/100 ft^2 is required.

Compliance with an ASTM standard does not necessarily imply a quality product. ASTM standards are developed through a consensus agreement among manufacturers, contractors' associations, consultants, and other interested parties. Often, minimum product physical properties are set as standards.

Building Codes

Building codes in use across the United States have listed limited information concerning placement and numbers of fasteners for shingles. The 1997 Uniform Building Code[4] (UBC) requires four fasteners per shingle. The UBC refers to "special conditions and in special wind regions" where additional attachment shall be per manufacturer's instructions. The 2003 International Building Code[5] (IBC) and the 2001 Florida Building Code[6] refer to ASTM D 3462 as a minimum requirement for fiberglass shingles. These two codes also refer to ASTM D 3161,[7] "Wind-Resistance of Asphalt Shingles," for attachment procedures in winds up to 110 mph. The Florida Building Code, under Roofing Application Standard (RAS) No. 115, calls for six fasteners per shingle in "High Velocity Hurricane Zones."

ASTM D 3161 is a test procedure and does not provide specific requirements for the number of fasteners to be installed in shingles. ASTM D 3161 defers to recommendations from shingle manufacturers. Manufacturers typically refer back to the local building code with regard to recommendations for additional attachment. For the consumer or applicator, this circuitous route of recommendations does not provide useful information that may be necessary for proper shingle installation and performance.

Fastener Location and Number

Shingles manufactured with the highest degree of quality control can be improperly installed and used in inappropriate situations. The proper number and location of

Photo 3B – Chalk lines.

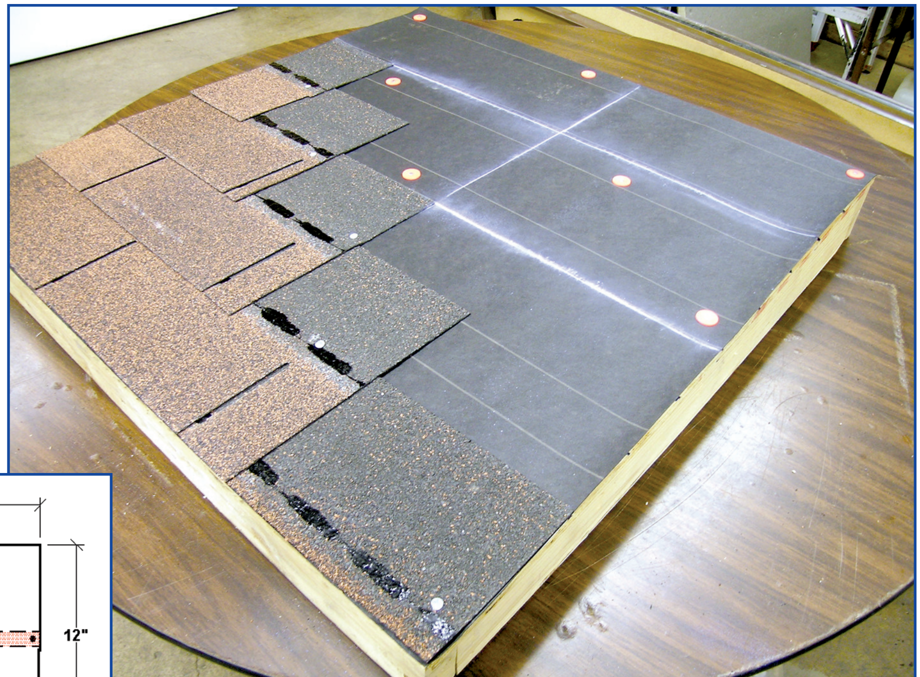
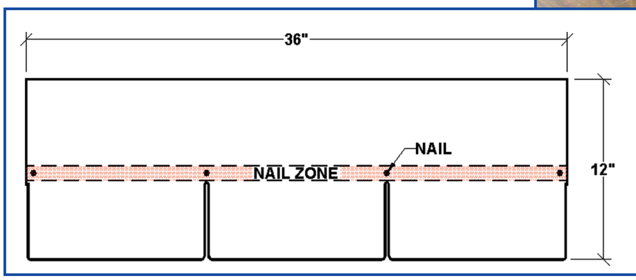


Photo 3A – Nail zone.



fasteners used to attach shingles is critical to successful performance. With respect to fastener location, many shingle manufacturers refer to the "nail zone." The nail zone, for 12" x 36" shingles, is typically along the midsection of the shingle, approximately 5.5" to 6.5" above the butt edge (*Photo 3A*). Some manufacturers have a line marked on the shingle that indicates the proper fastener location. Typical manufacturer recommendations call for placing the fasteners so the upper top edge or "head lap" of the preceding shingle is penetrated as shown in *Diagram A*.

Proper placement of shingles is also critical. It is important that the shingles be installed with the proper exposure and the proper head lap. Improper placement is shown in *Diagram B*. In order to ensure proper placement of shingles, contractors should put chalk lines both horizontally and vertically on the underlayment prior to the placement of shingles (*Photo 3B*).

All shingle manufacturers who were reviewed require a minimum of four fasteners per shingle. Specific recommendations in "high wind zones" are somewhat vague. Several manufacturers show up to six fasteners per shingle in "high wind areas." The decision of what is considered a high wind area is left up to the designer, roofer, or consumer.

Laboratory Analysis

A total of 13 fiberglass shingles from various manufacturers were acquired for a series of tests, including six three-tab shingles and seven laminate shingles. Several different laboratory tests were performed in order to determine the physical properties of each shingle:

- Desaturated mat weight
- Tensile strength
- Tear strength
- Fastener pull-through: single layer, double layer
- Fastener pull-through, laminate layer: single layer, double layer

Small samples from the 13 shingles were placed in a bath of hot, circulating solvent. The asphalt and granules were

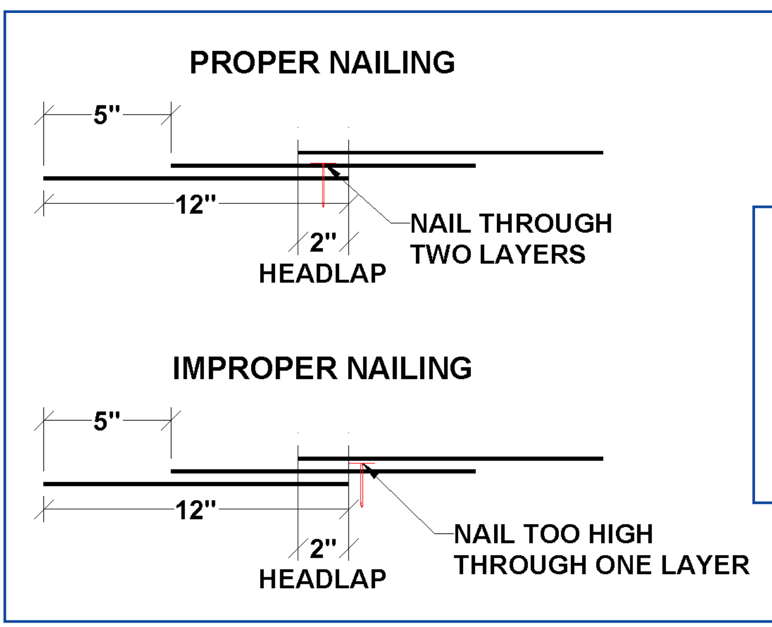


Diagram A

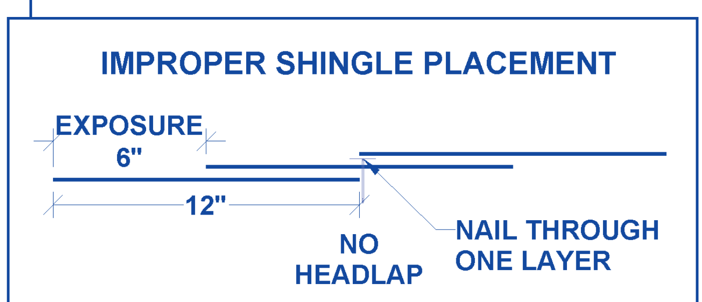


Diagram B

Photo 4 – Desaturated mat weight.

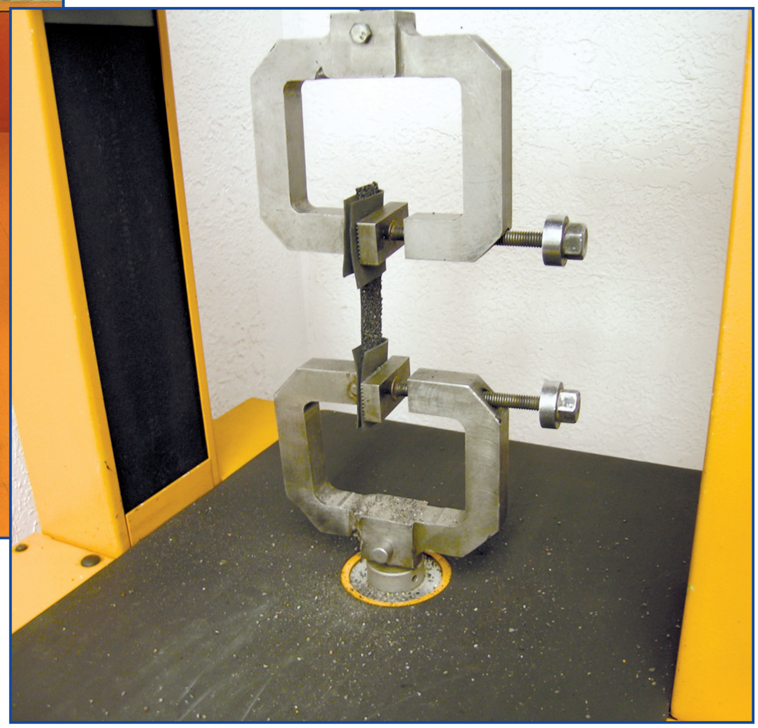


Photo 5 – Tensile strength.

extracted from each sample until a clean fiberglass mat was obtained (*Photo 4*). The fiberglass mat samples were dried and weighed. The desaturated, dry, fiberglass mat weights ranged from a low of 1.67 lbs/100 ft^2 to a high of 2.17 lbs/100 ft^2. All of the samples tested contained fiberglass mats that exceeded the ASTM D 3462 minimum requirement of 1.35 lbs/100 ft^2.

The shingles were also tested for tensile strength (*Photo 5*). Tensile strength is not listed as a requirement under ASTM D 3462, but was performed for informational and comparison purposes. The tensile strength ranged from a low of 82.0 lbf to a high of 119.0 lbf.

The Elmendorf Tear Test, ASTM D 1922 (*Photo 6*), was performed on each of the thirteen new shingle samples. The tear strength ranged from a low of 830.0 g to a high of 2,190.0 g.

Under ASTM D 3462, the minimum tear strength requirement is 1,700.0 g. Overall, eight of the 13 samples did not meet the minimum ASTM requirement, including three of the three-tab shingles and five of the laminate shingles. It is interesting to note that the product that fell below the 1,700.0 g tear resistance requirement was contained within packaging that stated the shingles were manufactured to ASTM D 3462 standards (*Photo 7*).

A fastener pull-through resistance test was performed with single and double layers of shingles. The purpose of the two methods of testing was to simulate proper and improper fastener placement. If a shin-

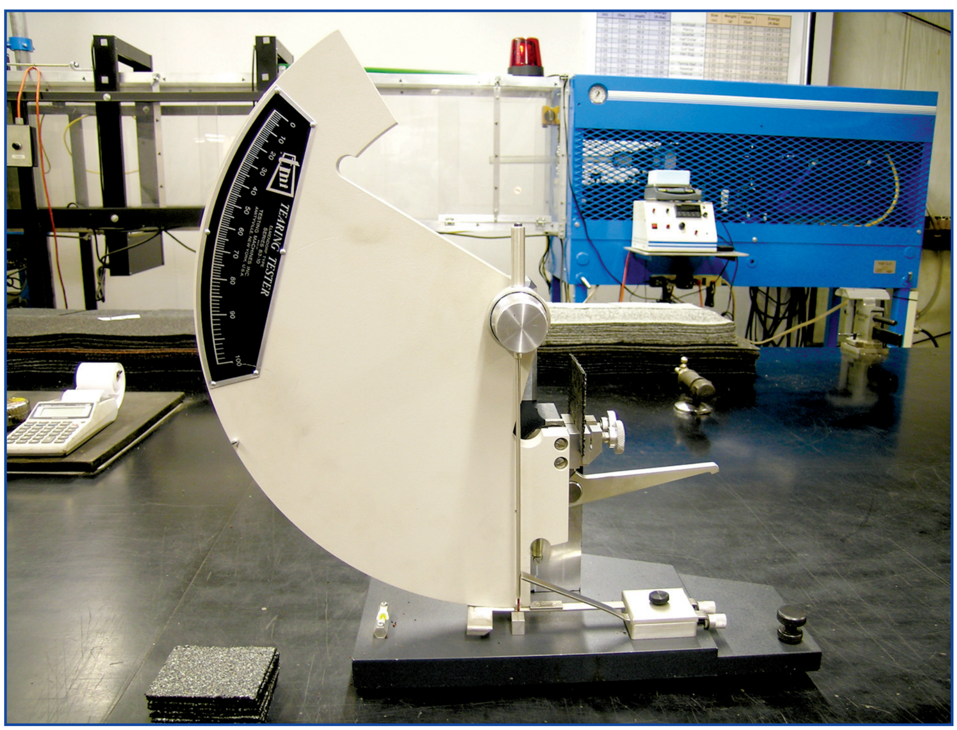


Photo 6 – Elmendorf tear test.

Photo 8 – Fastener pull-through.

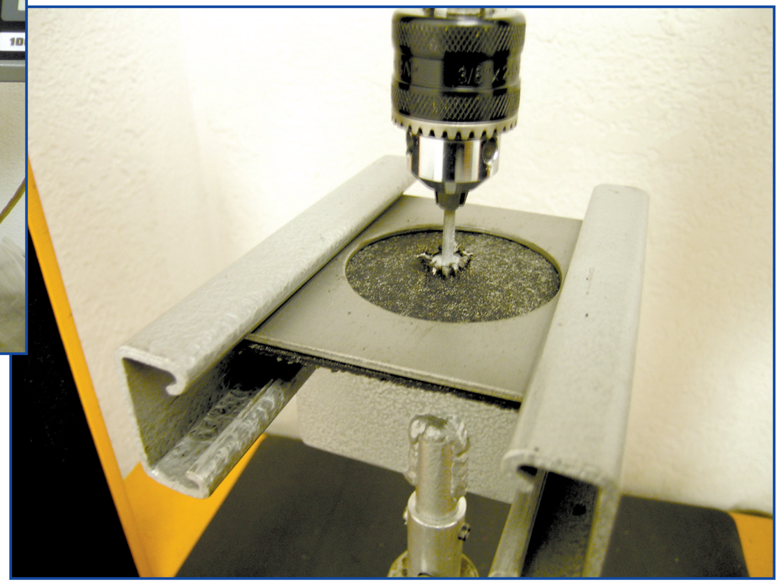


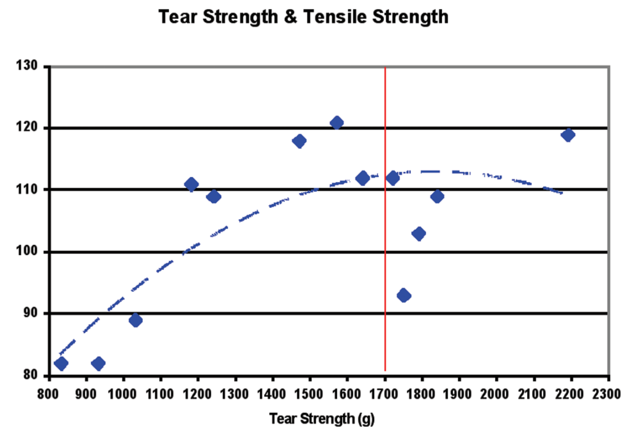
Photo 9 – Fastener pull-through.

gle were to be nailed well above the nail zone, only one layer of shingle would be penetrated. Within the three-tab shingles, the single layer pull-through resistance ranged from a low of 19.50 lbf to a high of 32.25 lbf. The double-layer pull-through resistance ranged from 38.55 lbf to 58.23 lbf. The ASTM D 3462 requirement for a single layer is a minimum pull-through resistance of 20.0 lbf.

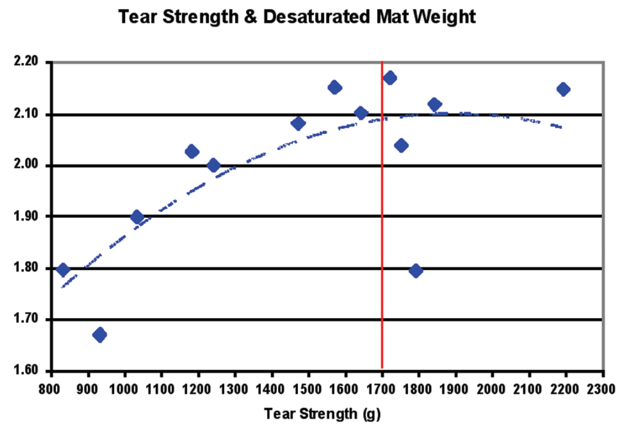
To simulate nailing too high (out of the nail zone), a fastener pull-through test in the single layer of laminate shingles was performed (*Photos 8* and *9*). The results ranged from a low of 16.46 lbf to a high of 29.91 lbf. When laminates are tested at the proper location (with-

Sample	Tear Strength (g)	Tensile Strength (lbf)	Desaturated Mat Weight (lbs/100ft²)	Pull-Through Single Layer (lbf)	Pull-Through Laminate Area (lbf)	Pull-Through Nailable Layers (lbf)
T-A	1240	109	2.00	24.34	---	40.48
T-B	2190	119	2.15	32.25	---	58.23
T-C	1640	112	2.10	28.35	---	46.31
T-D	1720	112	2.17	27.89	---	46.05
T-E	930	82	1.67	19.50	---	38.55
T-F	1790	103	1.80	22.74	---	33.40
L-A	1570	121	2.15	22.77	48.18	85.37
L-B	1840	109	2.12	29.91	50.89	104.60
L-C	1180	111	2.03	16.46	44.75	80.83
L-D	830	82	1.80	16.65	24.55	54.63
L-E	1030	89	1.90	29.22	32.43	67.53
L-F	1750	93	2.04	25.49	44.89	87.43
L-G	1470	118	2.08	25.51	43.32	81.81

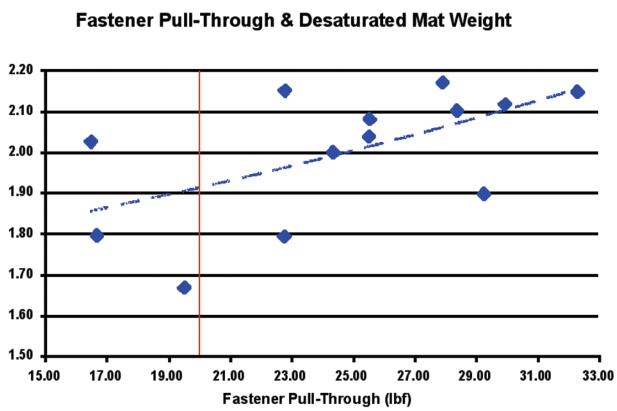
Table A



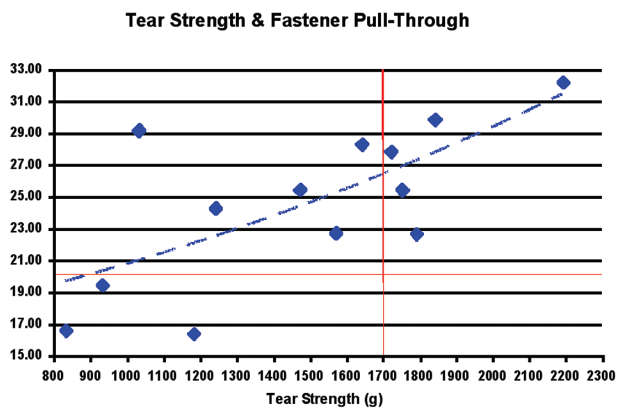
Graph A



Graph B



Graph C



Graph D

Graphs A-D

in the nail zone), the pull-through resistance ranged from 24.55 lbf to 50.89 lbf. Fastening with a headlap condition, the fastener pull-through resistance ranged from a low of 54.63 lbf to a high of 104.60 lbf. Based on data listed in *Table A*, it is clear that when a fastener is placed at the proper location, fastener pull-through resistance approximately doubles that seen when a fastener is improperly placed.

A summary of overall physical property data is included in *Table A*.

Comparison of Data

The correlation of the physical property data was compared four different ways:

- Tear strength – tensile strength, *Graph A*.
- Tear strength – desaturated mat weight, *Graph B*.
- Fastener pull-through – desaturated mat weight, *Graph C*.
- Fastener pull-through – tear strength, *Graph D*.

Within *Graphs A*, *B*, and *D*, a vertical line at 1,700.0 g has been inserted to indicate samples that fell below the ASTM D 3462 minimum requirement for tear strength. Data points to the left of the line represent samples that did not meet the minimum requirement.

A vertical line within *Graph C* and a horizontal line within *Graph D* have been inserted at 20.0 lbf to indicate those samples that fell below the ASTM D 3462 minimum requirement for fastener pull-

Photo 7 – Shingle label on batch that fell below the 1,700.0 g tear resistance requirement.

through. Data points to the left of the vertical line and below the horizontal line represent samples that did not meet the minimum requirement.

In reviewing *Graphs A - D*, clear correlations exist between tear strength and tensile strength, tear strength and desaturated mat weight, fastener pull-through and desaturated mat weight, and tear strength and fastener pull-through.

Conclusions

Successful performance of fiberglass shingles is clearly dependent upon quality control and workmanship during the manufacturing process. From a workmanship standpoint, the proper number and location of fasteners in the "nail zone" is critical. It is also critical that the contractor aligns or places the shingles properly. Other factors certainly come into play, such as properly driven fasteners and adequate performance of the self-adhesive strip.

ROOF KNOWLEDGE ASSESSMENT

Test your knowledge with the following questions developed by Donald E. Bush Sr., RRC, FRCI, PE, chairman of RCI's RRC Examination Development Subcommittee.

1. **What information should be sought during an interior inspection of a roof soffit through removal of a ceiling panel or other access mode? These inspections should be part of all roof condition assessment inspections.**

2. **What information should be noted when inspecting the underside of all roof decks?**

3. **Why is it important to know if there are changes in deck types and/or span direction?**

4. **What conditions found during a roof condition assessment would indicate the need for tear-off and replacement?**

Answers on page 30

ROOF KNOWLEDGE ASSESSMENT

Answers to questions from page 29:

1. **A. Steel decks**
   - **Corrosion/rust.**
   - **Differential deflection at side or end laps.**
   - **Condition of welds.**
   - **Do rooftop components – HVAC, other equipment, access hatches, etc., have their own structural angle supports?**

   B. Wood decks
   - **Warping.**
   - **Shrinkage.**
   - **Rotting.**
   - **Excessive joint gaps.**
   - **Anchorage.**

   C. Structural concrete
   - **Cracks over one-eighth inch.**
   - **Excessive deflection in evidence.**
   - **Spalling.**
   - **Rust staining.**

   D. Poured gypsum
   - **Excessive deflection of bulb tees.**
   - **Staining of form board.**
   - **Cracking.**
   - **Evidence of excess moisture.**

2. **Changes in deck type or span direction**
   - **Drain locations and drain leader accessibility.**
   - **Evidence of foundation settlement (cracks in bearing walls).**
   - **Location of rooftop HVAC units and supply ducts or chiller pipes.**
   - **Evidence of leakage and/or condensation.**

3. **Expansion and contraction must be considered in the replacement roof design.**

4. **Extensive ponding.**
   - **Deteriorated deck.**
   - **Wet and/or deteriorated insulation.**
   - **Poor anchorage of deck and insulation with no practical way to mechanically anchor the components.**
   - **An essentially irreparable membrane.**

Reference: ***Manual of Low-slope Roof Systems*** **- Fourth Edition**
NRCA

Based upon data generated to date, shingles manufactured with a higher mat weight have increased tear strength and a higher fastener pull-through resistance. It is also clear that shingles manufactured with higher tear resistance will have increased fastener pull-through resistance. The higher the fastener pull-through strength, the more resistant a shingle is to failure at a nail head as a result of uplift during wind events. Fiberglass shingles should be manufactured in compliance with ASTM D 3462 requirements.

Building codes and shingle manufacturer recommendations for additional fasteners in "high wind zones" are ambiguous and confusing. The public would be better served if building codes and shingle manufacturers were more specific with regard to the need for additional fasteners within "high wind zones."

Author's Note: Special thanks to Gerald B. Curtis, CPRC, for technical assistance in the preparation of this article.

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7. *Florida Building Code* (2001), Second Edition, International Code Council, Chapter 15.

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ROOFING WASTE

Recent statistics from the roofing industry have shown that roofing accounts for 0.1 percent of the U.S. Gross Domestic Product, but roofing materials contribute 6 percent of the volume in landfills.

— RRCI