A TECHNICAL PERFORMANCE APPROACH TO A NEW BUILT-UP ROOFING PRODUCT

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The development of built-up bituminous roofing in the United States has historically evolved by trial-and-error. This paper reports a departure from this crude empirical approach: a technological performance approach to development of a new BUR product via extensive laboratory and field testing, that is, to my knowledge, uncommon in the American roofing market. The research and data bank behind this product development have replaced trial-and-error with a sound foundation of product design based on performance requirements.

RESEARCH PROGRAM OBJECTIVES FOR A NEW BUR PRODUCT*

In 1975 the basic tenets for the development of a fiber-glass-based BUR product, were established by consensus following consultations between both technical and marketing personnel.

These are the program's basic goals:

1. To supply the highest quality of BUR technology and support to the roofing contractor and building owner.
2. To emphasize the performance aspect, not prescriptive product specifications.
3. To minimize liability risk for all parties involved in BUR by performing extensive R & D and field testing of products prior to their introduction to the marketplace.
4. To upgrade the BUR products and systems so they remain compatible with changes in construction techniques and architectural designs.

RESEARCH PROGRAM FOR THE FIBERGLASS PLY SHEET PRODUCT

Backed by a laboratory equipped with the latest testing equipment, development of this fiberglass ply sheet product and evaluation of roofing membranes constructed from it have taken more than six years.

For accurate correlation between laboratory and field membrane samples, data were obtained from samples either hand-mopped in the laboratory or taken from field-applied roofs and thus believed to represent actual field conditions.

To define performance parameters for this new BUR product it was necessary to:

1. Conduct performance testing of conventional roofing products and membranes.
2. Perform extensive laboratory and field testing of the fiberglass products, membranes, and systems.
3. Retest the fiberglass test roofs after 3 to 4 years of the field service environments.
4. Develop the concept of performance (not prescriptive) criteria.
5. Analyze and correlate data from all laboratory and field test materials.

TECHNOLOGICAL SUPPORT EFFORTS

To comply with the basic tenets of the fiberglass roofing development program, it was necessary to divide the effort into:

1. Initial laboratory testing
2. Test-roof construction and testing
3. Retesting of test roofs after service exposure
4. Product optimization and system improvement activities.

Each of these four aspects of the development program are discussed separately below.

As with most current BUR testing, NBS Report BSS55, by Mathey and Cullen, "Preliminary Performance Criteria for Bituminous Membrane Roofing," guided the testing and development program.

The testing of BUR samples often results in data scatter, due to different sources of asphalt, age of the sample, and the nonhomogeneity of the membrane itself. Despite this scatter, significant conclusions emerged from the general trends and test-result indications. Table 1 data are the averages of all the tested samples. Depending on the membrane and the temperature, the general scatter was between +8 to +14% from the average.

1. Initial Laboratory Testing

Because of its inorganic reinforcement web, the new fiberglass-based ply sheet offers many advantages over conventional organic BUR products. Stability, moisture resistance, fire resistance, and lack of extreme temperature sensitivity are well known for glass products. The new fiberglass ply sheet product was designed as a technical compromise between handling requirements and field-performance needs. A product may perform well in the laboratory but, if it can't be applied successfully in the field, it will not

* This program and the technical data presented in this paper, relate to the development of Certaglass® ply sheet.

perform its intended function. Ease of field application was, therefore, an important factor in this product's development. A variety of conventional roofing products were investigated to establish the fiberglass ply sheet's handling characteristics (workability/ease of application) necessary to match desirable and acceptable field standards and to ensure that the finished membrane retained all desirable performance characteristics.

Table 1 lists six of the membranes tested during the laboratory development program. The four listed properties, though, not the only investigated properties, represent the most important criteria for a roofing system. All membranes were designed and constructed to meet the NBS preliminary performance criteria for bituminous BUR. As shown in Table 1, both the 3-ply and the 4-ply fiberglass membranes exceed the preliminary requirements established by NBS for 4-ply systems.

2. Test Roof Construction and Testing

Evaluation of samples from field applications and correlation with results from laboratory-prepared samples are critical to the development of a new product since, as mentioned earlier, it isn't acceptable to have a material that only "worked well in the lab." A survey of roofing contractors identified systems most frequently used in today's roofing practice. Membranes incorporating the new fiberglass ply sheets were installed throughout the continental United States and, to date, after 6 years, there hasn't been a single product, membrane, or system failure. Only 5% of these jobs were monitored by us during their fabrication, the other 95% not monitored during construction were applied in accordance with normal roofing practice. These roofs have been visually inspected every 6 months, and samples from selected roofs have been removed and tested every few years.

TEST ROOF PROGRAM [1]

Specification and Products [2]	Jobs	Squares
3CG-GSI (T)	21	7,798
3CG-GSI	28	36,040
4CG-GSI	7	13,531
4CG-SSI	13	4,755
4CG-SSW	5	4,767
3CG-GSW	5	5,820
CB-2CG-GSW	11	3,411
CB-3CG-SSW	1	400
CB-2CG-MSW	12	3,498
3CF-MSI	11	3,342
2CG-MSI	3	400
CB-1CG-MSI	3	935
Total =	**120**	**84,697**

[1] Partial list of representative systems. Actual is now over 105,000 squares.

[2] Legend:
CG = Fiberglass Ply Sheet
CB = Experimental Glass Base Sheet
MS = Experimental Glass Cap Sheet (Mineral Surfaced)
GS = Gravel Surfaced
SS = Smooth Surfaced
I = Insulated Deck
W = Nailable Deck
(T) = Taped Joints

3. Retesting of the Test Roofs After Service Exposure

Test results on samples taken from new roofs, and from these same roofs after several years' service, are presented in Table 2. All tested membranes, new and old, exceeded the NBS preliminary performance criteria for tensile strength, thermal expansion coefficient, and Thermal Shock Factor established for 4-ply roof membranes. These results validate the soundness of the technical approach to the product design. Through the basic tenets established before laboratory work on this fiberglass ply sheet began, we were able to simulate field service conditions.

The data in Table 2 indicate general characteristics of the behavior of a BUR membrane in service. An aging membrane generally suffers reduced Thermal Shock Factor, since tensile strength, load-strain modulus, and thermal expansion coefficient all increase with age. The data also shows that, even after 4 years' service, membranes constructed from the new fiberglass ply sheet exceed, the NBS Preliminary Performance Criteria for new BUR systems.

4. Product Optimization and System Improvement Activities

The intent of current and future work is, through continued monitoring of test roofs and correlation of data with samples artifically aged in the laboratory and tested using tensile-fatigue techniques, to scientifically estimate roof service life. Detailed monitoring of the behavior of membranes during extended service life will form the basis for further product improvements.

The fiberglass ply sheet entered the market in 1978 in climatological areas where the minimum two-year test roof qualification program had been completed. Subsequent introduction into other areas has followed as the required test-roof exposure and testing is completed. The successful performance of these roofs is testimony to the soundness of this approach to the development and introduction of a new roofing product.

Parallel development of a fiberglass-based cap sheet product has been conducted since 1976. The required two years of field service exposure and retesting has been completed for several climatological areas and the laboratory test program is complete. Release of this cap sheet is scheduled for mid-1981 in several climatological areas. Consistent with the basic tenets of these developments, future fiberglass products will also be released to roofing contractors when the required field experience has been successfully demonstrated and correlated with laboratory test data.

The table on the next page shows the number of laboratory and field samples tested for the work in this article.

CONCLUSIONS

Both 3-ply and 4-ply fiberglass membranes meet and exceed the NBS Preliminary Performance Criteria for BUR membranes. Although the original criteria were not related to age, the data clearly show the ability of these fiberglass roofs to meet the criteria in the laboratory, in the field, and after four years' service under a wide range of climatological conditions.

Summary

A technological performance approach has been shown to lead to successful roofing product development by a blending of sound technology with the practicality required for field performance. The practicality includes sample preparation using mopping techniques, its field testing, and consideration of the "workability" of the product such as ease of drying-in, quick adhesion, and a compatible surfacing, coupled with controlled bleed-up.

Market introduction of any fiberglass-based BUR system specification involving materials described in this paper is based on three criteria:

1. Exceeding the NBS Preliminary Performance Criteria in the Laboratory.
2. A minimum of 2 full years of successful field performance on a number of test jobs by different roofing contractors in a specific climatological area.
3. The ability of those field test roof samples to meet and exceed the criteria, in both the "new" and the field "aged" condition.

This type of development program can ensure the success of all other roof system components by providing the technological foundation for construction of quality BUR systems with demonstrated field performance.

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Fiberglass Membrane	**Laboratory Samples**	**As-Constructed Field Samples**	**3 to 4 Yr. Old Field Samples**
4 ply	630	168	126
3 ply	420	84	84
3 ply & exp. Cap Sheet	252	42	42
3 ply & 40 lb. Organic Base	168	84	84
3 ply & exp. Base Sheet	168	—	—
2 ply & exp. Base & Cap	168	—	—
2 ply & exp. Cap Sheet	252	84	84
2 ply & exp. Base Sheet	168	—	—
2 ply & 40 lb. Organic Base	252	—	—
Total Samples = 3,360	**2,478**	**462**	**420**

	TENSILE STRENGTH, LB/IN, OF WIDTH								LOAD STRAIN × 10 ^{4} LB/IN.				COEFFICIENT OF EXPANSION °F × 10 $^{-6}$						THERMAL SHOCK FACTOR	
TEST ROOF LOCATION & SYSTEM SPECIFICATION	70°F		30°F		0°F		−30°F		70°F		0°F		73 30°F		30 0°F		0−30°F		°F	
	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T
Wichita Falls, Texas 4CG-GSI 3½ years old (unsurfaced)	297	239	337	300	304	273	298	255	1.6	2.0	2.6	2.4	21	12	18	10	43	42	272	270
Wichita Falls, Texas 4CG-GSI 3½ years old (surfaced)	300	185	302	188	355	277	217	204	1.5	1.4	2.3	2.4	10	7	15	13	20	28	771	412
Nashville, Tennessee 4CH-SSW New (unsurfaced)	151	148	235	245	307	262	300	312	1.2	1.4	1.8	1.8	20	11	7	9	37	31	460	470
Nashville, Tennessee 4CG-SSW 2 years old (surfaced)	220	214	253	281	348	305	330	340	1.4	1.6	2.6	2.7	15	16	23	25	35	50	382	225
Orinda, California 3CG-MSI New	153	126	231	224	270	215	325	230	1.0	1.0	3.0	1.4	26	20	17	25	17	23	529	670
Orinda, California 3CG-MSI 2 years old	207	174	333	224	338	262	309	260	3.2	2.9	2.9	2.4	14	14	20	27	21	38	555	287
Corbin, Kentucky 4CG-CSI New (unsurfaced)	208	178	320	266	294	261	221	217	—	—	3.1	1.7	7	11	5	17	31	34	495	508
Corbin, Kentucky 4CG-CSI 3 years old (surfaced)	162	116	351	283	318	234	264	208	1.2	0.8	3.3	2.8	8	3	17	24	33	43	292	194
Billings, Montana MS-3CG-SSW New (unsurfaced)	248	149	334	270	316	304	375	270	1.7	0.8	1.9	2.8	13	10	12	18	12	29	1386	374
Billings, Montana MS-3CG-SSW 3 years old (surfaced)	254	206	368	289	371	337	335	301	3.1	3.5	2.9	2.9	7	12	20	14	35	34	365	341
Billings, Montana RB-3CG-SSW New (unsurfaced)	188	145	366	250	353	292	307	220	1.5	0.9	4.1	2.6	18	14	20	7	18	11	478	1020
Billings, Montana RB-3CG-SSW 3 years old (surfaced)	238	157	403	230	383	354	267	252	1.5	1.1	1.5	1.3	7	11	17	24	34	39	750	698

TABLE 2
Data from test roofs of fiberglass membranes in the "New" as constructed condition and after field exposure for the designated times.

	TENSILE STRENGTH, LB/IN, OF WIDTH								LOAD STRAIN × 10 ^{4} LB/IN.				COEFFICIENT OF EXPANSION °F × 10 $^{-6}$						THERMAL SHOCK FACTOR	
SYSTEM	70°F		30°F		0°F		−30°F		70°F		0°F		73 30°F		30 0°F		0−30°F		°F	
	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T
4-Ply Fiberglass Membrane	211	189	308	288	335	311	316	284	1.3	1.3	2.1	2.5	12	16	12	12	25	25	640	500
3 Ply Fiberglass & Experimental Cap Sheet	198	181	326	300	355	338	341	310	1.3	1.3	2.7	2.4	14	18	16	16	24	22	550	640
3-Ply Fiberglass & 40 lb. Organic Base Sheet	185	158	331	257	364	278	318	243	1.1	0.9	2.9	1.9	14	15	10	9	22	21	570	690
3-Ply Fiberglass Membrane	149	131	215	190	222	218	222	218	1.0	0.8	1.4	1.5	14	15	12	11	22	24	705	615
2 Ply Fiberglass & Experimental Cap Sheet	153	121	225	194	232	211	241	205	1.0	0.8	1.8	1.5	18	17	18	19	25	25	515	560
2-Ply Fiberglass & 40 lb. Organic Base Sheet	135	111	214	177	255	203	242	188	0.9	0.6	1.8	1.3	9	10	15	11	23	27	615	580

TABLE 1
Laboratory developmental testing of fiberglass roofing systems.