NATIONAL BUREAU OF STANDARDS REPORT

9381

PROGRESS REPORT ON EXPOSURE OF NEW ROOFING SYSTEMS

by

Thomas H. Boone and William C. Cullen

Materials and Composites Section
Building Research Division
Institute for Applied Technology

Sponsored by

Office of the Chief of Engineers, U.S. Army
Directorate of Civil Engineering, U.S. Air Force
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NBS PROJECT 421.04-12-4212447 31 July 1966 **NBS REPORT** 9381

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I. INTRODUCTION

Many new roofing materials and roof systems have appeared on the market during the past decade. Some of these systems have been introduced as substitutes for conventional types of bituminous roofings for both flat and steep roof decks, whereas, others have been developed to serve a particular need which conventional roofs can accomplish only with difficulty. Obviously, in some cases, the new systems fulfill both needs. In fact, a few of the newer systems allow for the utilization of the roof areas for work or recreation.

A previous report(1) 1/ gives our observations of the performance of some of these systems under service conditions. In addition, performance testing or new roof systems on Guam and Okinawa have also been described in a previous report.(2) This report gives observations of roofing materials exposed to the weather at the National Bureau of Standards, Washington, D.C. site from May 1964 to June 1966.

1/ Figures in parenthesis indicate the literature reference at the end of this report.

2. EXPOSURE SITE AND MATERIALS

2.1 Exposure Site

The building selected for the exposure tests was a single-story structure having a gable type roof deck and constructed of thin-shell concrete. This has been described in reference (3). The slope of the roof deck from ridge to eave was about 1¼ inch per foot. The four foot wide panels were connected to each other by aluminium bolts and the joint was caulked with a polysulfide sealant. The uncoated concrete roof panels were exposed to the elements almost 10 years before this series of tests were inaugurated. The interior of the building was open to outside air circulation both winter and summer. The building is shown in figure 1.

2.2 Roofing Materials

Two types of roofing were evaluated in the program; prefabricated sheets and liquid-applied coatings.

For the most part the sheet materials consisted of a laminate of a weatherproof elastromeric film and an asbestos felt reinforcing backing and were applied to the concrete deck with an organic solvent-based adhesive. In many cases the side laps were taped.

The liquid-applied roofings were brushed, rolled, or sprayed in multilayers directly on the concrete deck. These systems consisted of: chloroprene, neoprene, and chlorosulfonated polyethylene (Hypalon), [2/] butyl-rubber with polyvinylchloride/acetate copolymer, silicone rubber, polyurethane foam, asphalt, and butyl rubbers either emulsified or dissolved in a volatile solvent. Reinforcement mediums of fiber cloth, glass random mat, or chopped glass fibers were frequently employed.

2/ Registered trade marks are used in this report in order to identify the materials or mechanical device more adequately. In no case does such identification imply recommendation or endorsement by the National Bureau of Standards nor does it imply that the material identified is necessarily the best available for the purpose.

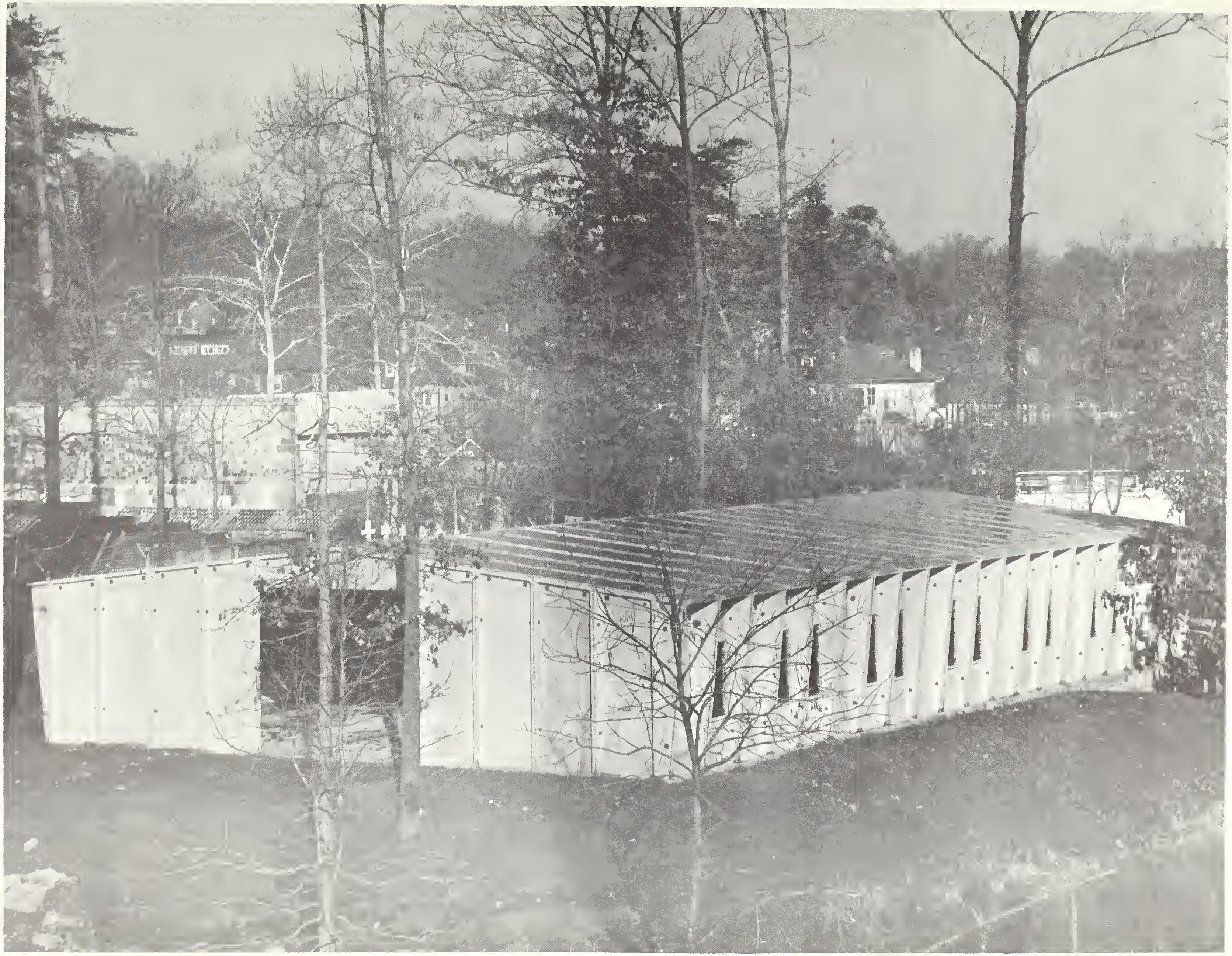

FIGURE 1. BUILDING OF PRECAST THIN SHELL PANELS USED FOR TEST ROOFS.

In some cases a decorative and protective top coating was applied while in others the material was left exposed to the weather.

Two traffic deck systems were also included. Locations of the roofing materials on the test roof are illustrated in figure 2.

From the beginning of these experimental installations, it was recognized that the performance of the test materials may be jeoparized by careless or untrained mechanics. The test roofs that are described herein were therefore placed under well controlled conditions. Highly skilled employees of the manufacturer, assisted by personnel of NBS, were used to install the roofs. The recommendations of the manufacturer in respect to the method of application, were followed as nearly as possible.

3. OBSERVATIONS

The primary objective of this investigation was to determine the weather resistance of some of the newer roofing systems. Further objectives were to obtain costs of material and application and information on utilization and application techniques. The manufacturers of the various systems are kept informed on the current performance of their respective materials. As a result of this exchange of information formulations have been changed where warranted.

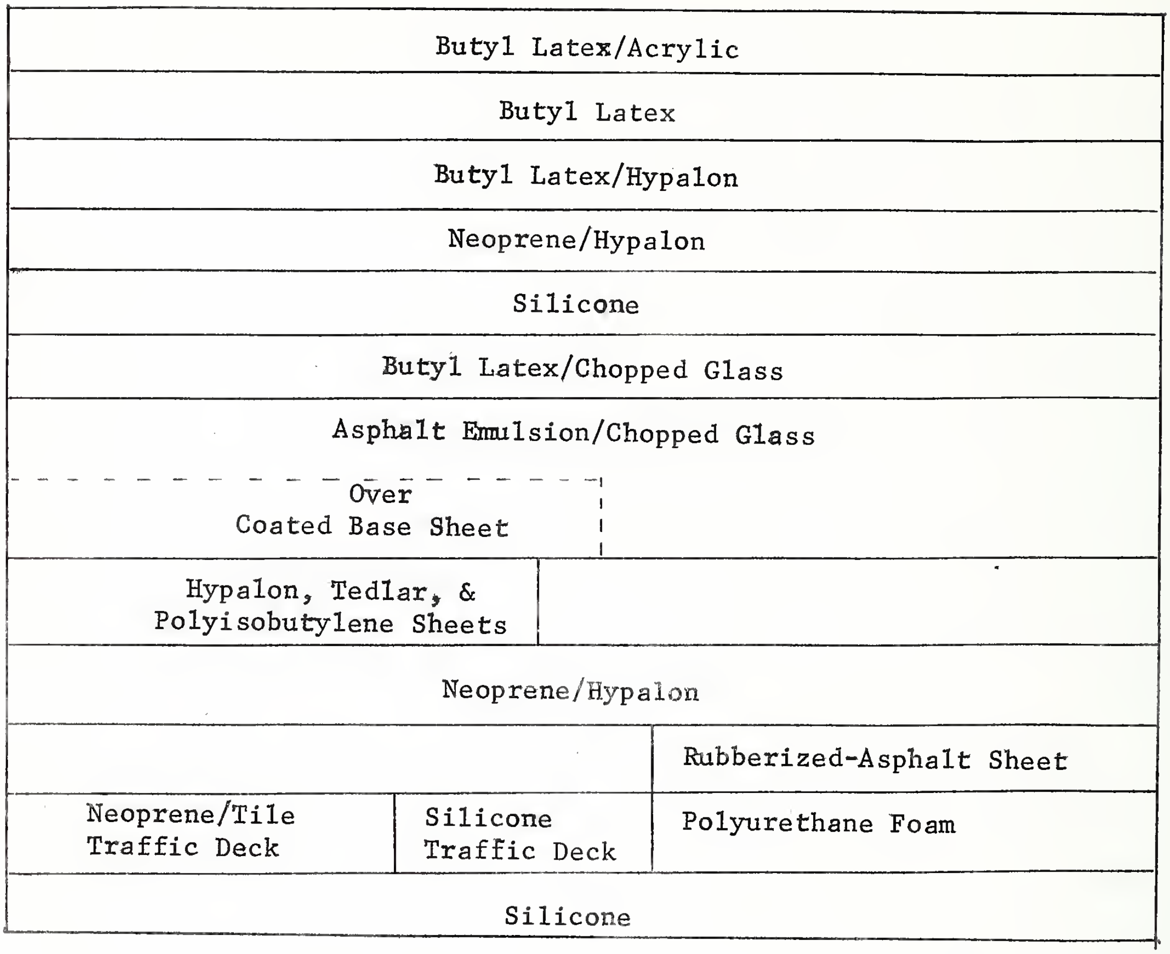

Figure 2. Location of roofing materials on test roof

3.1 Liquid - Applied Systems

3.1.1

a. <u>Butyl Latex with Acrylic Top Coat Applied May 7, 8, 1966</u>

In the first spray application of butyl latex (wet film thickness of 10 to 15 mils.) a lightweight fiberglass scrim was placed. After 3 hours drying a second coat (40 mils. wet film thickness) of butyl latex was placed over the scrim. After 24 hours cure a top spray coating of modified acrylic emulsion was applied to provide protection from dirt accumulation. The wet film thickness of this top surface was 10-15 mils.

b. Results

Within 2 months large cracks in acrylic top coating were observed. As a result, in October, 1965 the complete system was ruined and a new system was reapplied using an improved formulation for the top coating. During the winter of '65-'66 small cracks again were observed in the acrylic coating and by May 1966, (7 months later) were quite evident as shown in figures 3 and 4. The butyl base coating which became exposed by the open cracks in the acrylic coating had a dark, dirty appearance.

3.1.2

a. <u>Butyl Latex; No top coating</u>

The roofing system was applied in the same manner and at the same time (May 7, 1964) as described in 3.1.1

b. Results

With the exception of dirt accumulation and darkening, the material showed no signs of deterioration. See figure 7 for comparison of darkening.

FIGURE 3. BUTYL LATEX WITH ACRYLIC TOP COATING SHOWING CRACKING IN THE ACRYLIC AFTER 7 MONTHS EXPOSURE. PANEL IN UPPER LEFT CORNER OF THE SAME SYSTEM UNEXPOSED

FIGURE 5. TYPICAL CRATER-LIKE SPOTS ON HYPALON TOP COAT.

FIGURE 4. OVER-ALL VIEW OF BUTYL LATEX/ ACRYLIC SYSTEMS.

3.1.3

a. <u>Butyl Latex - Hypalon Top Coat</u>

The butyl latex was applied in the same manner and at the same time (May 7, 1964) as described in 3.1.1. After curing the Hypalon (chlorosulfonated polyethylene) coating was applied by roller with a wet film thickness of about 15 mils.

b. Results

Small crater-like spots appeared on the surface shortly after drying of the coating. Although these spots became more visible with time (see figure 5) there did not seem to be any break in the Hypalon coat.

3.1.4

a. <u>Neoprene-Hypalon</u>

Two coats of black neoprene were applied with heavy nap rollers on October 28, 1963. The first coat was dry before application of second coat. One coat of Hypalon was applied within three hours and on May 8, 1964 the second Hypalon coat was applied. The wet film thickness of each coat was about 8 mils.

b. Results

The crater-like spots as seen on sample roof 3.1.3 were also noticeable on the roof (see figure 5). A slight color change which may have been caused by the black neoprene bleeding through the Hypalon was noted.

3.1.5

a. Silicone

This two component roofing system was applied with a brush in three coats-primer, and two base coats. The primer and first coat was applied November 1963 and the second base coat May 19, 1964. Because of the heavy dirt retention (see figure 6 and 7) another application, by the manufacturer, was placed in a different area of the test roof on July 8 and 9, 1965.

b. Results

The second silicone test area was applied in the same steps as that of the first with a modified formula to reduce dirt retention. Figure 8 illustrates the heavy dirt retention of this second roof.

3.1.6

a. Butyl Latex-Chopped Glass Fiber

A system using butyl latex emulsion - chopped glass fiber combination employing a spray gun identified as the Sealzit Gun was applied at a rate of 6 to 8 gallons per 100 square feet. The emulsion-glass ratio was one gallon of emulsion to 1/6 pound of glass.

The concrete roof test area was primed with latex on November 10, 1963 and butyl-chopped glass was applied on July 29, 1964.

b. Results

Orginally the surface was slightly off white color with the glass fibers visible but completely coated with the latex. After two years exposure the surface was lightbrown and glass fibers on the top surface were uncoated and in some cases easily picked off the surface. See figure 9.

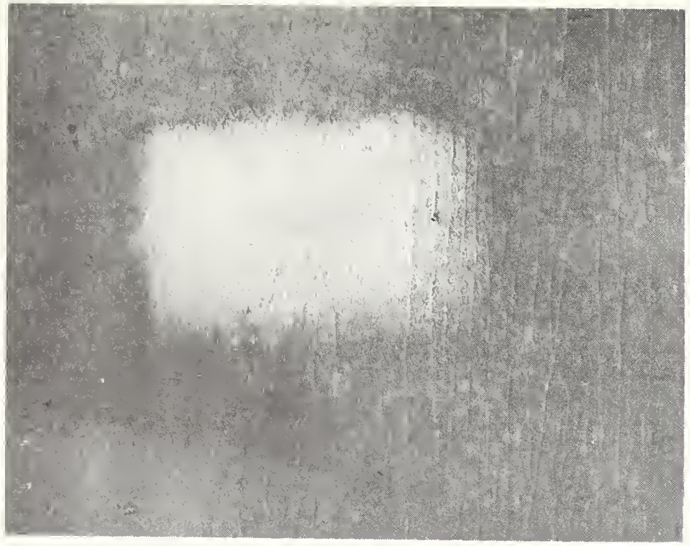

FIGURE 6. SILICONE ROOF AFTER 2 YEARS EXPOSURE. RECTANGULAR AREA CLEANED BY SCRUBBING WITH WATER AND CLEANSER.

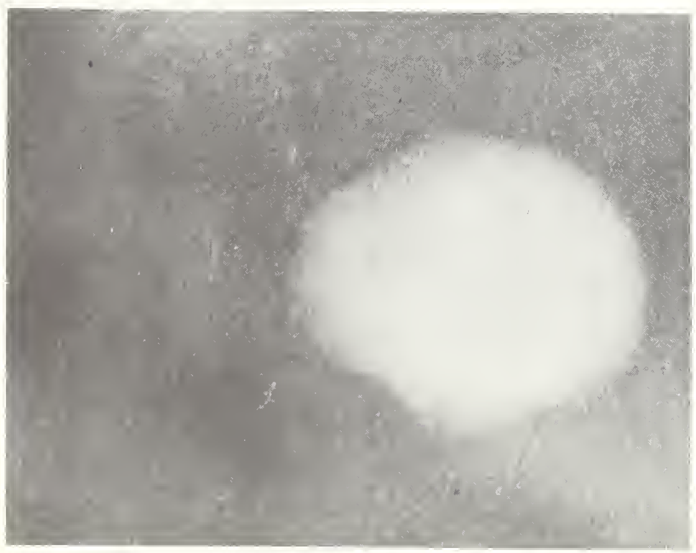

FIGURE 8. SILICONE ROOF AFTER 1 YEAR EXPOSURE. RECTANGULAR AREA CLEANED

BUTYL LATEX/ACRYLIC

BUTYL LATEX

BUTYL LATEX/HYPALON

NEOPRENE/HYPALON

SILICONE

FIGURE 7. VIEW OF 5 ROOF SYSTEMS SHOWING VISUAL DIFFERENCES CAUSED BY AGE AND DIRT RETENTION AFTER 2 YEARS. ORIGINAL APPEARANCE OF ALL ROOF SYSTEMS WAS SNOW WHITE.

3.1.7

a. Asphalt emulsion - chopped glass

This system consisted of a clay-type asphalt emulsion - chopped glass combination applied with the Sealzit Gun. The manufacturer reports the emulsion was modified by the addition of a latex type material. The combination was applied at a rate of about 7 gallons per 100 square feet and the emulsion-glass ratio was one gallon to 1/3 pound glass.

The material was sprayed over the untreated concrete and over coated base sheet applied to the concrete.

A second section of the concrete test roof was covered with the base sheet and the first coat of the asphalt-glass was sprayed both on the base sheet and on the untreated concrete area on November 10, 1963. The second coat of asphalt-glass was applied July 29, 1964.

b. Results

Exposure of the glass fibers was evident as in the butyl systems. The material cracked and separated between concrete panels. See figure 10. The coated base sheet separated from the concrete and blistered. See figure 11.

3.1.8

a. Polyurethane foam

This system consisted of two spray coatings of polyurethane which foamed in place to a total thickness of about one inch. The material foamed and dried to touch within minutes after spray. Second coat applied fifteen minutes after first. After one hour a brush application of white polyvinyl acetate masonry paint was applied. A second coat of paint was applied after 24 hours.

The material was applied directly over a concrete roof panel on June 10, 1965.

FIGURE 9. BUTYL LATEX - CHOPPED GLASS ROOF SYSTEM AFTER 2 YEARS EXPOSURE. GLASS FIBERS ARE EXPOSED.

FIGURE 10. ASPHALT EMULSION- CHOPPED GLASS SHOWING CRACK IN 2 YEAR OLD COATING OVER A JOINT AND EXPOSURE OF FIBER GLASS.

FIGURE 11. ASPHALT EMULSION- CHOPPED GLASS OVER COATED BASE SHEET. THE BASE SHEET, SEPERATED FROM THE CONCRETE AND BLISTERED.

FIGURE 12. POLYURETHANE FOAM SHOWING SURFACE DAMAGE OF TOP WEATHER COAT. UNEXPOSED PANEL IN UPPER LEFT CORNER.

b. Results

On July 8, 1965 a hail storm with hail stones the size of marbles damaged the paint coating and exposed the brownish foam. With the exception of this slight surface damage the material is in good condition. See figure 12.

3.2 Single-ply Roof System

3.2.1

a. Hypalon Sheet

The sheet has a 20 mil-thick chlorosulfonated polyethylene white top surface factory laminated to a 15 mil thick asbestos backing felt. The sheet was applied directly to the concrete with an organic solvent-based adhesive, overlapped joints and taped with Hypalon tape.

The Hypalon sheet was applied May 18, 1965.

b. Results

Within one month very noticeable brown stains appeared on the top surface. The stains could not be removed by scrub-washing. Chalking of the top surface was noticed after 8 months exposure. With the increasing chalking, the brown stains disappeared. See figure 13.

3.2.2

a. Polyisobutylene Sheet

The sheet has a 20 mil thick polyisobutylene black top surface which was laminated in the factory to a 20 to 30 mil asbestos backing felt. The sheet was applied directly to the concrete with an organic solvent-based polyisobutylene adhesive. The laps were sealed with the adhesive. A white brushed-on coating was applied to part of the roof.

The sheet was applied May 18, 1965.

b. Results

The black polyisobutylene surface and the coated surface have not changed from their original appearance in one year exposure. See figure 13.

3.2.3

a. Tedlar Sheet

The sheet has a 2 mil thick white polyvinyl fluoride top surface which was laminated in the factory to a 20 mil asbestos backing felt. The sheet was applied directly to the concrete with an organic solvent-base adhesive. The joints were taped with two-inch wide Tedlar tape having a pressure-sensitive adhesive backing.

The sheet was applied May 18, 1965.

b. Results

After one year exposure there was no change in the visual appearance of the sheet material. See figure 13. Dimensional change or deck movement caused adhesive overlap of the tape.

3.2.4

a. Rubberized-Asphalt Sheet

This sheet has an 80 mil-thick black rubberized-asphalt top surface which was laminated in the factory to a 20 mil asbestos backing felt. The sheet was applied directly to the concrete with an organic solvent-based adhesive spread in ribbons. See figure 15. The laps were sealed with the same adhesive.

b. Results

After seven months exposure there was no visible change. See figure 14.

3.3 Traffic Deck

3.3.1

a. Neoprene Sheet - Flexible Tile

The system provides a membrane base sheet with a tile walking surface applied in the following steps: neoprene primer; neoprene adhesive applied to deck and felt side of membrane; sheet of 15 mil black neoprene top surface factory laminated to a 20 mil asbestos backing felt contact bonded to deck; entire sheet surface coated with the neoprene adhesive; the back of each 18x18x1/8-inch tile also coated with the neoprene contact adhesive; tile installed leaving 1/16-inch open joint between tiles; the completed deck rolled with heavy roller.

The traffic deck was installed May 5 and 6, 1965.

b. Results

After one year exposure no visible change had occured. See figure 16.

3.3.2

a. Silicone Traffic Topping

Over the concrete panel a primer applied at the rate of 1 gallon per 100 square feet was used. A sand filled silicone mix was then trowled over the surface approximately 1/16-inch thick.

The material was installed July 9, 1965.

b. Results

After one year exposure there were no visible signs of deterioration. Unlike the two silicone roof coatings, the surface of the traffic topping had very little dirt retention.

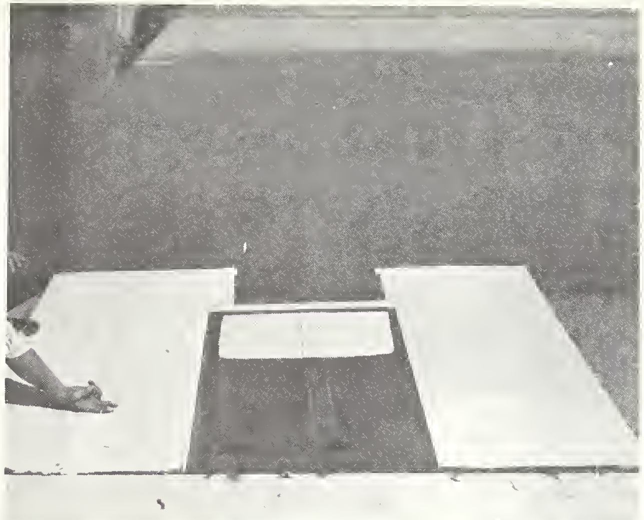

FIGURE 13. SINGLE-PLY ROOFING SYSTEMS. LEFT TO RIGHT, HYPALON (NOTE CHALKING ON FINGERS) POLYISOBUTYLENE, AND TEDLAR.

FIGURE 14. RUBBERIZED-ASPHALT SHEET. THE WHITE WRINKLE APPEARANCE WAS INHERENT IN THE SAMPLE.

FIGURE 15. APPLICATION OF RUBBERIZED ASPHALT SHEET WITH ADHESIVE APPLIED IN RIBBONS.

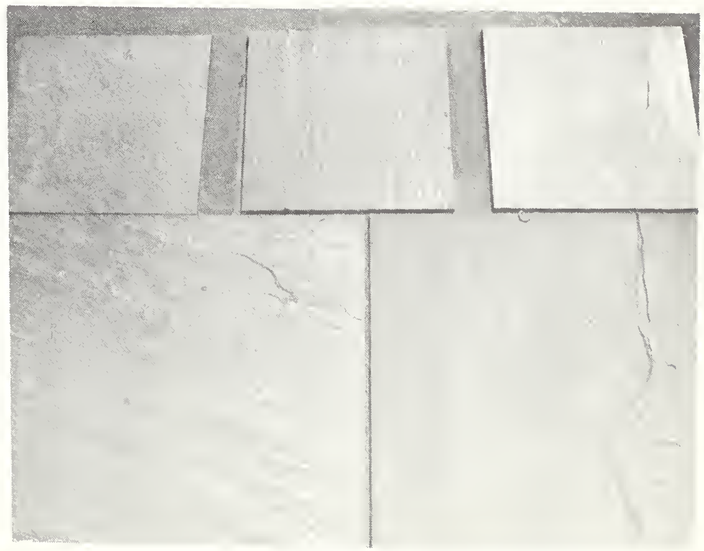

FIGURE 16. FLEXIBLE TILE TRAFFIC DECK SHOWING SLATE-LIKE TEXTURE MOLDED ON THE SURFACE BY THE MANUFACTURER.

4. SUMMARY AND CONCLUSIONS

4.1 Performance

Table 1 gives a summary of the performance of the roofings systems described in this report. When major deficiencies were discovered the manufacturers of the roof system were notified and encouraged to rectify the trouble or install a modified system.

Where these products are commerically available a price range based on the installation methods used in this test is given in Table 1. Government specifications, where applicable, are also given.

In the fluid-applied roofings the systems using the Hypalon as a top weather coating seem to maintain their original appearance and showed no visible signs of deterioration. The polyurethane foam roofing also seems to have excellent performance. This system serves as insulation as well as roofing. Recommendations have been made to the manufacturer to provide a more elastic and durable top weather coating on the polyurethane foam.

The single-ply sheet materials all performed well. The manufacturer of the Hypalon sheet claims that their newer material does not chalk.

The two traffic deck materials were placed at the only access to the roof so as to receive all traffic visitors. However this traffic was light, less than 10 persons a month. Both systems were designed to provide roofing systems and walkway surfaces. The two systems performed well.

4.2 Application

As mentioned in the beginning of this report highly skilled and experienced personnel were obtained to install each roof. In spite of this, time consuming delays on two of the three systems using spray equipment were experienced. Each delay was caused by mal-functioning of the specialized spray equipment. The coatings using chopped glass and the polyurethane, because of mixing with the glass or activator at the nozzel must be applied with specialized equipment. Roller application proved most satisfactory in this series of tests.

With the exception of the need to warm the adhesive used for applying the rubberized-asphalt sheet all other sheet systems were applied with no difficulty.

5. ACKNOWLEDGMENT

The authors acknowledge the advice of the various members of the Tri-Service Committee in the selection of materials for study and their assistance in evaluating performance. Representatives of the following companies also cooperated in this program by providing material, labor, and suggestions:

Armstrong Cork Co.
B. F. Goodrich Co.
Bilton Insulation & Supply Inc.
E. I. du Pont de Nemours and Co.
Enjay Chemical Co.
Flintkote Co.
General Electric Co.
Gibson-Homans Co.
Johns-Manville
Pittsburgh Plate Glass Co.
Shell Development Co.

6. REFERENCES

(1) NBS Report 7737 "Progress Report on New Roof Systems" by William C. Cullen (November 1962).

(2) NBS Report 8352 "Performance of Roofings on Guam, M.I. and Okinawa, R.I." by William C. Cullen (20 May 1964)

(3) Amirikian, Arshem; "Multipurpose Building of Precast Thin-Shell Panels" Journal of American Concrete Institute, No. 12 Vol. 31, p.1243-1252 (June 1960)

7. NOTE

Neither the contents of this report nor the fact that the investigation was conducted by the National Bureau of Standards may be used for advertising or promotional purposes.

Table 1 - Summary

Roofing System	Age Years	Appearance	Condition	Cost Per Square
Fluid - Applied				
Butyl latex	2	Fair (Dirty)	Good	
Butyl latex/Acrylic	2	Poor (Cracking)	Poor (Cracking)	
Butyl latex/Hypalon	2	Good	Good	\$15-\$20
Neoprene/Hypalon 1/	2	Good (Slight Yellowing)	Good	\$25-\$35
Neoprene/Hypalon 1/	2	Good	Good	\$25-\$35
Silicone	2	Poor (Very Dirty)	Good	
Silicone	1	Poor (Very Dirty)	Good	
Butyl latex/chopped glass	2	Fair (Dirty)	Fair (Glass exposed)	
Asphalt/chopped glass 2/	2	Fair (Deterioration)	Poor (Glass exposed cracking at joints)	\$15-\$25
Polyurethane Foam	1	Fair (Paint Chipping)	Good	
Single-ply Sheet				
Hypalon	1	Good	Fair (Chalking)	\$32-\$45
Polyisobutylene 2/ 3/ 4/	1	Good	Good	
Tedlar 2/ 3/ 4/	1	Good	Good	\$35-\$45
Rubberized-Asphalt	1	Good	Good	
Traffic Deck				
Silicone	1	Good	Good	\$100
Neoprene/Tile	1	Good	Good	\$225-\$275

1/ "Elastomer Roofing - Fluid Applied for Concrete Roof Decks" Dept. of the Army, OCE <u>Draft</u> Military Guide Specification CE - 220.13

2/ "Roofing Systems" General Services Administration, Public Building Service Guide Specification 213-4 (April 1965)

3/ "Elastromeric Roofing Systems" Department of the Navy, Bureau of Yards and Docks, Type Specification TS-R8, (21 May 1965)

4/ "Guide Specification for Elastomeric Roofing Systems", Department of the Air Force Facility Design and Construction Air Force Pamphlet AFP88-007-2 (18 March 1966)