

New Method

FOR MEASURING THE WIND RESISTANCE OF ASPHALT ROOFING SHINGLES

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ON BEHALF OF THE ASPHALT ROOFING
MANUFACTURER'S ASSOCIATION

In the early 1990s, in response to a growing concern in the building industry, the Asphalt Roofing Manufacturer's Association (ARMA) undertook the challenge to establish a Wind Uplift Performance Test and Evaluation Procedure that would more closely approximate conditions experienced on the roof.

Through the efforts of a special task force formed of member companies, a multi-year program was conducted at Colorado State University's (CSU) Wind Engineering Laboratory to determine and characterize the effects of wind passing over sloped roofs and the resulting effects on the attached asphalt roofing shingles. The ARMA-funded research included studies of wind effects over full roofs as well as scale models of various roof shapes and how airflow affects the individual shingle. ARMA extends its appreciation to fellow ARMA members for their efforts and assistance with the ARMA High Wind Research Program. These include Charles Harper (retired), Tamko Roofing Products; Robert Metz, Celotex Corporation; and Joe Jones (retired), ARMA.

Initial investigation disclosed that the various building codes and design standards should recognize that, as individual units, asphalt roofing shingles could not effectively be evaluated by test procedures designed for membrane assemblies.

Asphalt roofing shingles have long been recognized for their inexpensive cost and good performance, making them the choice



Full-scale test house.

for most homes in the United States. Initially, wind resistance was provided by interlocking shingle designs or through the use of heavier products. This changed in the late 1950s with the introduction of the self-sealing asphalt roofing shingle.

The wind resistant feature of the self-sealing asphalt roofing shingle was first tested and certified by U.L. 997 and ASTM D-3161. These tests did not duplicate actual rooftop conditions, but rather provided a reasonable test method to distinguish between wind-resistant and non wind-resistant asphalt roofing shingles.

Additional data gathered after severe wind events, such as hurricanes, have further established the favorable performance of properly applied and sealed asphalt roofing shingles. The data disclosed, however, that varying the wind velocity alone could not explain the different performance of similarly-applied and

conditioned asphalt roofing shingle roofs.

The primary disagreement with U.L. 997 and ASTM D-3161 was that the test procedures were run under controlled conditions, blowing air at one velocity and direction across the shingle surface, dislodging any shingle with a bond weaker than the test conditions. In the real world, each roof has a different history of design, application, temperature, and wind exposure.

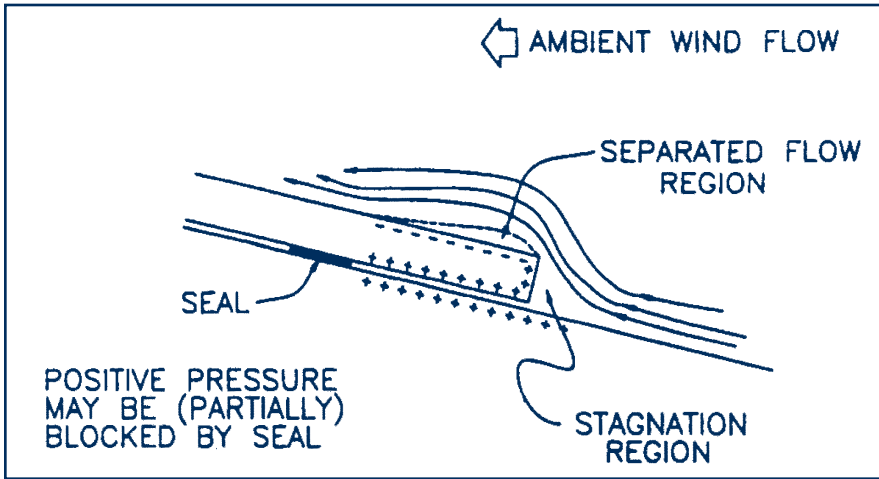


Figure 1: Local wind flow over shingle showing uplift mechanism.

Proper application, (such as fastener type, number, and placement), along with adequate sealing are the keys to asphalt roofing shingle performance. For areas of severe weather, asphalt roofing shingles are tested to higher wind speeds. This alone is not enough to simulate the varying forces which occur on the roof. Testing at higher wind speed alone could even lead to false expectations that might not be realized on the roof under actual wind conditions.

Observations of actual conditions after a severe wind event show that damage varies from roof to roof, even on adjacent structures exposed to similar wind conditions. Damage can occur in areas such as around the eaves, ridge, rake, and valley, while nearby mansards or other slopes are undamaged. Older roofs can go undamaged while newer roofs are blown off. Entire decks have been blown off the building while the attached asphalt roofing shingles stayed intact.

The various results cannot be explained by wind velocity alone, as variables such as application, sealing, and asphalt roofing shingle style and type can account for a number of the inconsistencies. Observation and research suggest that consideration must be given to the swirling characteristics of the wind as it impinges on roofs of different shapes, sizes, and slopes.

Other variables that the study identified that must be factored into the equation are:

- Wind (instantaneous) velocity
- Roof shape
- Slope

- Height of eaves
- Ridge height
- Duration of the gusts
- Peak speed of the gusts
- Wind (average) velocity
- Shape of the shingle
- Shape of the self-sealant adhesive on the shingle
 - Air density
 - Shingle position relative to roof penetrations
 - Pattern of wind acceleration
 - Other factors

Because of the scope and size of this research project, the initial study was divided into three phases. This allowed for previously gathered Colorado State University research information to become an integral part of the next phase. Phase IV is currently underway and when completed will produce a final report.

Phase I

Research conducted at Colorado State University used the Meteorological Wind Tunnel to study surface effects of wind on scale models of whole buildings and sections of full-scale roof

decks. The models were subjected to wind at different angles and velocities, measuring the lifting forces that lead to blow-off. Data were gathered to track wind patterns and relative wind speeds. Peak wind speeds caused by turbulence generated by various wind angles and roof shapes were identified. These "hot spots," where vortices and gusts are generated, had a much higher wind speed than the average approach wind speed. This research supported the belief that the industry practice (ASTM D-3161) of predicting wind resistance by directing a steady wind across a small section of roof deck was not representative of actual rooftop conditions.

Phase II

Phase II used the data gathered during Phase I to measure the

Wind Load Model

$$\hat{P} = \frac{1}{2} \rho \bar{U}_{ref}^2 \left(\frac{\hat{U}_{roof}}{\bar{U}_{ref}} \right)^2 \bar{C}_p$$

where

\hat{P} = peak uplift pressure that a shingle must resist, Pa,

\hat{U}_{roof} = peak gust wind speed on the roof, m/s,

ρ = air density, kg/m³,

\bar{U}_{ref} = mean wind velocity approaching the building at eave height, m/s,

\bar{C}_p = shingle uplift pressure coefficient.

Figure 2: Wind load model.

effects of roof penetrations (such as chimneys, dormers, etc.) as well as how the velocities and pressures affected sealed as well as unsealed shingles. This data allowed a "Load Model" to be designed that related peak wind approach speeds to the uplift force generated on the tabs.

Phase III

Phase III incorporated prior data to design a full-scale building, constructed on a turntable, in an area that frequently experiences high winds. A scale model of this building was also studied in the Wind Tunnel to verify the correlation between the tunnel and the actual full-scale test. This study validated the "Load Model" as a realistic method to calculate the relationship between the wind speed and uplift force.

Summary

This research on a "New Method for Measuring the Wind Resistance of Asphalt Roofing Shingles," has provided an important scientific understanding and basis for describing the interaction of high wind with asphalt roofing shingles. Further, this research conducted both in the wind tunnel and correlated under actual rooftop conditions, has designed a "Load Model" that can now be used by manufacturers when designing and producing asphalt roofing shingles. Phase IV, the final step of the wind research, is scheduled to be completed in the year 2000. Phase IV is being conducted jointly by ARMA and Underwriters Laboratories (U.L.). When finished, the complete research findings will be published and submitted to major model building code groups for inclusion in their building codes. (Basic data of this initial paper is contained in a report issued by Dr. J.A. Peterka of Colorado State University and can be obtained by request from ARMA.) When completed, this research will provide the roofing industry with the ability to define and establish a realistic method for measuring the wind resistance of asphalt roofing shingles. ■

References

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Charles O. Everly, P.E., CBO, Sarasota County, Florida; Robert R. McClell, P.E., S.E., Building Officials and Code Administrators International Inc.; James R. McDonald, Ph.D., P.E., Institute for Disaster Research, Texas Tech University; Kenneth D. Rhodes, P.E., Underwriters Laboratories; Walter J. Rossiter, Jr., Ph.D., U.S. Department of Commerce, National Institute of Standards and Technology; George A. Smith, P.E., Factory Mutual Research Corporation; Thomas L. Smith, A.I.A., RRC, National Roofing Contractors Association.

"Wind Uplift Model for Asphalt Shingles" J.A. Peterka, Ph.D., Cermak Peterka Petersen, Inc., Wind Engineering Consultants; J.E. Cermak, Ph.D., Cermak Peterka Petersen, Inc., Wind Engineering Consultants; L.S. Cochran, Ph.D., Cermak Peterka Petersen, Inc., Wind Engineering Consultants; B.C. Cochran, Cermak Peterka Petersen, Inc., Wind Engineering Consultants; N. Hosoya, Cermak Peterka Petersen, Inc., Wind Engineering Consultants; R.G. Derickson, Consulting Engineer; Charles Harper, Asphalt Roofing Manufacturers Association; Joseph Jones, Asphalt Roofing Manufacturers Association; Robert Metz, Asphalt Roofing Manufacturers Association.

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Ray Corbin is Director of the Better Understanding of Roofing Systems Institute (BURSI), sponsored by Johns Manville. He holds several U.S. roofing shingle design and application patents, is a faculty member of RIEI, and has served as Chairman of the Code Committee for ARMA. Corbin is a former recipient of the Horowitz Award for his contributions to *Interface* journal.



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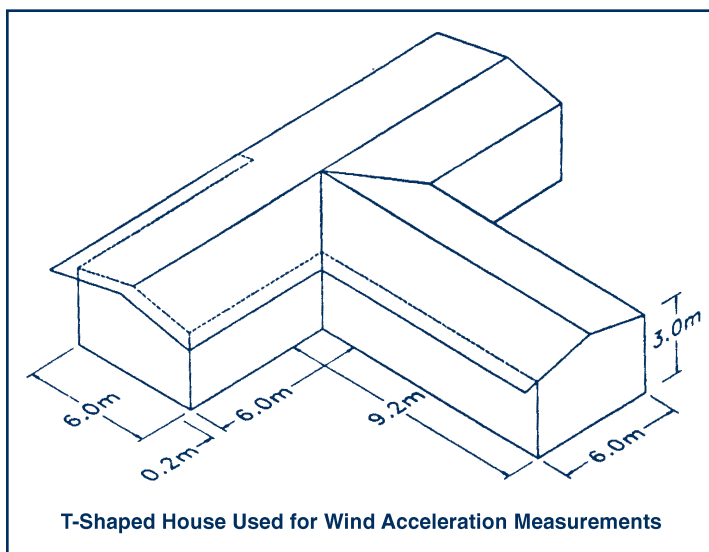


Figure 3

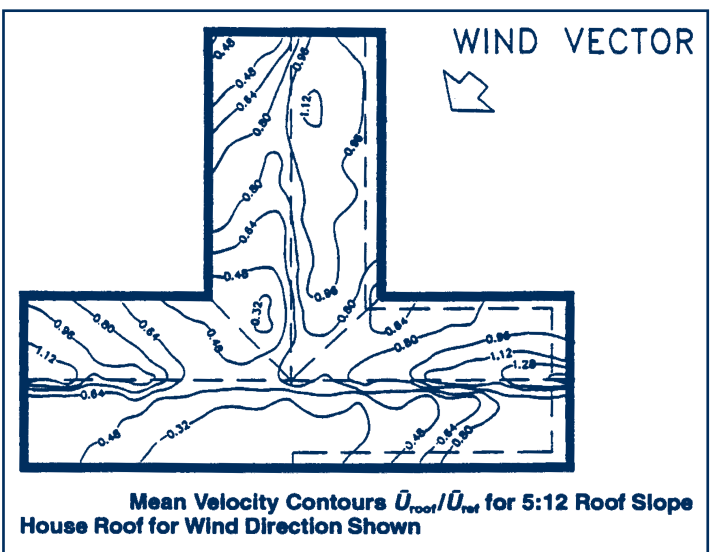


Figure 4