BUILDING UP A TOLERANCE

BY JIM KOONTZ

In the fall of 1985, the National Roofing Contractors Association (NRCA) published a document entitled "Quality Control in the Application of Built-Up Roofing".

This document reviewed workmanship, test cuts, and the examination procedures to be followed during membrane construction.

The NRCA makes a general recommendation that a person knowledgeable in roofing technology and good workmanship practices make a continuous visual examination of the application of a built-up roof. The NRCA also discourages the removal of 12"x12"samples for laboratory analysis inaccordance with ASTM D2829. Instead, the NRCA recommends that 4"x40" samples to

CHART NO. 1

INTERPLY BITUMEN
INDIVIDUAL SAMPLES

	BITUMEN – lb./100 ft.² – ply	
	ASPHALT	PITCH
SPECIFIED	25.00	30.00
AVERAGE RESULTS	27.08	30.07
STANDARD DEVIATION	5.20	6.27

	SAMPLES WITHIN TOLERANCE RANGE	
TOLERANCE %	ASPHALT	PITCH
± 25 %	76.47 %	80.00 %
± 20 %	69.41 %	64.62 %
±15 %	58.82 %	55.38 %

be removed in accordance with ASTMD3617.

The sample, taken prior to the application of gravel is to be examined at the project site and reset into the membrane.

The on-site NRCA analysis of the 4"x40" samples involves the examination of three different characteristics of workmanship, which are interply bitumen rates, membrane construction and membrane integrity. This requires the on-site inspector to weigh, measure, and perform a visual examination of each sample.

As of the writing of this article, only two major manufacturers have endorsed the quality control document. The Asphalt Roofing Manufacturers Association (ARMA) has not endorsed the document. It is obvious that the document is not a consensus of the diverse opinions in this industry.

Manufacturer's objections indicated to ROOFER Magazine (October '86 — pgs 36-44) are centered around the tolerances of interply bitumen rates suggested by NRCA and the problem of the document conflicting with manufacturer's specifications.

One area that has received littleattention is the 4"x40" test cut that the document recommends. Laboratory analysis indicates that the tolerances outlined in the document are not representational of what is being installed in today's BURs; in some areas, they are much more lenient.

To further explore the NRCA document Roofing Engineering, Inc. (REI) tested 150 BUR samples measuring approximately 4"x40".

Three specific areas were examined, with the following data tabulated: interply bitumen application rate, membrane construction, and

CHART NO. 2

HEADLAPS
INDIVIDUAL SAMPLES

	HEADLAPS
SPECIFIED	2.00 INCHES
AVERAGE	2.15 INCHES
STANDARD DEVIATION	.58 INCHES

HEADLAPS	SAMPLES COMPLYING
2.0" OR GREATER	66 %
1.5" OR GREATER	94 %
1.0" OR GREATER	97 %

interply voids. The intent was to use the NRCA document as criteria for judging the integrity of a newly installed BUR and confirm the results with laboratory analysis.

BETWEEN THE SHEETS

The 150 samples were removed from approximately 35 different projects. All were taken from roofs assembled with glass fiber felts meeting ASTM D2178, Type IV. Of the 150 samples, 85 were asphalt and 65 were pitch, removed from new roofs constructed during theSummer and Fall of 1986.

The samples were weighed,measured and visually

examined at all edges, following the NRCA procedure. Afterwards, each one was separated and analyzed inaccordance with ASTM D2829/ASTM D3617 procedures.

REI separated the 150 samples into two bitumen groups; asphalt and pitch. All of the asphalt samples were removed from projects where the interply asphalt was specified as 25 Ibs/sq. The pitch samples were taken from projects where the interply bitumen rate was specified at 30 Ibs/sq (See chart 1).

The average interply mopping rates, along with their standard deviation, did not vary significantly from results obtained in a Roof Engineering data base published in ROOFER Magazine (May '84 —pgs 6-10).

The NRCA recommends a job average tolerance of plus or minus 25% of the amount specified. The average is based upon a minimum of three samples. If it is below the 25% tolerance level, the contractor is to add additional felts.

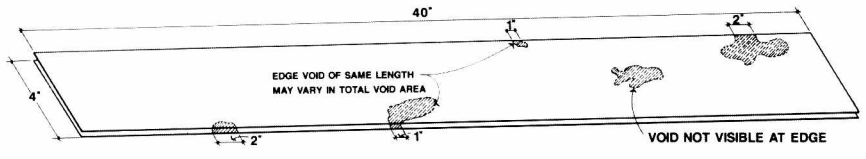
In the event the job average interply mopping is over 25%, the roof is then conditionally accepted. The NRCA job average basis does not take into account individual sample highs or lows.

As an example, three samples could be removed with interply weights of 15, 25, and 40 Ibs/sq. The bitumen application tolerance range for 25 Ibs plus or minus 25% is from 18.75 to 31.25 Ibs/sq.

Two of the samples would be outside the tolerance range but the average of the three samples (26.67Ibs/sq) would fall well within the specified job average range.However unlikely that occurence might be, it does illustrate that potentially "bad" roofs can pass the scrutiny of NRCA recommendations.

Chart 1 shows that for asphalt application. 76.47% of all individual samples fall within the 25% tolerance, For pitch roofs, 80% of all individual samples fall within the 25% tolerance.

CHART NO. 3
EDGE VOID / SQ. FT. OF FELT



TOTAL LENGTH OF EDGE VOIDS ALLOWED = 6"
AREA OF FELT 160 SQUARE INCHES OR 1.11 SQ. FT.

$$\frac{\text{TOTAL LENGTH EDGE VOIDS}}{\text{SQ. FT. OF FELT}} = \frac{6}{1.11} = \frac{5.40 \text{ LINEAL INCHES OF VOIDS}}{\text{SQ. FT. OF FELT}}$$

LAP IT UP

In all 150 samples tested, each contained at least four plies of felt.The primary factor evaluated was headlap construction. The average headlap was 2.15" with astandard deviation of .58". Most manufacturers recommend a 2" headlap.

The NRCA takes the position of installing a headlap as specified but with a tolerance of at least a 1" headlap. In examining the results of the data base, 97% of all samples are above the 1" or greater criteria (see chart 2).

With respect to headlap, the results of the 1986 data base are more favorable than data base results generated in 1984. The examination of these as well as prior data bases, shows that a 1" or greater headlap is easily obtainable and expected in BUR constructions.

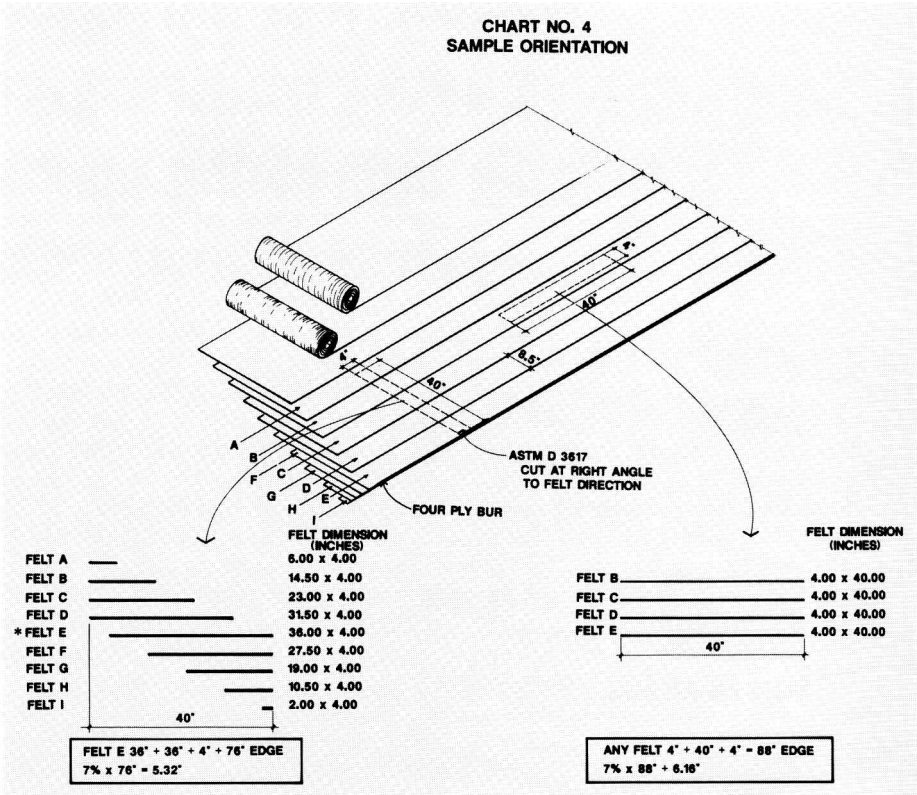
It also appears, upon examining the data, that a 1.5" or 2" headlap will occur in the majority of BUR constructions.

MEMBRANE INTEGRITY

Possibly the most complex area is the position of the NRCA concerning voids located between interply felt construction. The NRCA recommends a visual examination of the perimeter edge of a 4"x40" sample. Voids that are visible at the edge are measured and compared with an anticipated maximum set by the NRCA.

Measuring and counting edge voids can be easily performed by a field quality controller. The obvious advantage of this point of the NRCA procedure is tat it provides the roofer

CHART NO. 4
SAMPLE ORIENTATION



with a quick method of checking the overall quality of the roofing system.

The NRCA procedure generates one very important question: Is the measurement of lineal voids at a perimeter edge a reliable and predictable method of analysis of all voids within the roof sample?

Prior studies have not addressed lineal edge voids but instead, have measured the area of voids. From a measurement standpoint an edge void may or may not relate to the actual area of the voids.

Is the measurement of lineal voids at a perimeter edge a reliable and preditable method of analysis of all voids within the roof sample?

Note in Chart 3, two I" edge voids may have totally different areas of void. This produces a situation in which relying strictly on edge voids is potentially unreliable.

A VOID PROBLEM

Initially, it is important to examine what the NRCA proposes.NRCA's document states on page15: The total aggregate length of all bitumen-encapsulated voids be-tween any two plies in a given sample may be up to a maximum of 6 inches (7% of a sample edge).

The NRCA indicates that the maximum length of voids between any two plies may be up to 6" or 7%.

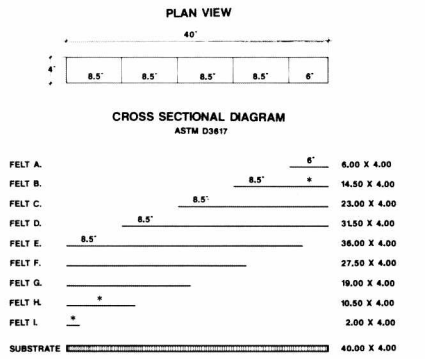
A 4"x40" sample removed in accordance with ASTM D3617 should be cut at a right angle to the direction of the felts (see Chart 4).

Note that the longest felt at any point within this cross-sectional sample would be 4"x36"! Felt E. The outer edges of the exposed felt total 36"+36"+4" - a total of 76".

At the 7% rote, the total aggregate length of voids that would be

allowable between that ply and other plies or substrates would be 7%x76", or 5.32 lineal inches of voids. The only way to obtain the maximum of 6" would be to take the sample parallel

CHART NO. 5
FOUR-PLY ROOF SAMPLE



FELT	DIMENSIONS	TOTAL EDGE LENGTH	VOID LEN. 7% MAX
A.	6.00 X 4.00	16.00	2.00 *
B.	14.50 X 4.00	33.00	2.31
C.	23.00 X 4.00	50.00	3.50
D.	31.50 X 4.00	67.00	4.69
E.	36.00 X 4.00	76.00	5.32
F.	27.50 X 4.00	59.00	4.13
G.	19.00 X 4.00	42.00	2.94
H.	10.50 X 4.00	25.00	2.00 *
I.	2.00 X 4.00	8.00	2.00 *
TOTALS:			28.89" OF VOIDS

* 2" OR 7%, WHICHEVER IS GREATER, NRCA POSITION

to the felt direction.

This method would not comply with ASTM D3617. However, this procedure would result in felts with dimensions of 4"x40" as shown in Chart 4. It would produce a perimeter edge of 88" (40 "+40"+4" +4"). When this figure is multiplied by 7%, the aggregate length of voids of 6.16" is obtained.

In following the NRCA procedure, it is important to note there is not a stated limit on the total number of edge voids allowed within a sample. The document only addresses the number of edge voids between any two plies. In other words, there is not a total slated number of voids for either a three ply or four ply assembly.

REI took it a step further. Calculations for the maximum allowable length of interply voids for a four ply assembly are generated in Chart 5. Note that the total length of edge voids in a four ply assembly could be as high as 28.89 lineal inches of voids.

In a three ply assembly the voids would measure 22.20 lineal inches. The probability of voids occurring at the edge in these quantities is very unlikely but NRCA allowable.

Mathematically, it is difficult to accurately compare edge voids from one assembly to another. This is primarily due to the difference in the number of felts found from sample to sample.

To compare one roof sample to another, with respect to edge voids,the total length of edge voids must be divided by the area of felts in a sample. By using this calculation.samples can then be compared one to another.

Assuming that the maximum number of edge voids between two 4"x40" felts (or one felt and its substrate) is 6", a figure of 5.40 lineal inches of void per square foot of felt is generated. Note thecalculations in Chart 3.

According to the NRCA document, this maximum aggregate length of voids per square foot offelt could be allowed between any two plies in a given sample.

VOID DATA BASE

REI visually examined each of the 150 BUR samples using the NRCA method, followed by a separation of the sample in accordance with the ASTM D2829/ASTMD3617 procedures. After separation of the sample, the actual area of voids was then tabulated (see chart 6).

The edge void length averaged 0.49 lineal inches per square foot of felt, with a standard deviation of 0.51". Note the maximum allowable value following the NRCA procedure is 5.40 lineal inches per square foot of felt; approximately10 times higher than what could be expected on an average basis.

The total length of edge voids per square foot was also compared to the total area of voids on a "per square foot basis" (see Chart 7). The total average area of voids per square foot resulted in an average of 1.26 square inches, with a standard deviation of 1.27 square inches.

Taking the average plus one standard deviation approximately two thirds of all samples fall below 2.53 square inches of voids per square foot of felt. This is slightly below 2% of the felt area.

OTHER TESTS

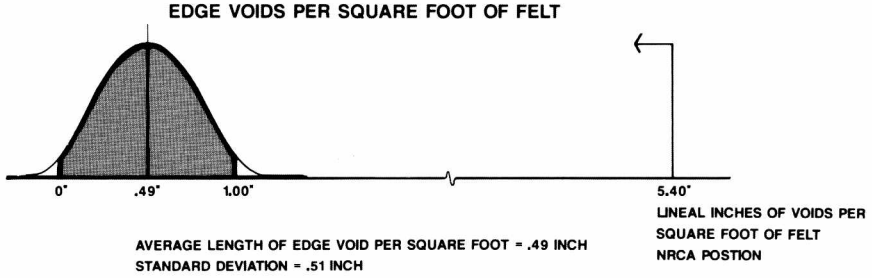
In a prior study reported by Dwight Jennings in Roofs and Roofing (1981), he had analyzed 10,000 BUR samples.

Jennings' report concluded that the average American roofing contractor can consistently produce a BUR roof membrane withless than 3% voids by area in the interply. The overall recommendations by Jennings was for a maximum allowable of 5% voids by area.

Data bases generated by REI, both in 1984 and 1986, indicate that a 2% void area on average is obtainable. Air Force Manual 91-36 set a total number of voids of 5 square inches/sq ft of felt. Note that this would be approximately 3.50% of felt area/sq ft of felt.

In the 150 samples tested, 59 samples, or 39.33%, did not have any edge voids. However, of those 59 samples, 26 did have voids within the sample.

CHART NO. 6
EDGE VOIDS PER SQUARE FOOT OF FELT



The area of these voids was measured and the data base indicates that when a 4"x40" sample is examined and is free of edge voids, there is still a 44.06% chance that some voids will occur within the interior of the sample. However, the probability of those voids being significant is very low.

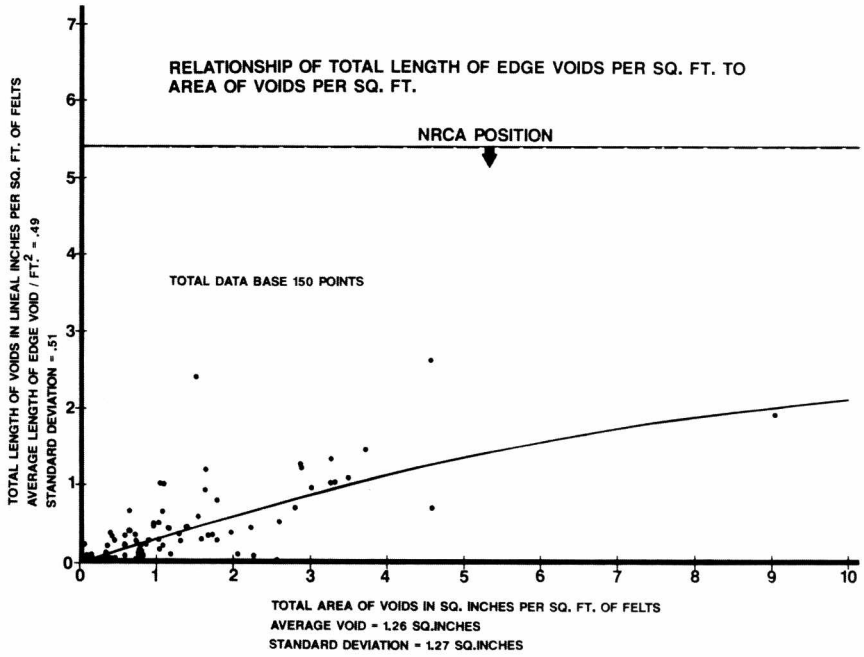
In samples where voids are absent from the edge, the database indicates that the hidden interply voids located within the center of the sample, but not at the edge, have an average of .64 square inches per square foot, with a standard deviation of .51 square inches.

This means that the area of voids within these samples is less than 1% of the total felt area. It appears that when a 4"x40" sample is removed and no edge voids are found, one can predict with some reliability that the number of voids in the sample is relatively low and would be well within previously accepted industry standards.

The primary problem begins when edge voids appear. In examining Chart 7, note that there is a wide range in the correlation of edge void length to area voids.

As an example, at the 1.0" edge void location in Chart 7, the area of voids can range from approximately 1 to 3.5 square inches/ft. This type of wide dispersion of data indicates that the reliability of field edge void analysis is unpredictable.

CHART NO.7



CONCLUSIONS

The position of NRCA with respect to interply bitumen rates, headlap applications and voids is rather broad from the stand point that the large majority of samples will fall within the guidelines of theNRCA. Reliance upon edge void analysis of a 4"x40" sample can be particularly deceiving. Built-up roof membrane manufacturers should develop their own individual guidelines for acceptability if this method of analysis is continued in use.

Field quality control can provide a very important function in the proper application of a built-up roof system. The NRCA's position of advising full-time inspection by a person knowledgeable in roofing can be extremely beneficial during the application of a BUR. If the NRCA document is to be accepted as criteria for all BURs, then further examination is warranted by the results published here. However noble the efforts of the NRCA are, it is clear that the tolerances in the document could be manipulated into deceiving criteria for judging the integrity ofa BUR.

Complete reliance upon the document especially by non-roofing personnel, could possbily create devastating results. It is the recommendation of REI that the NRCA carefully review its position with respect to "Quality Control in the Application of Built-Up Roofing". RM

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