NATIONAL BUREAU OF STANDARDS REPORT

10 357

FLOORING PROBLEMS IN GOVERNMENT AGENCIES

U.S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

NATIONAL BUREAU OF STANDARDS

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by

Winthrop C. Wolfe

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NBS

U.S. DEPARTMENT OF COMMERCE

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FLOORING PROBLEMS IN GOVERNMENT AGENCIES

WORKSHOP ON FLOORING

Sponsored by

Building Research Division
Institute for Applied Technology
National Bureau of Standards

FIELD STUDIES OF FLOORING

and

OVERLAYS FOR CONTAMINATED CONCRETE FLOORS

by

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Sponsored by
Office of the Chief of Engineers, U. S. Army
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Statistical analyses of the data on straight-pull bond tests in Part 4 of this report were performed by Dr. David Hogben of the Statistical Engineering Section, using an OMNITAB computer. Miss Mildred Post of the Materials Durability and Analysis Section analyzed some of the commercial products described in this study for purpose of identification.

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1. INTRODUCTION

Flooring problems in government agencies and contributions of the Building Research Division to flooring problems and performance tests was the subject of a Workshop on Flooring at the National Bureau of Standards on February 3, 1970. This Workshop, attended by 65 representatives of government agencies, was led by T. H. Boone and W. C. Wolfe, who are among the organizers of the ASTM Committee F-6 on Resilient Floor Coverings. The Proceedings of the Workshop are included in this report.

Flooring work at the Building Research Division is divided between development of performance tests and standards and consultative and advisory service to government agencies. The Workshop speaker from the Public Health Service discussed the problem of the development of adequate guide specifications for flooring, including resilient floor coverings, carpet, and monolithic surfacings. Valid and meaningful performance tests are vital to development of flooring specifications. The staff of the Building Research Division works closely with ASTM Committee F-6 and also with Committee C-3, which includes Subcommittee S-4 on Monolithic Surfacings. This cooperation is valuable in developing performance tests and standards. The Division has also made extensive field studies of flooring in order to assist the Armed Services with flooring problems and to validate laboratory performance tests. One of the most pressing problems is military installations in bonding of monolithic surfacings and the results of research on bonding to contaminated concrete are reported here.

2. WORKSHOP ON FLOORING

MORNING SESSION - PROJECTS AND PROBLEMS AT NBS

ASTM, BRD and Performance Specifications

by Thomas H. Boone

In this morning's session we will hear from speakers on the subjects of general research on flooring, a specific problem oriented program on measuring the floor surface resistance to movement of wheeled vehicles, on carpets and flammability, on economics of flooring and on problems related to the maintenance of flooring.

I will attempt to set the stage for this workshop with a short review of the past, and information on standards being studied outside the Government.

First, let us look back 10 years - when vinyl flooring, at over $1.00 per square foot was the hot thing on the market - when old line carpet men still considered tufting a flash-in-the-pan- when it was thought that nylon as a carpet fiber whould never amount to much - when ceramic wall tile was beginning to push plastic wall tile off the market. At this time, a short 10 years ago vinyl-asbestos versus asphalt tile was the big issue among the Federal design and procurement offices.

During this time we, as Federal employees, can gain some satisfaction from the fact that the criteria established by the many Federal Specifications on flooring became the norm for the industry. In fact, the situation with resilient floorings up to now has been that they have been pretty well covered by a good set of federal specifications which describe the more widely used varieties. These specifications were written for government purchases; the tests were selected to cover the essential properties which would identify the material and assure that a material of good quality was delivered. They do not point out subtle differences between competitive varieties of the same type of flooring; they do not tell the consumer which flooring is better in general; they do not, in most cases, tell which flooring is best for a particular application.

But, here we are 10 years later

- carpets are moving up the wall
- advances are still being made in fiber technology
- resilient flooring producers are looking at resins other than vinyl and continuing to make their products more like carpets.

We are now finding that our materials-oriented specifications fall short of our performance-oriented demands. There is a need to compare the wear of laminated, homogeneous and fiber flooring. We are concerned with flame spread and smoke on all flooring; also comfort, sound absorption and static--none of which are found in our present specifications. In other words, it now appears to be necessary to transform the testing from assessment of quality to some sort of measurement of usefulness.

Two years ago this month, an ASTM Technical Committee on Resilient Flooring was formed to try to work out, bring up to date, and standardize the nomenclature, the definitions and the test procedures for flooring.

There are 47 members on this committee--10 flooring producers, 10 producers of raw materials used in, or products related to flooring, and 27 consumer and general interest members. Included are members from the Federal Government-- Army, Navy, Air Force and G.S.A. The committee consists of working groups on:

Geometrical Measurements - i.e., size, thickness, squareness, weight, and surface characteristics.

Rheological Properties - i.e., flexibility, resiliency, compression, hardness, and impact resistance.

Service Properties - i.e., aging, appearance, abrasion resistance, resistance to common chemicals, cleanability, resistance to soiling, scratching and moisture.

Special Properties - i.e., acoustical, slipperiness, electrical, and fire resistance.

Another group in the committee is producing definitions for flooring.

The Consumer Council on resilient flooring of the American National Standards Institute is in the process of deliberations as to what the consumer really wants, or, more logically, what the consumer really <u>needs</u> in the way of consumer standards for resilient flooring.

ASTM Committee F-6 will be asked:

1) To prepare a statement in laymen's language of what a flooring system consists of.

2) Whether or not a particular floor is suitable for installation above grade, on grade, or below grade.

3) Whether or not a particular floor is recommended for installation in commercial, light commercial, residential, or light residential conditions.

In addition, this ASTM Committee will be concerned with international standards and will be responsible for representing the United States on the International Standards Organization.

Flooring Research at BRD - Basic and Problem Oriented*

by Winthrop C. Wolfe

We arranged this workshop in flooring as part of a series, but it is a golden opportunity to bring together representatives of government agencies who are interested in flooring specifications and flooring problems. These people represent the two aspects of our work - basic and problem oriented. Our basic mission is to develop performance standards but a large part of our work is consulting - helping other agencies with flooring problems. Of course, there is feedback from one to the other. Performance requirements relate to actual problems as well as to what people want. Sometimes people are not aware of a performance requirement until they are made aware by accidents. People were not aware of the fire hazard of carpets until there were disastrous fires in which lives were lost and property damaged. Who would think about slip resistance as a performance requirement unless we found that people slip on floors? And how could a slipperiness test be developed without considering what happens when people actually slip on floors?

Why are we interested in the performance concept? It is because we want to cut costs and get the best value for the money; we want a product that will do the job; and we want to make decisions about all the new products on the market today.

The Building Research Division has been evaluating carpet in comparison to other floor coverings because carpet has become competitive and is being considered as a replacement for resilient floor coverings, such as vinyl asbestos tile. In developing performance standards, we attempt to place all products on the same basis and subject to the same performance tests. No one has ever suggested that vinyl asbestos tile is a fire hazard but carpet has been suspected. In a performance standard for floor coverings or in considering whether or not to replace vinyl asbestos tile with carpet, we must consider fire safety. This problem will be discussed by Mr. Ryan.

In future work on performance tests, it is essential to correlate laboratory tests with service or use conditions. For standardization purposes, test samples must be well characterized by composition and, in the case of carpet, by construction. As much information as possible should also be obtained on physical properties related to performance. Wear and other performance characteristics should be well known. Samples should be chosen over a range of wear characteristics from poor to superior and the same products should be used in the laboratory tests as in the service tests.

There is nothing new about research on performance tests for floor coverings at the National Bureau of Standards. Work of this kind has been done for many years but needs revival and updating. BMS Reports 34, 43, and 68 were issued during 1940 and 1941 entitled "Performance Test of Floor Coverings for Use in Low-Cost Housing", Parts 1, 2, and 3. Wear tests were performed on a variety of floor coverings, including linoleum, wood flooring, and monolithic surfacings. Building Materials and Structures Report 130, "Methods and Equipment for Testing Printed-Enamel Felt-Base Floor Covering" was issued May 1, 1952. This report not only included laboratory tests with the Schiefer abrasion machine but also service tests in the old Munitions Building in Washington. It was concluded that there was a positive correlation between the laboratory and service tests.

Not only have we researched laboratory and service tests for smooth surface floor coverings but also for carpet. Herbert F. Schiefer in Research Paper RP1505, J. Res. NBS 29, 333 (November, 1942), "Wear Testing of Carpets", reported good correlation between tests with laboratory machines as the NBS Carpet Wear Tester and service tests in the Procurement Building in Washington, D. C. Since the carpet and fiber industries have shown an interest in the NBS Carpet Wear Tester, we have resumed work with it and have compared results using different wheel facings with tests on the Taber abraser. Wheels used on the Taber abraser were developed by Arthur Hockman of the Building Research Division in cooperation with the Norton Company for testing natural stone. Instead of testing different weaves of wool carpet, as in Schiefer's work, we have concentrated on comparisons of smooth surface floor coverings with low or medium level looped pile carpets made of wool, acrylic, and nylon.

One of the difficulties in wear testing is to decide on a criterion of wear. Some workers have tried to apply measurements and find correlations too precise for the nature of laboratory and service tests. Others have merely used comparison photographs, which yield no quantitative date (ASTM D2401, Tentative Method for Service Change of Pile Floor Coverings"). In our work, we have used wear through to the backing or through the wearing surface as the criterion. If a floor covering is not completely worn through, we measure depth of wear and extrapolate. This procedure and the same test equipment has also been used on smooth surface floor coverings, including linoleum, vinyl asbestos tile, sheet vinyl, printed enamel felt base, roto vinyl, and several types of monolithic surfacings. We expect to issue a report in the near future.

In trying to establish correlations between service and laboratory tests, we have relied on past experience as a rough guide but the urgent need at present is test sites for floor coverings. The Building Research Division has outdoor weathering stations for organic coatings and house siding but no corridors for flooring tests. We need cooperation from other agencies in establishing such sites if we are to develop valid performance tests for floor coverings.

* Only a brief digest is included here since the material is covered in an article by W. C. Wolfe, "Performance Tests for Floor Coverings", ASTM Materials Research and Standards, Vol. 10, No. 7, 15-18 (July, 1970).

Floor Surface Resistance To Movement Of Wheeled Vehicles

by Leopold F. Skoda

1. Introduction

An increasing number of hospitals are contemplating the use of carpeting as a floor covering. One problem that must be considered if carpeting is to be used, is the probability of increased starting and rolling resistance of wheeled vehicles to the floor surface. Hospital equipment ranging from bed stands that weigh less than 100 pounds, portable X-ray units that may weigh as much as 1000 pounds, must be moved from one location to another, often by female hospital personnel. The questions now arise as to the effect of the floor covering on the forces required to move equipment over it, and the methods of measuring these forces.

The National Bureau of Standards conducted a research program to develop a testing procedure to measure starting and rolling friction of wheeled vehicles on various floor surfaces. A hospital bed was selected as the test vehicle to be used in the study as it is the most prevalent piece of portable equipment in a hospital. Instrumentation was devised to measure the forces required to initiate motion as well as to measure the forces required to maintain motion of the bed. Forces were measured with the bed empty and with an applied live load of 300 pounds. Nine different floor coverings were tested while the test bed was equipped with casters designated by the manufacturer as "hard" and "soft".

2. Procedure

The possible variables in this test procedure can be classified into two groups. The "hardware" variables include the floor systems to be tested, the wheeled vehicle and live load to be used, and the size and type of wheels for the vehicle. The "measurement" variables include the method used to measure the forces involved in producing and maintaining motion, the rate of motion of the vehicle, and the distance through which the vehicle was to be moved.

In order to provide a test floor durface that was smooth, level, and free from local irregularities often present in existing flooring, a wooden platform was designed and built to accomodate the flooring materials to be tested.

The platform was 4 feet by 12 feet in plan. The framing members were 2 by 4's, placed longitudinally 12 inches on center. The top surface was 3/4-inch plywood attached to the framing members with an industrial adhesive and flat head wood screws. The bottom surface was 1/4-inch plywood also glued and screwed to the framing members. Vinyl asbestos tile was applied in a conventional manner to the top surface and was carefully cleaned and waxed. Foot traffic was not allowed on the platform so that the surface was not subjected to wear prior to testing. The platform was carefully leveled using a builder's level before testing was initiated. Wood shims were placed where needed to accomplish leveling and the platform was checked for level periodically throughout the testing program.

The floor systems selected for test were chosen because they were representative of those used or considered for use in hospitals. The floor coverings included hard surfaces, such as vinyl asbestos floor tile, and soft surfaces, such as deep pile, well padded carpeting. The vinyl asbestos tile system was used as a basis for comparison of the other systems since it is the floor covering most used in hospitals and presents little difficulty involving the movement of equipment.

Table I lists the floor coverings used in the testing program. The floor coverings included five nylon carpets of various tuft designs and backings, two polypropylene carpets and an embossed vinyl sheet material with attached sponge vinyl cushion. All soft coverings selected were of a commercial grade carpeting and were installed by a staff member of the National Bureau of Standards according to instructions supplied by the manufacturers except covering H which was stretched over a hair felt pad and nailed about the periphery of the platform by a professional carpet installer.

The wheeled vehicle selected for the test was a hospital bed, because its weight, 290 lbs, is near the mid-range load for wheeled hospital equipment. Two sets of casters were selected to be used with the bed. Each set was five inches in diameter and was purchased from the same manufacturer to minimize possible variation in axles, swivel bearings and attachment hardware. The compositions of the sets of casters were classified as "soft" and "hard" rubber. Durometer measurements of the "soft" rubber wheels averaged SHORE A-2/76, while measurements for the "hard" rubber wheels averaged SHORE A-2/92.

A 6,000-kgf capacity universal testing machine was adapted for use in measuring starting and rolling forces. The sensing element in the load measuring system of the testing machine was a strain gauge load cell. The load cell was removed from its conventional position in the load-strain apparatus and attached to the foot of the bed in a horizontal position as shown in Figure 1. A flexible cable was then passed from the load cell around a fixed pulley and attached to the movable crosshead which is also shown in Figure 1. This technique provided direct horizontal force measurement at the bed, eliminating any frictional forces that occurred in the attachment hardware and also providing extremely reproducible rates of motion. The applied load measured by the load cell, and the distance traveled by the movable crosshead was recorded on the x y strip chart recorder of the testing machine.

The fastest rate of motion of the movable crosshead of the testing machine was 20 inches per minute, and this speed was used in the tests. The distance traveled by the bed during the test was approximately 20 inches. Since the circumference of a 5-inch diameter wheel is approximately 16 inches, the procedure was to initiate motion and continue for a distance of about 4 inches. The machine was stopped, wheel alignment checked and adjusted as illustrated in Figure 2 and a second 4-inch distance initiated. The third distance traveled was also about 4 inches. The fourth and final increment was initiated and allowed to continue until the end of the platform was reached. This procedure assured at least one complete revolution of the wheels.

Several precautions were taken to reproduce the same conditions for each floor system and each set of wheels. Each caster in a set was numbered to match a position on the bed so that it could be replaced in the same position on the bed for every test. A mark on the periphery of each wheel was made so that initial contact of the wheel with the floor system being tested would be identical for each floor covering tested.

A typical force-distance curve resulting from the test series is illustrated in Figure 3. The force necessary to initiate motion is indicated by the highest point reached after the start of test and is designated (F_s). The force necessary to maintain motion is defined as the average height maintained after motion was initiated and is designated (F_r). The area under the curve used for rolling force calculations was taken as the distance traveled from the point where motion of the bed initiated to a point where a quarter of a revolution of the wheels occurred. The "distance" indicated from start of test to initiation of motion is attributed to the elastic properties of the attachment hardware and "slack" in the hospital bed itself.

The test results of the floor coverings are given in Table II. The floor coverings are listed in alphabetical order of increasing force required to start motion with the unloaded bed and hard rubber wheels. In succeeding columns for other test conditions approximately the same ranking prevailed with the most notable exception being that of floor covering G. For the latter, the force required to maintain motion of the bed was relatively lower, compared to the force required to initiate motion, than was the case with the other carpet-type floor coverings. This difference may have been due to the embossed pattern of floor covering G.

For all conditions of load and wheel selection vinyl asbestos tile (the control covering) exhibited the least resistance to initiate motion and to maintain motion as expected. Coverings H and I required the most force to initiate and maintain motion. The differences in measured forces between coverings H and I are essentially negligible.

The average values listed in Table II are included to emphasize two important results. A comparison of the average forces necessary to initiate motion for similar conditions of loading indicates only a 2 to 3% difference for different wheel designations. A comparison of the forces necessary to maintain motion for similar conditions of loading is identical. These comparisons lead to the conclusion that the wheels used which were designated as "soft" and "hard" rubber had little effect on the measured forces. An evaluation of the average force results coupled with the Durometer measurements indicated that no appreciable difference existed between the "soft" (SHORE A-2/76) and "hard" (SHORE A-2/92) rubber wheels.

The second important result noted by a comparison of the average values is that the addition of a 300-pound live-load to the 290-pound bed approximately doubled the forces necessary to initiate and maintain motion. These quantities imply an essentially linear relationship between the forces to initiate and to maintain motion and the loads to be moved. Although only two loads were used in this series of tests an evaluation of the data for the variety of floor coverings tested leads one to the conclusion that a linear relationship exists for any load between those limits.

When the reported loads for vinyl asbestos tile (Covering A) are compared to those loads reported for the rest of the floor coverings in the test program it is evident that more force was required to initiate and maintain motion in all cases including the softer coverings. The force required varied from approximately 1.3 to 4.7 times as much as the force measured for vinyl asbestos tile.

A similar conclusion can be reached using the data shown in Figure 4. This is a plot of the ratio of the values of forces necessary to overcome starting friction (F_s/F_r) included in Table II. With few exceptions the plotted points indicated an approximately constant value of F_s/F_r equal to 1.3.

4. Conclusions

The conclusions drawn from the results of this investigation are as follows:

1. Floor coverings which were soft and cushiony to walk on offered 1.3 to 4.7 times as much resistance to movement of wheeled vehicles as did the vinyl asbestos tile.

2. Differences in measured forces required to initiate and maintain motion which can be attributed to wheels with Durometer numbers ranging from SHORE A-2/76 to SHORE A-2/92 were

negligible.

3. A ratio of approximately 1.3:1 existed between the force required to initiate motion and the force needed to maintain motion for a load range of 290-590 pounds, for the coverings tested.

4. The forces required to initiate and to maintain motion for all floor coverings, were approximately proportional to the weight of the moving vehicle.

5. Recommendations

This study was essentially a pilot program to determine the magnitude of forces which are encountered by persons moving wheeled hospital vehicles over carpeted floors. It is recommended that additional research be conducted with the objective of developing a standard test method for evaluating floor coverings with respect to starting and rolling forces for wheeled vehicles.

6. Acknowledgement

This study benefited greatly from the cooperation of the carpet industry and the staffs of the Materials Durability and Analysis Section of the National Bureau of Standards and the National Institutes of Health. The investigation was sponsored in part by Division of Hospital and Medical Facilities, Public Health Service, Department of Health, Education and Welfare.

The authors with to especially acknowledge the work and constructive criticism of Mr. James Byrd of the Superior Carpet Shop Incorporated, Washington, D. C.

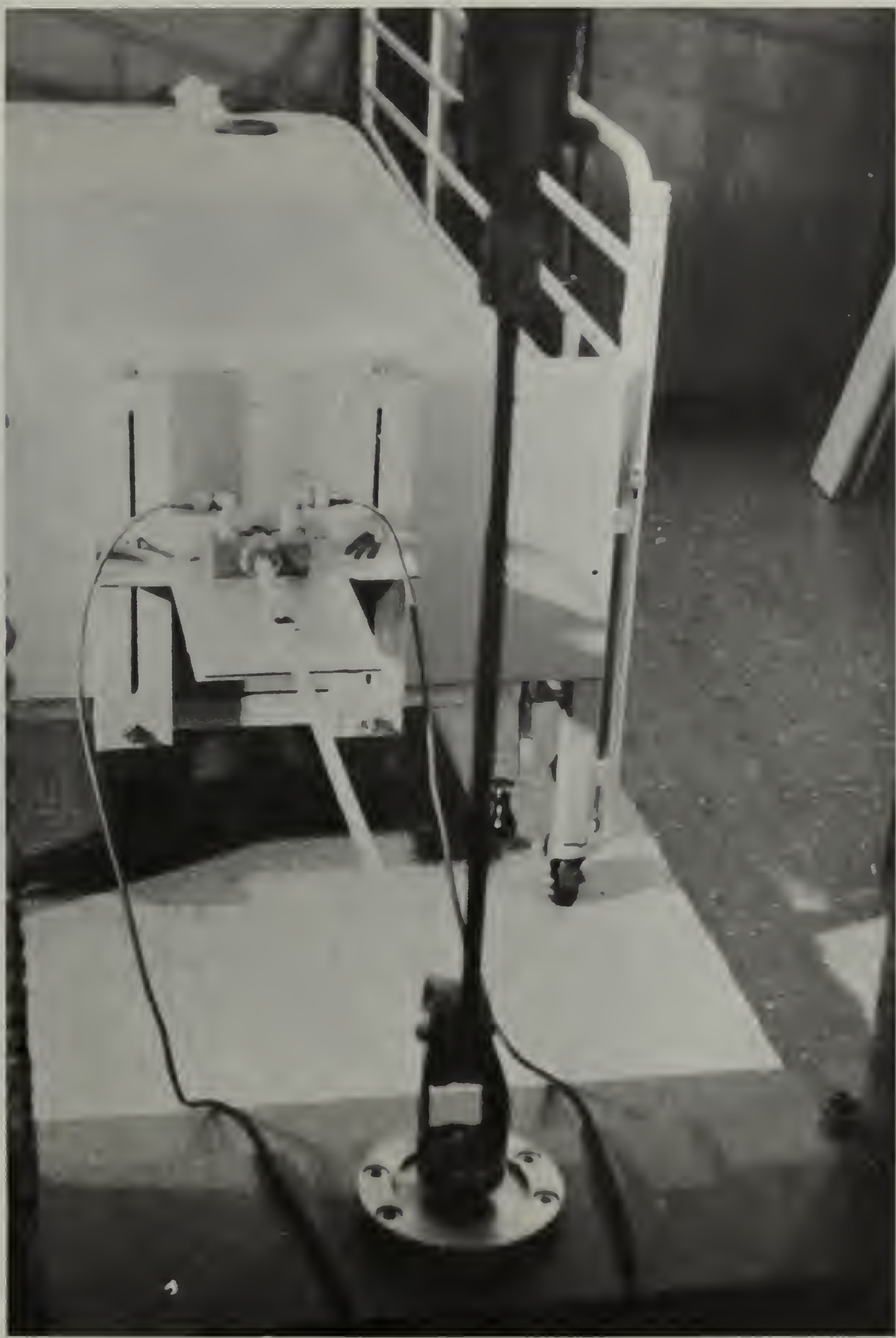


Figure 1. Equipment for testing resistance to wheeled equipment. Platform with carpet; hospital bed and connections to load cell, pulley, crosshead of load-strain testing machine.

Figure 2. Alignment of casters

Figure 5. Force Distance Curve for Determining Starting Force and Rolling Force

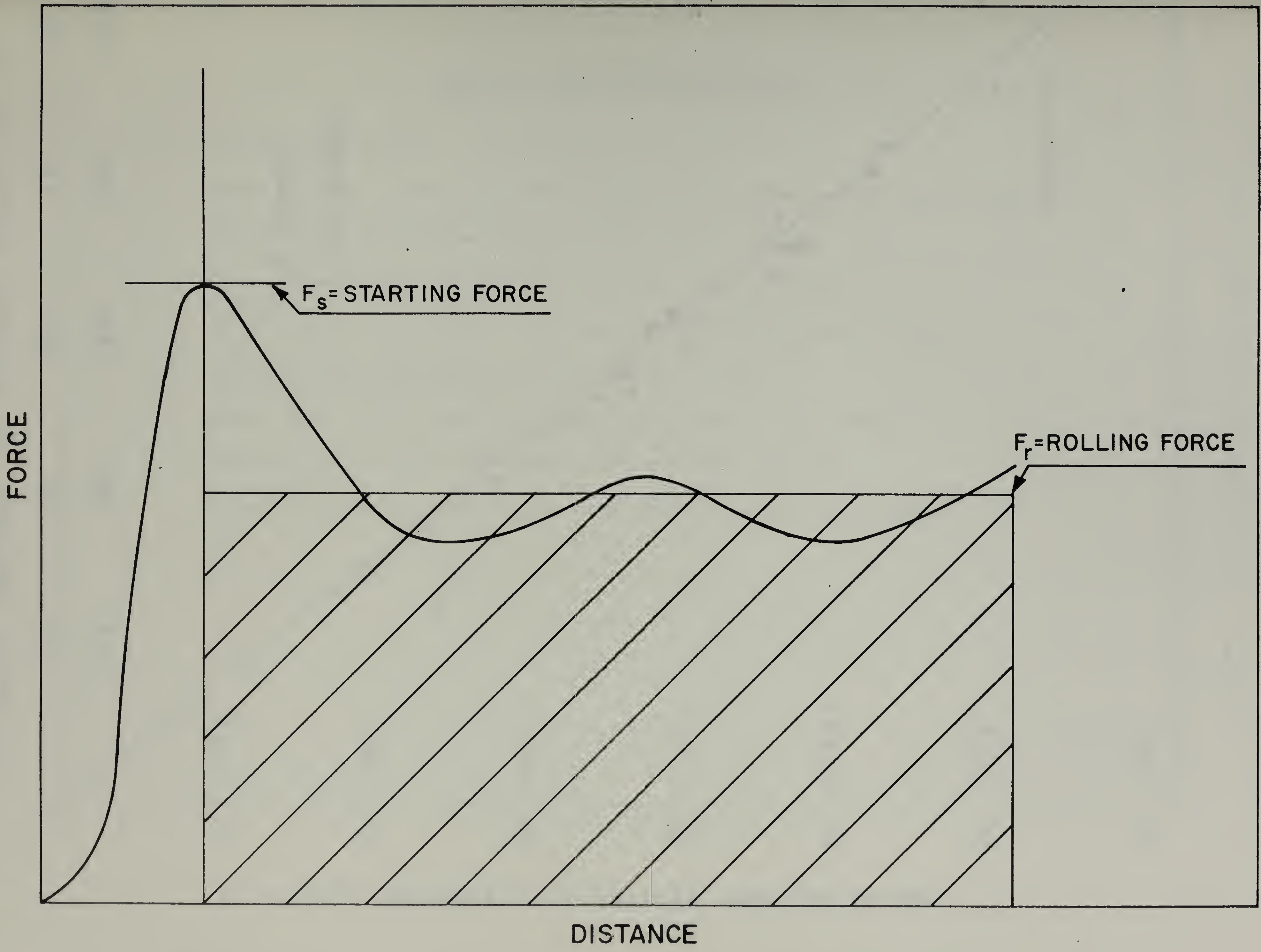


Figure 4. Ratio of Starting Force to Rolling Force

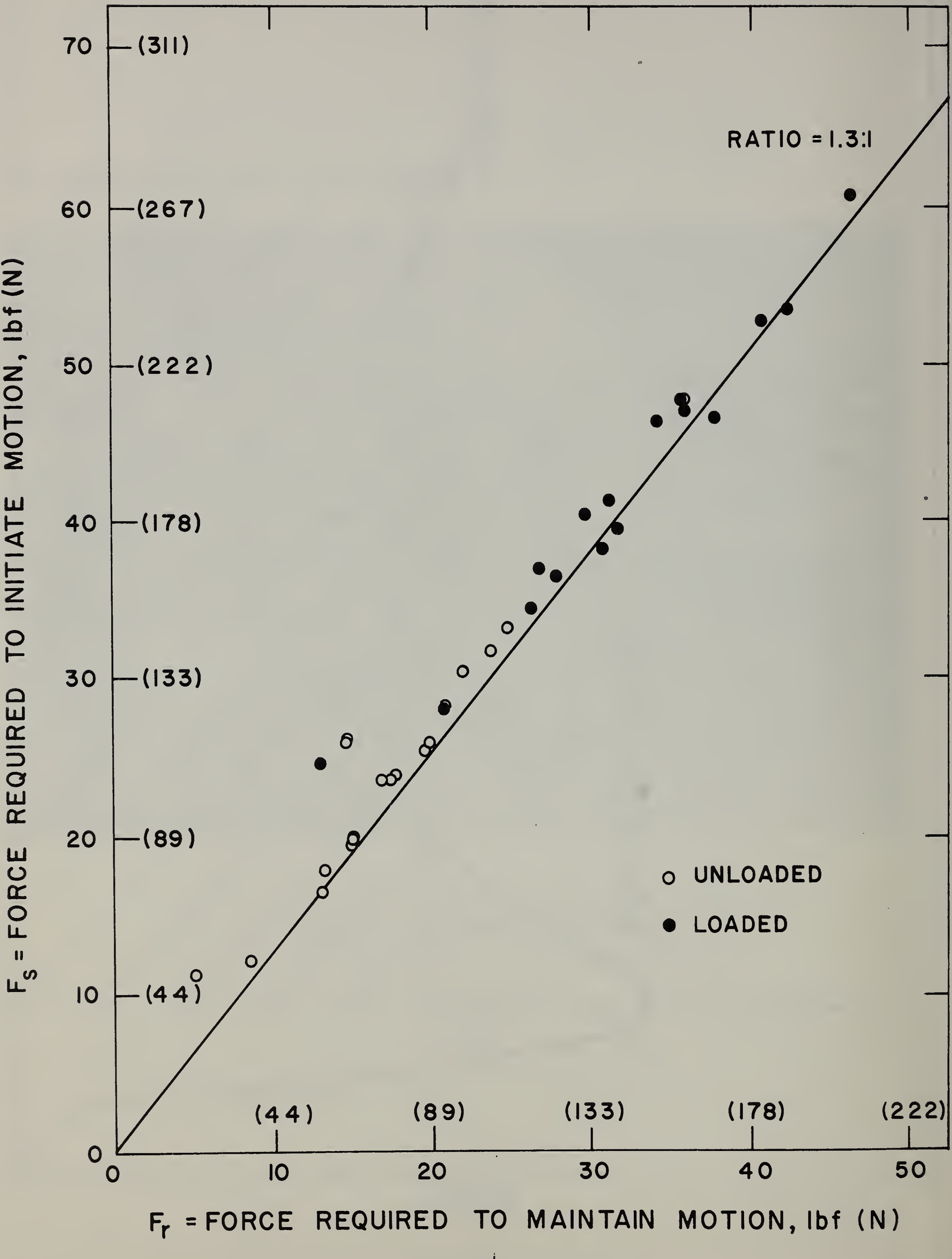


TABLE I. Floor Coverings Tested

A - Vinyl asbestos tile

B - Nylon modified upholstery weave carpet with attached sponge rubber cushion

C - Nylon looped pile tufted carpet without backing or pad

D - Nylon looped pile tufted carpet with solid vinyl backing

E - Nylon looped pile tufted carpet with attached foam rubber cushion

F - Polypropylene needlepunched non-woven felt carpet

G - Vinyl sheet floor covering with attached sponge vinyl cushion

H - Polypropylene tufted carpet stretched over hair felt pad

I - Nylon looped pile tufted carpet with attached sponge vinyl cushion

TABLE II TEST RESULTS

Floor Covering	Hard Rubber Wheels				Soft Rubber Wheels			
	Unloaded		300 lbf (1334 N) Live Load		Unloaded		300 lbf (1334 N) Live Load	
	F_s*	F_r**	F_s	F_r	F_s	F_r	F_s	F_r
A	11.1 (49.4)	5.3 (23.6)	24.6 (109.4)	13.1 (58.3)	12.0 (53.4)	8.8 (39.1)	28.1 (125.0)	21.2 (94.3)
B	17.2 (76.5)	13.3 (59.2)	36.9 (164.1)	27.1 (120.5)	19.6 (87.2)	15.1 (67.2)	38.2 (170.0)	30.9 (137.5)
C	20.1 (89.4)	15.1 (67.2)	41.3 (183.7)	31.3 (139.2)	18.0 (80.1)	13.4 (59.6)	36.4 (162.0)	28.0 (124.6)
D	23.7 (105.4)	17.1 (76.1)	46.4 (206.4)	34.5 (153.5)	19.9 (88.5)	15.1 (67.2)	39.5 (175.7)	31.9 (141.9)
E	23.8 (105.9)	17.8 (79.2)	47.7 (212.2)	35.8 (159.2)	26.0 (115.7)	20.9 (93.0)	47.4 (210.8)	36.1 (160.6)
F	24.1 (107.2)	18.2 (81.0)	46.8 (208.2)	36.2 (161.0)	25.5 (113.4)	19.2 (85.4)	46.5 (206.8)	38.0 (169.0)
G	25.9 (115.2)	14.8 (65.8)	34.9 (155.2)	26.5 (117.9)	26.2 (116.5)	15.0 (66.7)	40.4 (179.7)	29.7 (132.1)
H	31.6 (140.6)	23.9 (106.3)	57.0 (253.5)	48.5 (215.7)	28.5 (126.8)	21.2 (94.3)	53.5 (238.0)	42.5 (189.0)
I	33.3 (148.1)	24.9 (110.8)	60.8 (270.5)	46.4 (206.4)	30.4 (135.2)	22.1 (98.3)	52.7 (234.4)	41.0 (182.4)
Avg.	23.4 (104.1)	16.7 (74.3)	44.0 (195.7)	33.3 (148.1)	22.9 (101.9)	16.7 (74.3)	42.5 (189.0)	33.3 (148.1)

*F_s = force in lbf (N) measured to initiate motion.

**F_r = average force in lbf (N) measured to maintain motion.

Carpets and Flammability

by James V. Ryan
Fabric Flammability Section, Building Research Division

Speaking of fires in general, one question is, if there is a real going fire, how seriously will the fire affect the structure. Also, if there is a localized fire, how rapidly will it spread to other parts of the structure. Floor coverings have not been considered too important in this regard, although they have not been completely ignored by those who are working in this area. Some years ago the National Research Council of Canada did a study based on the ASTM E-84 tunnel test. This test is designed primarily for the measurement of flame spread properties of ceiling panels, other ceiling finishes, and walls. The Canadian group thought that, possibly, in a corridor, the flooring, whether oak, carpet or other material, might contribute only about one-fourth as much as the ceiling material. Hence they divided the requirement in the E-84 test by four. Today there seems to be more concern about the ignition properties of carpet as reflected by the recent proposed flammability standard for carpets and rugs which the U. S. Department of Commerce published in the Federal Register, December, 1969. This is subject to public comment and review and possible promulgation as a mandatory standard for carpets and rugs for sale and use in homes, offices, and places of public assembly and accomodation.

Another consideration in a fire is smoke and fumes and there is real interest in this aspect right now. It is my understanding that the State Fire Marshall's report on that Marietta, Ohio nursing home fire stated that 32 people were killed, all by smoke or toxic gases, and that the most probable cause of these gases was the carpet with a bonded rubber backing. Three weeks ago the subject of smoke and toxic fumes might not have been mentioned. The relation of the test in the proposed flammability standard to smoke and fumes is that if the floor covering does not ignite, it will not produce them. It protects the public against a smoldering fire which might start in the evening, as from a brand from a fireplace, and produce toxic fumes after the family has retired.

The test in the proposed flammability standard is a modification of the so-called pill test in Federal Specification DDD-C-95 for Carpets and Rugs. A small pill of the chemical methenamine is placed on a specimen and ignited by a match. According to our method the specimen is dried in an oven at 105°C and cooled in a desiccator over silica gel. The test is performed in a draft protected box with an open top, 1-foot cube. The specimen, 9-inches square, is placed in the box and a steel plate placed over it. The plate is 9-inches square and has an 8-inch diameter hole in it. The purpose of the plate is to keep the specimen flat, as would be the case in a large wall-to-wall carpet in a room. Otherwise such a small specimen would tend to cup and curl somewhat as it burns. The test criterion for an individual piece of carpet is that the area of charring, flaming, melting, or any other effect shall not spread to within one inch of this metal plate or a maximum of three inch radius from the point of ignition. This is a more liberal requirement than in Federal Specification DDD-C-95, which states that "the maximum dimension of the resulting area shall not be greater than two inches". However, Fed. Spec. DDD-C-95 does not require preliminary drying of the specimens. It is debatable which is a more severe test.

Now carpets and most textile materials are rather wild species to deal with. They are not like precision steels and that sort of thing. I didn't bring any specimens with me, but we have pieces of carpet from the very same roll from the same plant, where one piece will be burned completely out and the other piece will have a hole about an inch in diameter in the middle of the carpet. As a result, our test method requires that eight specimens be tested and that seven out of eight must pass the criterion of not having burned within an inch of the plate for the carpet to be considered acceptable. The test is pretty well along towards adoption and it is recognized that this is not a severe test. The burning of each pill produces about 1,050 calories, so it is not a big ignition source.

We have documented case histories of fires. One of these, involving a very small source of ignition happened in California about 2:00 A.M. A minister was writing his sermon at the dining room table while there was a fire in the fireplace in the living room. The minister heard a popping sound, looked into the living room, and saw that a fire on the carpet was spreading at an alarming rate.

He tried to stamp it out but could not extinguish the fire. He alerted his family, called the fire department, then tried to put out the fire with wet towels. He also shut the doors. The living and dining rooms and hallway were burned but the rest of the house was saved. The Fire Department put out the fire and nobody was injured.

Another documented fire occurred in Nashville in an apartment building where there was a long corridor with several doors and an enclosed stairwell off the corridor. A fire started in a coat closet inside one of the apartments off the corridor. The woman in the apartment discovered the fire and went next door to get help, leaving the closet and apartment doors open. By the time she got back the closet was completely involved. The carpeting in the hall caught fire from the intense radiation of heat from the open door, ignited, and spread 84 feet down the corridor, impeding rescue and firefighting attempts. Now this is a big fire compared to the other case I mentioned. Also, once this fire started there was undoubtedly considerable draft down the corridor. If that building had central air conditioning or blown air heat there was probably a draft in that corridor to begin with. In our test, in the proposed flammability standard, we tried to eliminate the draft factor, so that this test is recognized as a minimum or "first generation" test.

The question of draft is important. Under the Hill-Burton Act for several years the Public Health Service has been requiring that carpeting used in hospitals subject to this Act must have a rating of 75 or less in the ASTM E-84 tunnel test. In this test the carpet is tested on the ceiling of the tunnel. Many people, especially those in HEW have been critical of this test. HEW is most critical because they have spent money on research which has resulted in a better test for carpeting and in which specimens are subject to an appreciable source of ignition. The ignition source, which is bigger than the methenamine pill, simulates more nearly the circumstances in a corridor where the carpet is irradiated by a large burning object. This object could be a fire in a room radiated through an open door or a sofa burning on top with carpet below exposed to heat from the burning sofa. Mr. Julian Smariga of Public Health Service, HEW, authorized the money for this study, and he feels that it is far enough developed so that information can be released. You may contact him or Underwriters' Laboratories for more details.

QUESTION: How about your smoke test?

MR. RYAN: About four or five years ago, the Fire Research Section of the Building Research Division developed a test to measure the smoke produced from building materials and we have been using this test to measure the smoke produced from textile materials. We are going to look at this test more seriously as a result of the Marietta fire.

QUESTION: How about this rating of 50 in the smoke test in ASTM E-84? Is that applicable in this case? This is a very dangerous problem that we are seriously worried about and we can't wait five years for an answer.

MR. RYAN: I have been in the responsible committee for 12 years and the ASTM E-84 test method has not been extensively correlated with actual fire experiments. To be perfectly frank with you, I can't give you a good answer and I don't think anybody in the country can give you a good answer as to what 50 in the tunnel really means. Now we have had a research contract for about 8 months at Southwest Research Institute and they are not yet prepared to answer inquiries. They have not written us a final report. They have been igniting interior furnishings in a room and measuring the smoke, temperatures, levels of carbon dioxide and carbon monoxide, depletion of oxygen and have spot checked on other toxic gases. The present study was primarily concerned with beds and upholstered furniture, but I think the next phase will be carpet. Unfortunately, to answer your question, bed and sofa materials have not been tested in the tunnel so we can't tell you what measurements in the E-84 tunnel would mean in comparison to the results of these tests. We haven't yet studied materials that have been tested in the tunnel. I recognize that regulatory officials setting requirements for Federal, state, and city buildings have felt the need for some level of protection and have used numbers which they felt were reasonable. However, there has not been an adequate data base on which these people could make a selection.

QUESTION: Do present regulations apply to the whole carpet or just the underlayments?

MR. RYAN: The whole carpet. I believe that tests will be performed on carpet with and without underlayment and also on the underlayment alone, but I assume that the regulations apply to the carpet as installed. In the carpet the pile is the exposed surface for ignition.

QUESTION: I heard of a fire recently in a computer room where they had installed vinyl asbestos tile and the acid fumes destroyed a lot of the equipment. Have you heard of that case?

MR. RYAN: I have heard of two of three such fires from newspaper reports, not from official investigators. It is clear that there have been fires in computer facilities where there was damage from acid fumes but the source of the acid may have been from the floor, magnetic tape, or insulation around electric wiring. No one knows for certain the source of the acid fumes and I have not seen a clearly documented report that the acid came from the floor tile.

Economics of Flooring

by Philip T. Chen

Building Systems Section, Building Research Division

Although flooring is something provided for us to step on, it is more than that; it is a resource which we must respect and allocate wisely by economic principles. Once the cost of a particular flooring job is known, it is only the beginning. Then we must clean and repair it and, therefore, we must consider the maintenance or "in-use" cost. This leads to the concept of life-cycle analysis. Since this concept is based on the present worth analysis, it is designed to help Federal agencies to invest wisely in flooring. The performance approach to flooring considers all the elements which affect the cost of flooring from the planning, design, construction, all the way to the operation and maintenance phase.

I should like to quote from a paper written by T. H. Morlan of the Building Research Division:

> "Given some performance requirements which are determined by the kind of use the flooring will receive, a selection can be made from among flooring materials which meet these requirements. One of the most important things to be considered in choosing a specific material from among those which meet the performance requirements is cost. Just as performance takes place over time, so are costs incurred over time. In fact, the annual costs of maintaining a floor tend to be the larger portion of the cost of flooring. Therefore, in selecting the materials, use should be made of a means of comparing costs over the life of the materials, or perhaps even better over the life of the building.

One method of comparing costs over time is to discount the flow of costs which will be incurred in the future back to the same time as installation and first costs are incurred. The following formula discounts maintenance costs (M) and replacement cost (R) from the time they are incurred back to the time of installation.

$$L.C. = F.C. + \sum_{t=0}^{L} \frac{M_t}{(1+r)^t} + \frac{R_k}{(1+r)^K} + \frac{R_2K}{(1+r)^{2K}} + \ldots + \frac{S_L}{(1+r)^L}$$

where: L.C. = life cost

F.C. = first cost installed

M_t = maintenance cost in year t

R = replacement cost

k = replacement interval

L = life of the building

r = discount rate, i.e., rate at which money will increase over time left at interest rate r

S_L = salvage value at end of life of building (+ or -)

With such an approach the decision maker can easily evaluate the trade-offs between first cost and in-use costs or costs over time, in order to make a well-informed decision on the type of flooring best suited to his uses, budget, and tastes."

Life-cycle costing is a function of first cost (as of construction), plus maintenance cost, plus replacement cost. In the formula, the costs are referred to a certain interval. We are attempting to apply this formula not only to flooring but to overall Federal building construction with reference to building economics. This is all part of the Cost Analysis/Cost Synthesis project for the Federal Government, sponsored by the Departments of Health, Education and Welfare; Housing and Urban Development, Post Office, Veterans Administration, General Services Administration, and Department of Defense. Decisions made by administrators of public policy have a tremendous effect on the life-cycle cost of flooring, especially during the architect-engineer-designer stage. Once the decision is made it is hard to save money on maintenance. We should look at the building process as a whole as illustrated by the drawing of the Cubic Matrix (Figure 1.). In this matrix, under building process, we have requirements, programming, design, pricing, construction, and in-use (operation, repair, and maintenance or OMR). The following are definitions of building process and cost categories:

Building Process:

Requirements (Why) - Long range needs of an agency defines by the scope of activities to be housed.

Programming (What, Where, and When) - Definition of net space needs to house activities and development of budget.

Design (Schematics) - Basic concepts are investigated and one is chosen and developed to indicate basic space relationship.

Design (Preliminaries) - Schematic plans expanded to indicate construction systems and to form a base for working drawings.

Design (Working Drawings) - Preparation of the contract documents ready for bidding.

Pricing (Bidding) - Working drawings priced by contractors and subcontractors.

Construction - Period from acceptance of bids to operation and maintenance while building is constructed.

In-Use - Total operation and maintenance of a building over its life.

Cost Categories

Capacity Cost - Cost per functional requirements (Requirement).

Space Cost/Area Cost - Cost per Unit Area, usually in gross square feet (Programming).

System Cost - Total assembled costs of associated construction parts (Design).

Unit Cost - In place cost of basic building components including labor and materials (Pricing and Construction)

In-Use Cost - Cost of operation, maintenance, repair, and improvement of building components and system. (OMRI)

I shall now pose some sample questions to illustrate the Cubic Matrix on the economics of flooring:

1. Who is entitled to a carpeted floor?

2. Assume the maintenance cost for flooring is 50 cents/square foot/year. What is a square foot? Is the same cost alloted for all types of flooring and all types of use?

3. How much can we save on lighting if the flooring is very reflective? If the floor is a very light color, how much do we have to spend for maintenance?

4. Can we reduce the cost of cement finishing if we use carpeting?

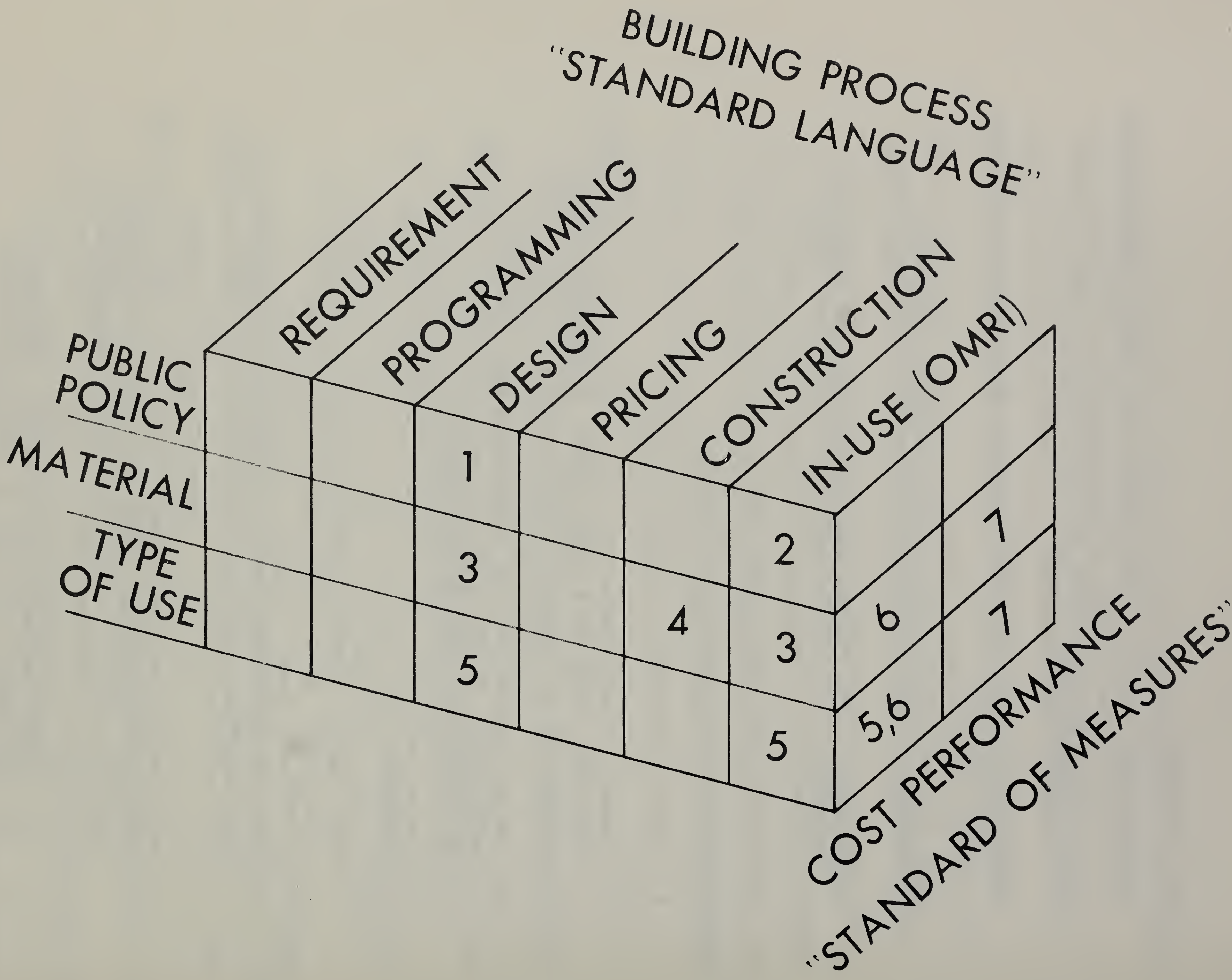
5. What type of flooring should be used for a "dust-free" clean room? What is the cost of maintenance?

6. Have you applied the logic of trade-off between the three M's, manpower, material, and machinery, as shown in Figure 2?

7. Have you developed maintenance standards? Have you defined levels of maintenance? Have you developed a standard reporting procedure compatible with the above? Do you know that the National Bureau of Standards has done work on:

   a. Initial performance of flooring materials?
   b. Performance with time of flooring materials (Exposure sites and field testing)
   c. Safety study - traction on flooring
   d. Developing the method of reporting the first cost and in-use (OMRI) cost and application of the life-cycle costing concepts in Building Economics.

FLOORING


BUILDING PROCESS
"STANDARD LANGUAGE"
REQUIREMENT
PROGRAMMING
DESIGN
PRICING
CONSTRUCTION
IN-USE (OMRI)
PUBLIC POLICY
MATERIAL
TYPE OF USE
1
3
5
4
2
3
5
6
5,6
7
7
COST PERFORMANCE
"STANDARD OF MEASURES"

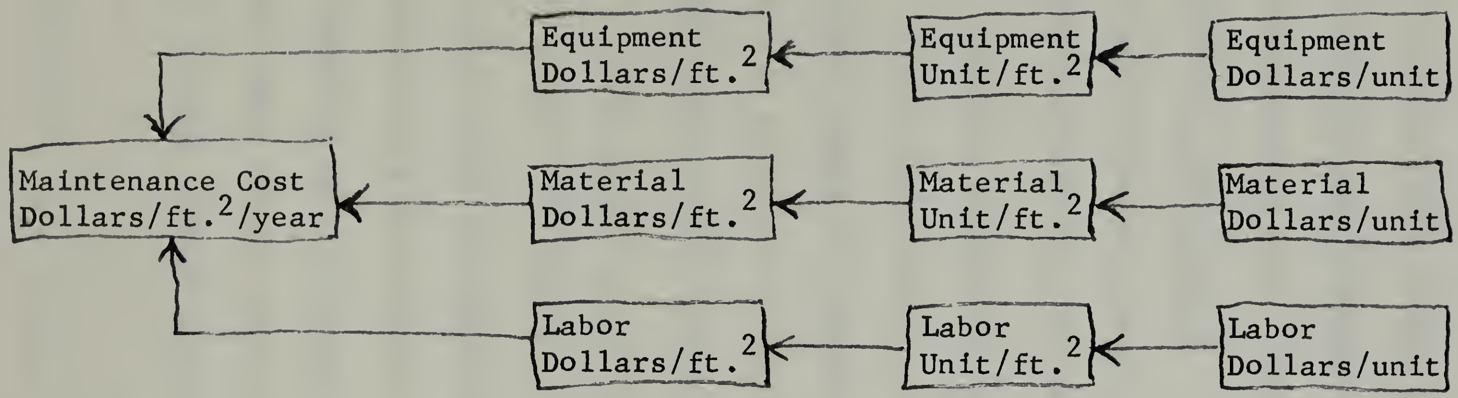


Figure 2. Trade-off Between Manpower, Material, and Machinery

e. Perception research (subjective) on color and sound?

First, let's discuss Question No. 1: Who is entitled to have a carpeted floor? According to some agencies, this is a matter of grade or rank. We should hope that it is a matter of economics. Let's go back to our policy makers and ask whether they should have an arbitrary standard for carpeted floors. Has anyone considered this question? (Ten hands raised). Question No. 2: should touch the hearts of most of you operation and miaintenance people. Assuming the maintenance cost is 15 cents per square foot per year, the question is, What is a square foot? Is the square footage gross, with corridors, without corridors, including what areas, etc.? We often keep three or four sets of books. I wonder whether this is advisable and if it is necessary, should the whole Federal Government know about it? Has anyone questioned this? (One hand).

Question No. 3 refers to how much money might be saved in lighting if a highly reflective floor is installed. It seems likely that a white floor might reduce the number of light fixtures necessary for proper lighting. Can contractors answer this question in terms of dollars and cents? Suppose we use a highly reflective white floor. Will this increase maintenance costs, as by requiring more janitors to clean up the heel marks, etc.? Have you gone through that? (Five hands).

As for No. 4, if we decide to install carpet over a concrete floor, can we save on cement finishing? Have you approached your architects or construction people that perhaps they can save money by not finishing the floor but that this will involve carpeting? (Five hands).

The scheme in No. 6 seems obvious for maintenance people, and you must have gone through the whole process of trading-off equipment, material, and labor. Have you applied this logic? (No response).

Now for the last question, No. 7: Have you developed maintenance standards and defined levels of maintenance? (Five hands). Do you know that the National Bureau of Standards has done work as outlined in 7 a, b, c, d, and e, and that this work is available in the Federal Government? (Twelve hands).

If you have developed maintenance standards, are your standards understood by your maintenance staff and can they be transferred from one agency to another in terms of performance? Can we define levels of maintenance? Some maintenance levels are not objective and are subjective in terms of appearance. This involves subjective judgements like - does it look dusty to you - does the color look alright to you - do the acoustical qualities sound alright to you? Then there is the question of reporting procedure compatible to the above? The National Bureau of Standards is interested in making sure that there is a standard reporting system among all federal agencies.

As for the work done here at the National Bureau of Standards, we have Mr. Wolfe here, who is the project leader for performance of flooring materials. Mr. Skoda has reported today on the safety study very ably. This is the beginning of a good project. Developing the method of reporting is our project here in the Building Systems Section in terms of performance and in terms of a reporting system for costs, etc. This project has to do with the application of the life-cycle costing concept to building economics. Then we have a Psycho-physics group here to conduct subjective research related to Perception Research on the range of human behavior in its reaction to flooring in terms of material, color, texture, etc. This type of research combines psychiatry, acoustics, and color research or optics and is a breakthrough in research which should interest all of you.

Maintenance of Floors at the National Bureau of Standards

by

Robert E. Roberts, Chief, Janitorial Services

I administer cleaning here at the National Bureau of Standards, and we do as good a job as we can under the circumstances, which I shall elucidate. We have here at the Bureau about 2,285,000 gross and about 1,600,000 net square feet of floor area. We have an authorized staff ceiling of 135, just reduced to 126, with present actual staff of 123. Of these, 12 men are permanently assigned to spray buffers. Those of you maintenance men from other agencies know that our staff is too small for the floor area. Usually cleaning staff is based on the net square feet of floor area to be cleaned but there are other factors which determine the size of the staff necessary to do the job. We have a night force of about 96 and the balance is on the day force for special cleaning, etc.

Most of the flooring here at the Bureau is vinyl asbestos tile and there is about 62,841 square feet of corridor area. We have roughly 25,000 to 35,000 square feet of terrazzo or terazzo-like floor areas. The resilient tile floor areas are maintained mostly by the spray-buffing process. We have decided here at the Bureau that we shouldn't apply water and scrubbing repeatedly on resilient tile. We felt that this is the most harmful practice to which the tile could be subjected and so far we have had a great deal of success with an almost dry method of cleaning which the trade calls "spray-buffing". First a synthetic polymer finish is sprayed on the floor in a fine mist. The finish is then agitated by machine, using an open weave nylon pad. The nylon itself is not abrasive but the construction of the pad is such that it has a mild abrasive action. The pad spreads the finish over the surface and at the same time destroys the surface tension of the existing finish, scrapes up the dirt embedded in the old film, and absorbs old finish and dirt in the pad. This results in a clean, bright, and shiny finish. This process does not completely eliminate stripping and refinishing but greatly extends the time between these operations. We are not involved with mops and buckets as would be the case if there were a scheduled program of stripping and refinishing throughout the plant area. It also allows more frequent cleaning of resilient tile areas. We originally planned to have 12 spray buffing machines for 12 different areas, each buffer assigned to a particular area or rotated on a programmed schedule to be in each area at least once every two weeks. The machines would also be used for emergency cleaning in trouble areas normally scrubbed, as at entrances, around snack bar areas, entrances leading in from loading ramps, etc. However, our staff ceiling was lowered and we have had difficulties in recruitment. Because of this we have been forced to use floor cleaning staff for routine tasks, such as trash collection, which must be done every night. Since spray-buffing must be done repetitively, we have temporarily lost the advantages of this process. If spray-buffing is not repeated, it may be necessary to start all over again and re-strip and refinish the floors. In most areas of the Bureau we don't even employ a waxing or finishing crew as such. Most of our resilient tile areas still have three or four coats of original finish, as we have never removed it. I would say that this particular room (Lecture Room A) is about 40 to 50 percent below normal maintenance standard as far as gloss, absence of marks, etc., mainly because of the lack of personnel to do the job.

We have determined that floor care represents about 40 percent of our maintenance budget and includes sweeping, scrubbing (if any), mopping, waxing or finishing, picking up spills, etc. In Fiscal Year 1969 janitorial services at the Bureau cost $806,000. More would have been spent if we had operated with a normal staff but that years we were down 129.5 average people on board, whereas our ceiling was 135. Even though we have not recently had the staff to employ spray-buffing properly we still feel that it is worthwhile to investigate new methods to see if it is possible to save the taxpayers' money.

Cleaning terrazzo floors is a simple operation. We use automatic scrubbing and vacuum machines, battery powered, such as made by Clarke or Lincoln. We put down three or four clear water applications per week, scrub it, and pick it up; after the area has been dust mopped first. This is the generally recognized care for terrazzo. I know that trade magazines and salesmen will tell you that a particular sealer or finish is necessary but these treatments generally only provide a lot more cost in labor for application. I wasn't here when the original sealer was applied to our terrazzo floors but it appears to me that two coats of permanent seal (probably phenolic resin) were applied. After that we scrubbed and scrubbed with water. Phenolic resin terrazzo seal works very well and then every couple of years the worst traffic patterns may have to be filled in and then we can forget it. The latex base type of seal proved to be an unhappy experiment here. We tried two coats over the phenolic sealer near the cafeteria and now it has permanent scuff marks on it and will have to be stripped off.

We have also been interested in carpet but decided to wait and see how Mr. Wolfe came out with his carpet study. We are skeptical about the published carpet studies like the one reported by Parks and his group at the University of Pennsylvania, partly financed by a resilient flooring manufacturer. There are also carpet studies financed at least partly by the carpet mills. All studies that we have made on carpet care lead us to believe that it is by far the cheapest covering that you can have on floors as far as maintenance dollars are concerned. It presents to most people a more pleasing and aesthetic look to an area; it is more conductive to study for people who need quiet; it absorbs more distracting noise; and so on. However, to be more competitive with resilient tile, it must have a comparable life. There are so many variables in places where flooring is to be used that it is hard to determine what is the life of resilient tile. The same applies to carpet. Also, there are different kinds of carpet and we need to know the life of each type. Of course, it is also necessary to figure the first cost or how much the carpet costs in the first place. The most expensive carpet is likely to be the least expensive as far as the maintenance dollar is concerned. Some years ago all expensive carpet was laid in 27-inch strips, which were sewn together and this is how the carpet in our red and green auditoriums were installed. One reason for this in years past was that the looms accomodated only 27-inch widths. Also, laying in narrow strips enables the operator in the area to remove the worn portions of the carpet from travel lanes and replace it with a strip in a less travelled area and thus double the life of the carpet. With modern broadloom carpet, it is necessary to replace a much larger area all at once. This makes it necessary to pay more for the carpet to get an acceptable wear factor and lengthen the maintenance life.

MR. WOLFE: Mr. Roberts, have you heard of a program offered by carpet mills combining carpet sale and maintenance?

MR. ROBERTS: I have heard of the program; in fact many contractors have told me that they offer building managers a janitorial contract, whereby the contractor will install the carpet and be given a contract to clean the building for a certain length of time, say five years, after which the owner of the building can have the carpet. This leads me to believe that carpet must be cheaper to maintain, otherwise no one would offer such a contract.

QUESTION: What is this buffing procedure that you were talking about? Do you use a machine?

MR. ROBERTS: Yes, it is like a wax buffer, but it might have a wire brush head instead of a bristle brush, so that the nylon pad would not get out of control underneath the brush.

AFTERNOON SESSION - PANEL DISCUSSION

Selection and Maintenance of Flooring by the Public Buildings Service

by

Kenneth F. Ward, Chief, Materials Branch, Public Buildings Service, General Services Administration

Mr. Chen mentioned the psychological aspects of floor coverings. In the Public Buildings Service of GSA, we have a one-year evaluation procedure which is in accord with his stated requirements in that the psychological and aesthetic aspects of a building are considered from the occupant's point-of-view. Office of Design and Construction personnel, primarily, meet and work with the architect, engineer, general contractor, and some of the prime sub-contractors. Questionnaires are circulated to get the occupant's opinions. At least from the occupant's point-of-view, we can determine if 180 feet is too far from the restroom or whether or not the vending room should have been a little larger and possibly in brighter colors.

With regard to life-cycle costing, which Mr. Chen discussed briefly, one study undertaken three years ago showed that the projected average cost of construction will increase on a linear or constant basis, while the expense for maintenance labor will increase at a cumulative or compound rate. The study showed that, based on cost increases, the construction of a building over a period of 40 years would have an estimated cost increase of 128 percent, whereas labor for maintenance would increase in cost 380 percent.

The interest of the Office of Buildings Management in flooring is as a user. We are concerned with flooring in three general categories - maintenance, evaluation, and construction. We are responsible for the policy guidance for a cleaning program involving about 7,000 custodial employees and a multi-million dollar amount expended for maintenance of floors. Consequently, we are very much interested in the best way to maintain floors with existing materials and equipment available through the Federal Supply Service.

A second category is our interest in new materials and coatings. We have an "in-house" program where products and equipment are evaluated to see if they will fit better into our method of operation. Hopefully, this leads to a request of the Federal Supply Service that some improvement or change be made in specification requirements. One completed study on a particular material eliminates stripping. This metal cross-linked, acrylic, co-polymer floor finish is being tested by the Federal Supply Service. It suggests a vast improvement over existing types of floor maintenance procedures. With available materials, our standards call for stripping and waxing every 63 work days. Any extension of this length of time, or elimination of stripping, waxing, buffing, and polishing, would be very important. Currently, the labor dollar in custodial work represents 96 percent of the total cost with four percent spent for materials. It can be seen, therefore, that we can afford to spend more money on better materials provided this action results in overall lower cost for labor.

Out third interest is in construction and our problem is to decide on the kinds of flooring which should be installed. We want the best kind of floor coverings consistent with what may be termed "optimal maintenance". Flooring may be procured on the basis of life-cycle costing with consideration given to the minimum amount of required maintenance. For example, wax is applied to vinyl asbestos tile for aesthetic, easy maintenance, and surface protection reasons. So, it is not meaningful to conduct abrasion tests on unfinished vinyl asbestos tile without the tile being tested according to some method of floor maintenance procedure. We are currently considering a project using this kind of approach and it may be rather extensive.

In conclusion, we do not believe that there is any magic formula for the solving of our problems. We do think, however, that there is a need for new approaches and fresh ideas. We thoroughly subscribe to this meeting and we hope that this kind of undertaking is continued.

Flooring Problems in Military Installations

by

John V. Blake, Buildings and Grounds Branch, Facilities and Engineering Division, Office of the Chief of Engineers, United States Army

The Facilities and Engineering Division or Post Engineers has to do with the operation and maintenance of Army facilities, specifically buildings. Flooring maintained by the Army runs over 900,000,000 square feet, equivalent to about 138 Pentagon Buildings. The greatest factor contributing to floor problems in the Army is the severe use or abuse to which the floors are subjected, largely due to lack of understanding of the proper care and cleaning of floors. Troops are constantly being instructed on the care of floors and control of abuse but it is only possible to minimize the severity. Directives prohibiting the excessive use of water, use of coasters under the legs of cots and chairs, etc. have only limited effect. The harsh use remains. A second factor contributing to flooring problems in the Army is the wide variety of facilities comprising the Army inventory including all types of construction, most usages, and located in many geographical areas and climates. Many facilities constructed during World

War I are still in use and are found in most Army posts. Locally some of them are at Fort Myer and Walter Reed Army Hospital. Maintenance, repair or replacement of flooring in these facilities are problems. During World War II thousands of wooden mobilization-type barracks, mess halls, and supporting facilities were constructed. Many have been in continous use since or have been pressed into use during the Korean and Vietnam crises. Providing floor coverings in these facilities commensurate with their value and expected retention is the problem today. The barracks do not present the only problem to Facilities Engineering. Nearly all posts have cold storage and meat cutting plants, laundries, bakeries, laboratories, kitchens, hospital operating rooms, machine shops and many other special facilities, all of which have unique flooring problems. Problems arise as a result of inadequate inspection at the time of construction. Such problems often are discovered some time later and have to be corrected by the Facilities Engineers. Inadequate design likewise results in the need for corrective repair and alterations after a facility has been constructed. The facility engineer has to make the best of what he has and take what corrective action he can.

What are some of the specific Army flooring problems? I stated previously that some of the floors in the wooden mobilization buildings present problems. A current problem is to find an economical sheet goods material for application on squadroom floors and barracks. A material must have low cost, generally predicated on about 3-5 years of intermittent summer use of the building. A felt backed pitch composition floor covering according to Federal Specification SS-F-1032, which was previously specified for use is no longer made in this country and is in short supply.

Following World War II the Army was faced with the problem of how best to provide a sanitary, durable floor for kitchens in mobilization type mess halls. Investigations conducted by the Chief of Engineers toward solving this problem were instrumental in the development of furane bedding and joint materials. It was found that quarry tile could be successfully applied directly on supported plywood using a 1/8-inch furane setting bed. In the period 1955-1957 this method was used extensively in Army bases throughout the continental United States in kitchens of mobilization-type mess halls. The forecast use of these mess halls was a time of ten years, after which they would be replaced. However, many of them have continued in use. The quarry tile set in furane was found to be too expensive for this type of use in mobilization-type buildings and the search for an economical material continued. In this area, the Corps of Engineers has devoted considerable effort towards finding a suitable overlay for deteriorated concrete or wooden floor areas subject to hard use and requiring scrupulous cleanliness, as in laundries, biological laboratories, kitchens, etc. This overlay has to be resistant to spillage of foods, fats, and oils; able to withstand moderate heat from ovens and hot water heaters; able to withstand flooding and scrubbing with hot water; able to resist wear and impact and be monolithic. Not the least requirement is that it has to bond to the old concrete. After extensive experimentation at the Fort Belvoir laboratory, a 1/4-inch polyester coating was found satisfactory and in April, 1966 resulted in the publication of MIL F-52505 by the Engineer Research and Development Laboratory. This specification covers two types - a troweled on industrial coating and a decorative terrazzo, using either marble or granite aggregate. It is important to note that for any such overlay, only experienced applicators should be used. The substrate must be carefully prepared and provisions of MIL-F-52505 and the manufacturer's instructions must be followed explicitly. We have experienced difficulties in these respects. An area which is a considerable headache for us is leaking showers and drainboards. This is not a problem with the quality of the tile or floor covering _per se_ but one of providing a completely waterproof membrane or pan under the setting bed. Not only does the GI use plenty of water in showering but also liberal applications of water in mopping and squeegeeing latrine areas. Any failure to provide a continuous, unbroken membrane turned out all vertical faces, to seal all water pipe penetration, to properly connect the membrane to the floor drain, is sure to develop in water leaking to the outside of the building, running out into adjacent rooms, or dripping to floors underneath. This is an example of where close inspection of construction is most important. Repair in this case is quite costly, since it is necessary to remove the tile and setting bed to locate leaks and make repairs. This applies also to concrete decks. Attempts to stop leaks by calking joints between tiles or by application of sealers to the surface of the tiles is apt to have futile as well as unsightly results. These are just a few of the many flooring problems which confront the Army.

In conclusion, I might say that rough Army use generally precludes the use of materials such as rolled on coatings and carpeting. Furthermore, suitable flooring materials for military use are prescribed in Department of Defense critéria and any deviation therefrom must be justified economically. In other words, the material must have long life with minimum maintenance and low initial cost.

MR. WOLFE: We have been doing research on overlays for covering contaminated concrete floors and are evaluating some systems that seem promising, like asphalt-modified epoxy and neoprene barrier between contaminated concrete and the topping. There is also a promising material, an oil-modified epoxy used to cover highways and bridges. Also, you mentioned sheet goods for squadrooms. We have found a company in New York which says that they will be able to supply a felt backed pitch composition floor covering at about 18 cents per square foot.

Monolithic Surfacings Used To Renovate Resilient Tile

by

George Erickson, Office of Housing Management, U. S. Department of Health, Education and Welfare

I was the paint technician with the Housing Assistance Administration for some ten years and during this time we initiated 17 paint and coating Federal Specifications in cooperation with General Services Administration. The most exciting of these was Federal Specification TT-E-00490A, which is for silicone alkyd exterior enamel. This specification was developed in cooperation with Dow Corning and has resulted in purchases by the U. S. Navy of 1,800,000 gallons of silicone alkyd enamel. We were assisted by paint chemists, such as Miss Mildred A. Post of the National Bureau of Standards, who assisted with some of the analyses.

In working with the seven regions of the Housing Assistance Administration and with a number of the 2,230 local authorities, I have been able to determine what is needed in the way of coatings. The agency is about thirty years old and we have tremendous maintenance problems which are increasing rapidly because of deterioration and vandalism in low cost housing. The most pressing problem in flooring is asphalt tile which needs replacement or renewal. Water on the floor in bathrooms, largely due to carelessness, causes problems. In bedrooms, corridors, and other areas we need to know what is best from the standpoint of economics, productivity and efficiency. Seven years ago one of our authorities was going to replace some asphalt tile and I considered the idea of cleaning the tile and coating it with oil-modified polyurethane. Experts said that solvents would seep underneath the tile and lift it. However, I thought it would be worthwhile to try it out in public housing. We removed the wax from about 2,500 square feet of asphalt tile which was in poor condition and needed removal. We then applied two coats of oil-modified polyurethane. Seven years later the floor is now intact and in perfect condition. With the assistance of Spencer Kellogg, the main raw materials supplier, we developed Federal Specification TT-C-540b for linseed oil-modified polyurethane coating. If exterior wood surfaces are cleaned and properly prepared and two or three coats of oil-modified polyurethane are then applied, the coating will not check or crack after four or five years service. In most cases, after five years another coating of oil-modified polyurethane can be applied after cleaning the surface, sanding lightly and then cleaning with mineral spirits.

We tried a number of coatings on concrete, wood, asphalt and vinyl tile, and plastered walls and thought moisture cured polyurethane coatings were the answer. About 25 months ago we started on a cooperative research program with Vanderbilt Chemical, Tecco, Inc., Spencer Kellogg, and Cambridge Tile of Cincinnati. This involved on-site evaluations. I was not satisfied with the first formulations which we tried. The epoxy formulations had an obnoxious odor, so that they were not acceptable. I suggested developing an emulsion epoxy to lessen toxicity, odor and eliminate fire hazard, especially since we were unable to use fans in confined areas to remove the fumes. Some of the industrial chemists then developed emulsion epoxy formulations. This not only eliminated the odor but adhered to concrete, wood, asphalt tile, plastered surfaces, and dry walls. We have tested this formulation throughout the country in public housing, meat packing plants, on floors where chemicals are spilled, in churches, hospitals, etc. The emulsion epoxy is a pigmented formulation and we are recommending a two application coat. A 1 1/2 to 2-hour drying time has been reduced to 45 minutes dry between coats. Over the emulsion epoxy, we apply a clear epoxy coat into which we flow the vinyl chips. We use a special type of chip which lies horizontally most of the time. Over that we put a clear epoxy coat and then two coats of glaze for housing. In other areas, where there is heavier traffic, we apply more glaze coats. The total thickness is 20-25 mils, including the chips. We expect to have a Federal Specification out in 60 to 90 days. Those responsible for the specification include some 30 industry representatives and the steering committee of the National Capital Housing Authority.

MR. WOLFE: Can oil-modified moisture-cured polyurethane be used over vinyl asbestos tile?

MR. ERICKSON: Yes, if properly cured. Vinyl, as you know, is much more harsh, so we want to scarify it. We need to sand it a bit. We don't want to necessarily do that on asphalt tile. We're going to do our best to spell out every single step.

QUESTION: Has a number been assigned to this specification?

MR. ERICKSON: Yes, by General Services Administration, but this must be cleared by the Department of Defense.

QUESTION: What is the cost of your seamless flooring system?

MR. ERICKSON: We have made applications at 70-75 cents per square foot laid down complete. We have been able to apply 5,000 square feet at a cost of 41 cents per square foot, as compared to asphalt tile at 35-42 cents and vinyl asbestos tile at 65-75 cents per square foot.

Flooring Failures

by

Lynnford Snell, Federal Housing Administration, U. S. Department of Housing and Urban Development

My general subject is flooring failure. The basic considerations in examining flooring failures are: (1) Selection, (2) Construction, and (3) Use of the flooring system.

(1) Selection. In the design engineering or planning stage, the question is - are the materials selected adequate for the intended purpose? I think we all feel that we need more information on this.

(2) Construction. In the construction state, were the specified materials and methods used in the project? Here is a case where we need better field identification of materials, perhaps certification and labeling programs, and perhaps a need for closer inspection.

(3) Use. Was the flooring system as originally anticipated during the selection stage and has the system been properly maintained during that period? We are trying to get more feedback along that line and we intend to develop a more thorough system within our Methods and Materials Section.

Any flooring failure should be carefully analyzed with these three points in mind and a system might fail due to a combination of selection, construction, and use. Unless cause and effect data are available, it is difficult to suggest remedies. We have had many types of flooring failures involving nearly every type of finished floor.

One is the failure of the thin slat block parquet. In some jobs we looked at, the slats had buckled 2-3 inches above the plane of the floor. We finally attributed this to moisture conditions during the adjustment of the air conditioning system.

We had several asphalt tile failures in a project where there was a white efflorescence over the face of the tiles due to moisture penetration through the slab system.

The product is often blamed for floor failures. We had a vinyl asbestos tile failure attributed to the particleboard underlayment which failed to meet our specifications in the Use of Materials Bulletin.

We have had some problems with carpeting, including two or three reports of fading and one of extreme wear, probably within the year guarantee that we carry. In the case of the three that were replaced by the manufacturer, the carpeting did not meet the standards.

To conclude, I should like to read a memo from one of our field offices, which is the type of thing we get into all the time. The subject is the single floor system.

"In the past several years, we have been made increasingly aware of problems evolving from the use of single combination subfloor underlayment systems in homes insured by our office. We estimate no less than 100 complaints a year serviced by our office in recent years concerning various deficiencies in the floor systems of this type. We, of course, receive a small percentage of the complaints in the field, since we only hear of those where the builder has not assumed the responsibility or has performed unacceptable remedial action. One reason perhaps for close association with this problem is that a great percentage of homes insured by our office are packaged or precut homes utilizing this system. The nature of the problems are varied but all seem to stem from the fact that plywood <u>does</u> flex even when nailed properly. The neck of deflection that occurs at the ends of the sheet tends to cause ridges and loosen the nails, crack and break tile. Tongue and groove sheets also, in some instances, evidence ridges and flexing between the sheets. Drying of the joints that occurs during the first heating season also contributes to nail pops, much like those on dry wall. Plywood sheets are subjected to rains, snow, freezing and thawing cycles, and delamination has been noted in the tongue and sheet edges. These delaminations and weakened glue lines also bring about objectionable ridges and breaking tile".

Now to get back to our requirements here. Our Minimum Property Standards state that the manufacturer's recommendations shall be followed in the installation of resilient tile. Several manufacturers recommend more than a single combination subfloor underlayment of 1/2- or 5/8-inch tongue and groove material. We know that by addition of glue to the joists and edges, strength is substantially improved. Many of the prefabricated homes, therefore, using glue and screws, have less problems. Some of the things that go along with this are very interesting. The manufacturer's instructions all involve using heavier subfloor material. As in Mr. Erickson's talk, here is something from the field. These are problems that we deal with every day.

MR. WOLFE: Have you read the recent article in FLOORING magazine about underlayments? They discussed the three types - plywood, particleboard, and hardboard.

MR. SNELL: I read the articles and comments about the certification program and discussed these with representatives of the industries involved. With the varied materials we put together, it is apparent in my discussions with the asphalt and vinyl asbestos tile people, other tile people, and the particleboard people, that there are certain types of adhesives that do a very fine job. There are certain types of adhesives that apparently attack whatever the particleboard is put together with and we have problems here. So it is a matter of finding compatible systems.

MR. WOLFE: Do you think it is possible that some hardboards could be so porous as to actually take up adhesive?

MR. SNELL: I think that there are many systems that work, but I think sometimes it is hard to take an overall group of things . . .

MR. WOLFE: The reason I asked is that we had a housing project with mastic failure and it looked as if the mastic had sunk into the hardboard and very little adhered to the tile.

MR. SNELL: Very possible. Perhaps there are adhesives that might do that.

MR. WOLFE: You mentioned that you are trying to promote a labeling program in the carpet and rug industry.

MR. SNELL: We do not promote a program. As an example, last week we met with the ceramic tile industry - Tile Council of America. They put together a certification and labelling program but this requires initial testing and how the quality control will go at this point I am not sure, as I do not have the program. This is for purposes of identifying the material and especially identification on the job.

Guide Specifications in the Public Health Service

by

Lawrence Katz, Chief, Specifications and Estimates Section, Design and Construction Branch, OBF, Public Health Service, U. S. Department of Health, Education and Welfare.

Deviating from the subject of maintenance, let's talk about specifications for a while. Since specifications have been under attack in the laboratories and have been blamed for construction failures, the word "specifications" needs a little defense. We in the Public Health Service have the guide specifications system and I shall give you a resume of our guide specifications for flooring.

We base our specifications on materials and performance. We use reference standards wherever possible, as Federal Specifications, ASTM Standards, ANSI Standards, standards from technical associations we think these are worthwhile, and I shall illustrate these as we go along.

Starting with the basic item, concrete, which besides wood is basic to all flooring systems, for concrete specifications we use the American Concrete Institute, as reference for our standards. The relatively new ACI 301 is for structural floors for buildings. ACI 302 covers concrete slabs, expansion joints, etc. ACI 318 covers the building code for reinforced concrete. Various concrete finishes are specified. One of our problems is the incorrect use of finishing specifications. For example, a second steel troweling is not desirable as a base for finished flooring and a float finish should be used in order to provide a good bond to the substrate. Usually a sealer or "hardener" is placed over the concrete slab. According to our criteria, a sealer or hardener should never be used on a slab which is to receive another finish. We also keep away from liquid membrane curing compounds. We feel that the best curing for concrete is moist curing for seven days with liquid water, polyethylene sheet, or building paper. The polyethylene or building paper should be weighed down so that it stays on during the curing period.

Another guide specification we have is for resilient flooring. For this we go into Federal Specification SS-T-312, now being revised and I have received a copy of the revision, SS-T-312A. They have improved it somewhat. I feel that this Federal Specification is of minimum value for asphalt, rubber, vinyl, and vinyl asbestos tile. For example, it still calls for 9 X 9 and makes no reference to 12 X 12 inch floor tile, now used in over 80 percent of construction. Something else I've been fighting about with the companies and this is reflected in my comments to the committee which is writing the Federal Specification - the factory applied waxing. There is no criterion at all in the Federal Specification. If you go to a plant which makes vinyl asbestos tile and note the impellers which feed the wax emulsion or whatever it is, there is no criterion for the amount applied, and I feel that this is one of the weaknesses in the Federal Specification. Vacuum finished tile is what we should be getting in this day and age. One of the reference standards we used was the Asphalt and Vinyl Asbestos Tile Institute. They have quite a bit of literature on recommended installation specifications, maintenance specifications, etc.

The next section is ceramic tile. Ceramic tile is one of the subjects on which there has been extensive industry research and study. There are standards out which are used and which I feel are quite adequate. For instance, the ANSI spec. A108.1, glazed ceramic wall tile, installed with portland cement mortar; A108.2, ceramic mosaic tile with portland cement mortar; A108.3, quarry tile and paving tile; A108.4, ceramic tile with water resistant organic mortar; A108.5, ceramic tile with dry set cement mortar; A108.7, conductive; A118.1, dry set mortar installed; A118.3, conductive dry set mortar; A136.1, with organic adhesive; A137.1, standard specifications for ceramic tile, which should eventually replace Fed. Spec. SS-T-308, which leaves much to be desired in this day and age. A new Fed. Spec., Interim SS-T-308c, will be replaced by a new issue of A137.1, according to industry. One of the problems with ceramic tile from the manufacturing end is that the standards are minimum and result in this country in competition between high and low quality tile. Tolerences get off and the joints are poor. There are also the Tile Council of America standards on installation and the materials involved are adequate. There are standards for conductive flooring, which can be used for ceramic tile.

The next subject is terrazzo. About the best reference on terrazzo is the National Terrazzo and Mosaic Association. They have specific details and technical data which is revised about every two years and a color catalog of 1966 issue. The Association goes into different methods for installation of terrazzo such as setting bed method, fill method, marbleistic, thin-set method. Recently, they have issued specifications of epoxies, latex, and conductive terrazzo. We use these references extensively.

Our office is now revising our guide specifications for floor coating systems. There are no Federal Specifications out which meet our requirements for various types of applications. What we are doing is setting up a schedule for various types of floor finishes with the generic terms describing them and the use function. For example, we get into such things as animal rooms, corridors, cage washing areas, laboratories of all types, mortuaries, prom decks, where we want certain types of flooring. In spite of what the sales promotion literature of the manufacturers tell you, one type of flooring will not suit every condition.

In talking to various testing laboratories and manufacturers, we are setting up a schedule which we will eventually expand into a guide specification as to the finish by designation, the generic terms, the uses, and the materials and performance specifications, using ASTM testing wherever possible. We have developed a specification of free access floor systems or pedestal flooring. I mention this even though it isn't flooring per se. You get various flooring materials over these. In the past, vinyl tile was the way to go. We have come to the conclusion that vinyl asbestos tile suits our purpose and it is more economical. There are 2 X 2 foot panels of other materials available from several manufacturers. These are more expensive but will eventually go down in price and are worth the maintenance saved. We could forsake initial construction cost and go into these types and would save quite a bit of money.

The subject of carpeting has been studied a lot lately, and I feel that we have had enough of it. We use Federal Specification DDD-C-95 as a reference and modify it. The trend in our medical facilities is to use more carpeting than before in corridors, non-medical areas, visitors areas, patient's rooms, entrances, etc. It has a definite place in our medical facilities, as a hospital or research building. We will probably use more of it as we go along. In any specification, a key point is no matter how good the specification is, it must be enforced. We enforce our specifications by testing procedures, independent laboratory testing, not testing in a manufacturer's laboratory. We have our own check of testing from NBS sources. We have our own independent laboratory back-up test. We go for certification on testing; we ask for samples, shop runs. We do not have the inspection staff that other agencies do, so we ask GSA or some other agency to inspect for us.

MR. WOLFE: How about performance specifications?

MR. KATZ: In new construction, the specifications should be much tighter than in maintenance and repair. Performance specifications depends on test development.

QUESTION: Is the factory finish merely a release agent to keep the tiles from sticking together and which comes off?

MR. KATZ: No, the manufacturers say that this is a beautiful coating which will last forever. I would welcome field waxing of tiles after construction but the manufacturers and Federal Specifications will not back you up on this.

Maintenance of Floors in Veterans Administration Hospitals

by

Mortimer Russell, Chief, Housekeeping, Division of Building Management
U.S. Veterans Administration

Let's go back to maintenance. Given the best specifications and enforcement, poor maintenance can ruin anything on the floor. Anyone who has been in this field long enough knows his specifications. A little background on the Veterans Adminsitration. I am with the Building Management Service - or Housekeeping. The Veterans Administration has a system of 166 hospitals in every state, varying in age from the early 1900's to 1969. The kind of dirt that comes into these hospitals is anything from ashes to cow dung. The accent of the maintenance is on sanitation first, as we deal with a medical environment. Aside from being sanitary, the environment must also be safe and aesthetically pleasant. These are the three qualifications. However, hospitals are not designed with housekeeping or environmental health factors in mind. Environmental health factors are what we have been talking about today and these include all kinds of pollution, including noise, static, slip resistance, etc.

We have all kinds of floors from wood to vinyl asbestos tile and these are in different areas, according to a schedule of floor finishes - mandatory for new construction - with some deviations. Each area has a certain prescribed floor finish. The main problem in maintenance is that we do wet cleaning because this is the way of getting rid of the bacteria - using detergents and disinfectants. Detergents and disinfectants have an effect on all kinds of flooring and whatever else you put on the floor, i.e., the finish. So this is one of our main problems. Now we have to stick with wet cleaning until we have evidence that there are other ways of killing bacteria. Maybe in the future there will be- maybe ultrasonics- or some other method. Now, in addition to using just plain wet cleaning, in an operating room, for example, we go even further;

it is almost flooding. If you use a lot of water, no matter how well the flooring is installed, you are going to have problems. The tiles come up and if you don't use the right detergent it affects conductivity. These are some more of our problems. It's not so much the flooring material as the supply, methods, and people that do the work that causes problems. Regarding supplies, we use, as the others mentioned, polymer finishes. Fortunately, there are many polymer finishes on the market, most of which are unsatisfactory. In addition, the whole subject is getting very confused. In trying to compete with carpets, I think the industry that makes finishes is trying to cut out some of the products that they formerly recommended. You now hear something like "You don't need sealers any more", "Just put down so many coats of finishes and that will do the trick". But we don't know whether this is the answer and we have to try it.

We have other problems with floors. There are in many hospitals roaches and other types of pests. Don't tell me pests shouldn't be in hospitals; they are. In order to take care of pests, you have to apply pesticides. Pesticides should be applied to the baseboard without hitting the tile. If these pesticides arenot properly applied, a lot of tile adjacent to the baseboard is ruined. So this is another aspect of our operations.

We do a lot of testing of all kinds of supplies and equipment and we have the facilities to do this but the results that we get are often very conflicting and you really can't do testing by mail.

It doesn't work for the central office to have people out in the field do it even if we have the protocol for testing, because what happens is that you try to lead your own office and the results you get can be entirely different. I am very critical of all testing unless I am right on the spot.

We allow carpeting only in certain areas according to use, mostly administrative areas at the present time. We don't have enough information on that subject and what information we have is very confusing. Take the bacteriology, for example. The people at PHS who are administering the Hill-Burton Act say we don't have to be concerned about it but recently two reports came out that said we were to be concerned about it. There are too many opinions on this subject and not enough correct opinions based on fact.

Concerning flammability, we are going along with the pill test at the present time but are taking a good look at ASTM E-84. Under consideration is a test of carpeting for our system before we put in any more. The problem we have had with carpeting is that they bought poor quality carpeting and by poor quality I mean indoor-outdoor carpeting. According to our experience, this does not belong in hospitals. You can do all the testing you want up here but nothing you do in testing indoor-outdoor carpeting matches what happens out there. You just can't get gum out of it and you can't clean that stuff when it gets good and dirty. It makes an awful traffic pattern. We've had trouble with carpet impregnated with stainless steel to prevent static. It works for a while, then the static comes back - so much so that the company gave us a refund on what they put down. So that's admitting something, isn't it. Now we have another little quirk: our patients like to throw cigarette butts on the floor, whether it's carpet or not; it doesn;t matter. This is a major problem. It's quite a job to prevent neuropsychiatric patients from smoking. These are some of the peculiar problems we've had.

I'm going to talk about the maintenance part now. For example, we are testing various types of seamless floors or poured floors. There are several different types but there is one we are studying right now. We have had varying success with poured floors and maintenance problems. Sometimes mops tear on the chips that are used in seamless floors. In other cases you find breakthroughs, in other cases stains and other problems. Some seamless floors are very good but expensive to install. An example of a new floor system is an acrylic panel which requires no finish. The product comes as tiles, which must be well installed over a very good subfloor, otherwise there will be trouble. We have a number of installations with this product. We did have trouble with one installation that did not have a good subfloor. If the subfloor is alright, then it's a pretty good thing so far. I don't swear by it yet; I haven't seen it.

MR. WOLFE: We have been testing this acrylic tile on access panels. Of course, I know it's very rigid and probably the reason why you need a good subfloor is because it must be perfectly level, as the tile won't conform.

MR. RUSSELL: Right.

MR. WOLFE: Also, it has pressure sensitive adhesive; it is self-sticking.

MR. RUSSELL: There is also a problem with a grouting. This has to be put down with a grouting and they haven't perfected the grouting. It collects quite a bit of dirt in heavy traffic areas, so that it isn't a seamless type.

MR. WOLFE: I have also heard about the problem with stainless steel fibers in carpet due to the steel fibers breaking and thus breaking the electrical continuity.

MR. RUSSELL: On the other hand, we have installations where copper is used in place of stainless steel and these work out alright so far.

QUESTION: In reference to all the studies and statements you made earlier about shortage of help, you have so many products that you h ave to work with in order to maintain and keep your costs down, has anybody ever considered upgrading the type of employee that would do this type of work? Basically, whether you like it or not, a person has certain shortcomings and might not accept the responsibility of the work that is required and what would happen in the long run. If you pay a person, say $1.50 an hour, you get $1.50 worth of work, regardless of the supervisor. This is pertinent to your remark about no matter how good the product is, if you don't have proper maintenance, you will be in trouble.

MR. RUSSELL: Well, you're absolutely right, but don't forget, we have a certain amount of money and we have to apportion it in the proper place.

REPLY: This is what we are talking about. You pay a technician or engineer X amount of dollars and you're training him to do certain things but you say that you don't need to pay the maintenance man a certain amount of money so that he can be responsible because maintenance is the greater portion of all the money that you're talking about. We concern ourselves with the initial cost but we're trying to design something that we can keep with lower maintrnance cost and the personnel working on this is one of the major problems with this thing.

MR. RUSSELL: That's true and that's common sense but common sense is not so common.

MR. SPENCE: I think it's going to be worse in a year or two; they are downgrading all our people one grade. You mentioned indoor-outdoor carpet. Are you using that as a trade name or a blanket term? We are having success with a carpet that can be used indoor-outdoor.

MR. RUSSELL: There was one original product of this type but now I don't know what it is.

MR. WOLFE: Was the carpet you referred to needlepunch or felt-like polypropylene?

MR. RUSSELL. Yes. Two persons reported success with antistatic sprays for carpet, which lasted about a year.

3. FIELD STUDIES OF FLOORING

Observations of the performance of floor coverings were continued along lines reported previously [1/]. In addition, field tests were initiated in which conditions were controlled as far as practicable. Information on the flooring installations in the article [1/] was inperfect and conditions are not well defined or controlled. Therefore, it was difficult to draw conclusions about performance of floor coverings. The value of field observations and field tests is twofold. First, they provide a direct evaluation of the floor coverings under observation. Second, they provide us with valuable background information and experience for future evaluations. This background may be utilized for a judgment type evaluation, as in deciding whether proposed flooring systems meet the Design Criteria for OPERATION BREAKTHROUGH. Field background is also valuable in developing bench or laboratory performance tests, which provide a more objective and unbiased method of evaluation than expert judgment. Such tests must be validated by correlations between laboratory results and performance under service or field conditions.

In this report, a distinction is made between field observations and field tests. By field observations is meant observations of flooring installations done commercially and not under control

1/ Winthrop C. Wolfe, "Field Study of Floor Coverings", FLOORING, Vol. 74, No. 11, 52-58 (November, 1968).

by the Building Research Division (BRD). In most cases, such observations are sporadic, not systematic, and do not include the actual installation. Most of the information is second hand and is obtained from contractors, workmen, materials suppliers, and personnel on the military base or wherever else the flooring was installed. Field tests, on the other hand are installations or tests on installations performed by the staff of BRD or under close supervision, where materials and workmanship are under control. Pertinent conditions, such as temperature, humidity, ground moisture, subfloor, etc. are known and recorded. Information about performance is obtained by first hand observation by BRD staff.

3.1 FIELD OBSERVATIONS

3.1.1 Further observations on field studies reported in FLOORING magazine, November, 1968.

EPOXY COATINGS

(b) TROWEL-ON INDUSTRIAL TYPE

FAILURE: previously reported as FAIRLY SATISFACTORY

WALK RAMP OUTSIDE COMMISSARY, 1967, No. 48. Only a little of the coating was left and most of the loose material was removed after two years' service.

POLYESTER COATINGS

(b) THIN-SET TERRAZZO

FAILURE: previously reported as NEW INSTALLATION

AIRLINE TERMINAL, 1968, No. 62. Cracks all the way across the lobby and walkway in a number of places. In some places the floor bulged or humped at the crack, indicating a structural or shrinkage problem. There are not many expansion joints and divider strips were placed at irregular intervals.

POLYURETHANE COATINGS

(a) BRUSH-ON OR ROLL-ON TYPE

FAIRLY SATISFACTORY

FIRE STATION, 1966-1967, No. 49. Most of the coating was in satisfactory condition after three years' service, with the addition of one glaze coat. In the area with floor drain, where fire hoses are hung, chips were knocked out by the fire hoses. This area, the area under the first truck, and the area near the back door, were refinished due to lack of bond. There is some scuffing and some chipped places. However, a painted floor would need repainting about every six months, which is expensive and shuts down operations.

SATISFACTORY

RESIDENCES-KITCHENS AND LIVING QUARTERS (2), 1966-1967, Nos. 52, 53. The polyurethane clear glaze on the wooden floors in both homes was in excellent condition after three years' service, with no yellowing or darkening and without refinishing. The brush-on decorative coating in No. 52 kitchen was in excellent condition except for separation around the edges against the painted wooden molding, to which the bond was poor. The kitchen in No. 53 showed some scratch marks and dirt and the occupant complained about difficulty in cleaning. However the appearance was fair to good. The surface was pebbled and also scouring powder had been used to clean the floor, both of which might account for difficulty in cleaning; scouring powder would cause scratches. Both kitchen floors had been in service for three years.

FAILURE: previously SATISFACTORY

STAIRS OUTSIDE BARRACKS, 1966-1967, No. 47. After three years' service the coating was badly worn all over.

CONCRETE FLOOR TOPPINGS BASED ON PORTLAND CEMENT AND ADDITIVES

(c) ASPHALT ADDITIVE

FAILURE: previously SATISFACTORY

PLUMBING SHOP, 1964-1966, No. 46. The general appearance was poor, with long cracks and gouges. When wet, workmen track in black marks into the office and locker rooms. The topping softens and turns black due to oil spillage. The original concrete floor had gouges which could not be repaired satisfactorily because the patches would not adhere. Adhesion of the present topping, however, is satisfactory.

3.1.2 Other field observations

3.1.2.1 ARMY MESS HALL KITCHENS - CONCRETE FLOORS - TEMPERATURES AND GREASE PENETRATION

There have been reports of monolithic floor failures due to temperature or temperature gradient underneath and near ranges and hot water heaters in Army mess hall kitchens. Accordingly, some measurements were made at Fort Belvoir, Virginia and Fort George G. Meade, Maryland, using a portable pyrometer and an iron-constantan thermocouple. Readings were taken under 13 ranges, a grille, 5 hot water heaters, and 2 bake ovens in 9 kitchens, eight in mobilization type company mess halls and one in a permanent consolidated mess hall. Temperatures under the equipment in degrees Fahrenheit in ascending order are as follows:

Ranges: 75, 75, 75, 80, 80, 85, 90, 95, 95, 100, 100, 125-130

Bake Ovens: 75, 95

Grille: 80

Hot Water Heaters: 75, 75, 95, 115, 145

Most of these temperatures are not high enough to cause trouble but continued exposure to temperatures of 130°F or 145°F might have an effect on some resin toppings.

It seems very likely that some cases of bond failures of monolithic surfacings in mess hall kitchens might be due to cooking grease which soaked into the concrete surface and was not removed before resurfacing. Experiments with cement mortar panels in our laboratories have shown that hot lard will penetrate up to 1/8-inch and test panels have soaked up as much as the equivalent of a pound of lard to 6 square feet of floor area. Tests were performed on concrete floors in five mess hall kitchens at Fort Belvoir, Virginia and Fort Meade, Maryland. In these tests, holes in the floors were dug to a depth of about 1/4-inch with a cold chisel and the hole, in each case, flooded with a one percent solution of Congo Red in water, then immediately rinsed with water. The greasy area appeared gray and the uncontaminated concrete underneath was dyed red. Grease penetration was estimated as 1/32, 1/16,

on the underside of the tiles which were removed and pieces of hardboard fiber were removed when the tile was pulled up. The superintendent said that the adhesive was asphalt emulsion. The trouble appeared to be caused by poor quality underlayment and calking and poor workmanship in installation.

3.1.2.3 ANIMAL CAGES - MONOLITHIC SURFACINGS AND RESILIENT FLOOR COVERINGS

3.1.2.3.1 PRIMATE CAGES IN ZOO, 1968-1970.

BRUSH-ON EPOXY COATING, No. 2, installed March, 1968.

After 2 1/2-years service was dirty and stained; coating had peeled off in several places.

TROWEL-ON EPOXY SURFACINGS, Nos. 7, 8; installed March, 1968.

After 2 1/2-years service, badly stained a brownish yellow and hard to clean but no bond failure.

TROWEL-ON EPOXY with urethane color coat, No. 9; installed June, 1968.

After two years service, fairly clean but badly peeled in large area.

TROWEL-ON EPOXY, exposed aggregate, No. 11; installed April, 1969.

After five months service, in excellent condition and easy to clean by hosing with water.

TROWEL-ON POLYESTER, ACRYLIC SEAL, No. 3; installed May, 1968.

Rough and dirty appearance but no bond failure.

TROWEL-ON VINYL-ACRYLIC, URETHANE GLAZE COAT, No. 5, Installed March, 1968.

Bond still good; can be cleaned but difficult to clean.

TROWEL-ON PORTLAND CEMENT - ACRYLIC LATEX TOPPING, No. 6, installed February, 1968.

Floor in good condition and easy to clean.

TROWEL-ON ALUMINA CEMENT - NEOPRENE LATEX TOPPING, No. 1, installed March, 1968

Badly stained and dirty; poor bond; large bare place in back of cage.

3.1.2.3.2 EXPERIMENTAL DOG KENNELS, GOVERNMENT - BRUSH-ON CLEAR EPOXY, 1969-1970

Cement terrazzo floor, installed in 1954, had eroded from dog urine, leaving exposed marble chips. The purpose of resurfacing was to smooth the floor for sanitation purposes and to protect the floor from urine, feces, etc. The floors were patched with an epoxy composition and the rough areas ground with a rough terrazzo grinder. The floors were then acid etched and rinsed with water. A clear epoxy brush-on coating was applied in two coats; total dry thickness was about 15 mils. The thickness was determined by micrometer measurement of a piece which had peeled off. The job was completed October 20, 1969. There is a circular floor drain in each cage, which is hosed down daily. After ten months, the coating was satisfactory in about two-thirds of the cages but there were problems in the other third. Some of the floors stained badly from the dog urine, while others were blistered and some peeled badly. The blisters were about the size of a quarter and there appeared to be a liquid underneath. The bond was tested in two cages which had not been used and in which the coating was intact. Even though intact, the coating could be peeled off with a knife and impact, as with a hammer, caused an opaque appearance and bond failure. Quantitative bond tests were performed, using the so-called "Pipe Cap Bond Test", developed by Mr. C. V. Wittenwyler of Shell Chemical Company and Chairman of ASTM Committee C-3 on Chemical-Resistant Nonmetallic Materials. Monolithic Surfacings is the subject of Subcommittee S-4 of the C-3 Committee. The test is described in this report under 4. Bonding of Monolithic Surfacings. A test in one cage resulted in bond failure at a stress of 167 psi, while a test in another cage showed failure at 132 psi. In several other tests, the epoxy cement failed at about 170 psi without bond failure. The results of these tests indicate good bond by straight-pull test but poor peeling strength. It would seem that the coating is successful as long as it is unbroken but a tear, gouge, or scratch can easily destroy the bond and cause the coating to peel off. This could easily result from a combination of dog scratching and penetration of water underneath the coating.

A test was performed on the floor of each cage to measure the amount of water vapor emmission through the cement terrazzo floor. This test is described in the MANUAL FOR THE PREPARATION OF SUBFLOORS FOR THE INSTALLATION OF SOLID VINYL AND RUBBER FLOORING, 2nd ed., FSF-593, Vinyl and Rubber Flooring Division, The Rubber Manufacturers Association, Inc., 444 Madison Avenue, New York, New York, 10022, 1963, AIA No. 23-T. On page 5 of the MANUAL it is stated that: "The moisture specification shall be that the emission of moisture vapor from the floor shall not be more than 3 (three) pounds per 1,000 square feet per 24 hours." The Vinyl and Rubber Flooring Division had been discontinued and test kits for the moisture test are available from National Testing Laboratories, Inc., 27-14 39th Avenue, Long Island City, New York 11101. The test unit consists of:

(1) A cylindrical plastic box about 1 inch high and 2 1/2-inches in diameter, containing about 11 grams of 8-mesh anhydrous calcium chloride, sealed with masking tape and enclosed in a sealed plastic bag.

(2) A transparent plastic cover with 1/2-inch flange, measuring inside 7- 1/4 X 9- 1/2-inches, about 1 1/4 inches high.

(3) Sealant to secure and seal the cover to the concrete floor. The cylindrical box, for each test, was weighed; the epoxy coating was scraped from the floor in an area sufficient to receive the plastic cover; the cylindrical box was opened and the top and masking tape placed beside it and the cover was quickly placed over these items. The assembly was left in place for 75 hours.

The quantitative requirement of not more than 3 pounds per 1,000 square feet moisture vapor emission is repeated on the first page of the instructions with the MOISTURE TEST UNIT. Also repeated is the qualitative requirement stated in the Rubber Manufacturers Association MANUAL that "A small amount of moisture will cause the calcium chloride to cake or darken. More moisture will cause drops to form on the calcium chloride and in severe case, the calcium chloride will disolve. If there is no sign of moisture - no visible change in the calcium chloride after the test is completed, the concrete floor will be considered to have met the specification." In the instructions but not in the MANUAL it is stated after directions for the quantitative test that "In areas 2,000 square feet or less a minimum of 3 tests shall be made, and for each additional 1,000 square feet one additional test shall be made. These tests should be made simultaneously and the test units should not be concentrated but should be located in various parts of the floor area. One unit should be placed near the center and others should be placed in edge areas but no closer than 5 feet from the edge".

Each kennel was only 4 ft. 7 in. wide and 12 ft. 8 in. long, so this requirement was impracticable. Only one test was performed in each cage and this was quantitative. After 75 hours exposure the calcium chloride in both containers was caked. The gain in weight corresponding to moisture in the unit in cage No. 119 was 7.064 g./o.478 sq. ft./75 hours, which corresponds to a gain of 10.4 lbs/ 1,000 sq. ft./24 hours. The gain in weight in the unit in cage No. 120 was 5.009 g./o.478 sq. ft./75 hours, which corresponds to a gain of 7.38 lbs./1,000 sq. ft./24 hours.

From the test it appears that two or three times as much moisture vapor is being emitted as should be for the minimum requirements for installation of solid vinyl flooring. The same would obviously apply for any impervious flooring. Unfortunately, no kind of moisture test was performed on the floor before installing the epoxy coating, according to Mr. Marshall White, Development Section, Research Facilities Planning Branch at the National Institutes of Health. Mr. White reported some studies in Report R-46 TESTS ON TILE-LIKE WALL COATINGS dated

September, 1966 for the National Institutes of Health of the Public Health Service, U. S. Department of Health, Education and Welfare. In these studies it was reported that epoxy and polyester coatings are not affected by moisture coming from underneath. However, this assumes good initial adhesion. It would have been advisable to have performed a test for moisture content as well as for moisture vapor emission. Moisture content can be measured conveniently by conductivity measurements, using special probes.

3.1.2.3.3 EXPERIMENTAL DOG KENNELS, PRIVATE - TROWEL-ON EPOXY, URETHANE GLAZE COAT, 1970

A trowel-on marbleized epoxy coating with urethane glaze was applied April, 1970 to a concrete slab on grade. The dog cages were off the floor, so that at least part of the urine and feces are probably caught before falling on the floor. Drains run the width of the floor. Cages are hosed down daily. The floor was in perfect condition with no bond failure after 4 months service.

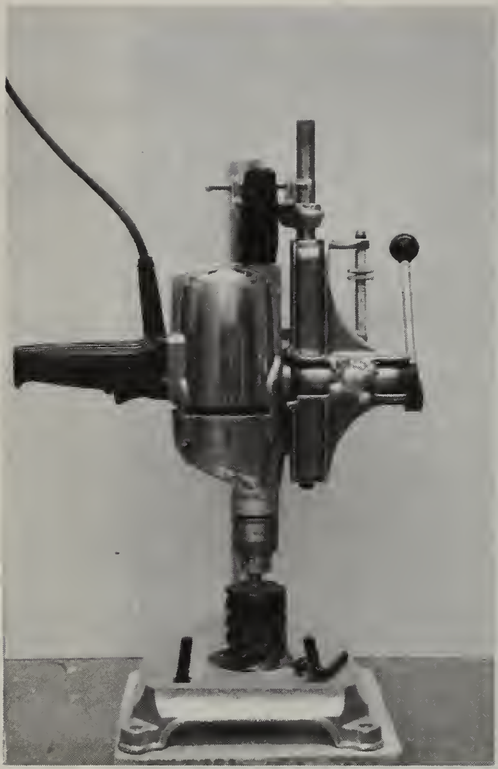
3.1.2.4 CARPET INSTALLATIONS - CASE HISTORIES

While most of these are private installations, observations can be applied to such government installations as Veterans Administration and military hospitals, commissaries, office buildings, and barracks.

3.1.2.4.1 SUBURBAN PRIVATE HOSPITAL, 1966-1969.

A commercial low-level loop pile commercial carpet with sponge rubber back was installed in the coronary care unit, an area which has relatively little traffic and spillage. The head nurse said that the

Moisture Test Unit on Floor of Dog Kennel, 3.1.2.3.2



Coring Equipment

Test Equipment

Pipe Cap Bond Test

carpet was much more comfortable and less noisy than resilient tile. She had no difficulty in moving beds or other wheeled equipment. After six months service, the carpet appeared clean and had been vacuumed only, not shampooed. After two years the coronary care unit was transferred and the carpet was removed. The new location of the coronary care unit and also the nurse's station was covered with another type of carpet, cemented down without backing. Some of the cement was spilled on the face and could not be removed without changing color. Also, the carpet soiled easily and there were some dark spots, a white stain, and a coffee stain in the nurse's station. On other floor, a rubber backed carpet in the nurse's station delaminated from the sponge rubber backing and also wrinkled. The same type of carpet had been installed in the business office and this delaminated after two years' service and appeared dirty.

3.1.2.4.2 CITY PRIVATE HOSPITAL, 1969-1970.

The carpet was installed February 1969 throughout an entire medical-surgical nursing unit with considerable spillage and problems with body wastes. This carpet was a medium level looped pile acrylic type with double polypropylene backing, wall to wall, cemented to the floor without cushion. According to our measurements, the pile height is 0.219 inch, total thickness 0.365 inch, weight of yarn is 58.9 ounces per square yard. Tests performed by the Flammable Fabrics Section indicated that the carpet passed the U. S. Department of Commerce Proposed Flammability Standard. Acoustics tests by the Building Research Division, before and after installation, showed reduction in noise level but it has not been established that this noise level reduction is significant. About two weeks before the installation, the Building Research Division recorded temperature and humidity continuously for a week, checking periodically with a wet and dry bulb sling psychrometer. The temperature and humidity varied somewhat but the temperature was about 75-80 deg. F and the relative humidity about 20-30 percent. In spite of the low humidity there have been no complaints about static charge from the carpet.

According to the maintenance staff at the hospital, the maintenance time and cost is about the same as for smooth surface resilient tile. The carpet is shampooed about every three months and vacuumed every day. Patient's rooms are shampooed after check-out. We have observed the installation periodically and appearance during the 1 1/2 year service period is fair to good. It is obvious from our observations that extensive spotting is necessary, even in the corridors, and there are numerous stains in the corridors from coffee, soft drinks, etc. but these are not very noticeable. There are noticeable stains in the patient's rooms and also cigarette burns, so that a number of repairs have been made by cutting out circular sections and cementing patches. The carpet appears a little matted and the pile needs brushing at intervals. The overall impression is that the carpet is satisfactory for corridors but not for patients' rooms and bathrooms.

3.1.2.4.3 URBAN SUPERMARKET, 1967-1970.

A sponge rubber cushioned, low-level looped pile nylon carpet was installed March 1967. The manufacturer's specifications were: 22-ounce, 10-wire, 100 percent continuous filament nylon face; 3/8 inch sponge rubber cushion cemented to the carpet. The carpet appears firm and food carts can be pushed over it readily but with somewhat more difficulty than over resilient tile. A few weeks after installation, there were black spots around the vegetable and meat counters, black streaks near the dairy counter, and a bad gouge near the entrance to the storeroom. The carpet is vacuumed every day and spotted frequently with a special detergent solution. A year after installation the appearance deteriorated markedly except around the check-out counter and the manager said that the cost of adequate cleaning and spotting was prohibitive. After three years the carpet in the worst areas around the vegetable bins, meat, and seafood counters, was replaced with the same type of carpet but different color. After this period the original carpet around the check-out areas was noticeably worn and the original carpet in the rest of the store continued to deteriorate gradually.

3.1.2.4.4 PRIVATE OFFICE BUILDING - CORRIDORS, 1966-1970.

A sponge rubber backed low-level looped pile woven nylon carpet was installed in the corridors of a 12-story office building in 1966 over resilient tile. In 1967 the carpet was in good condition except for some black heel marks in various locations and loose carpet and a tear on the 12th floor. The chief troubles were with adhesion and seams. Scrubbing tends to open the seams. Sponge rubber cannot be obtained in more than 54-inch width, so there are more seams than there would be with broadloom carpet. In 1970 the carpet was still in good condition, clean without stains. However, some areas appear patched and there is a split seam on the 12th floor, showing the sponge rubber cushion underneath. The corridors are vacuumed every night and spot cleaned with perchloroethylene but not shampooed.

3.1.2.4.5 ARMY BARRACKS, 1968-1970, WOVEN LOOPED PILE WOOL WITHOUT CUSHION

Lobby of men's barracks. Some problems initially with fuzzing but appears satisfactory after two years's service. Carpet is vacuumed daily but not shampooed. There are few cigarette burns and some depressions due to uneven pad underneath.

Lobby of women's barracks. Condition good after two years' service except for a number of stains. The carpet needs shampooing and spotting.

Day-room, women's barracks. A number of cigarette burns were noted after one year service but otherwise the carpet was in good condition. After two years' service the carpet appeared much dirtier, with a number of stains and cigarette burns but was otherwise in good condition. The carpet needs shampooing and spotting.

3.2 FIELD TESTS

3.2.1 ARMY BARRACKS CORRIDOR - BRUSH-ON COATINGS AND ABRASIVE SHEET VINYL, 1969-1970

Two brush-on monolithic surfacings and abrasive sheet vinyl were tested in the northeast corridor of Building 8543, Fort George G. Meade, Maryland. The corridor, about 10 feet long and 6 feet wide, runs from the outside door to the main corridor in front of the orderly room. The building is used as a training barracks by the Sixth Armored Cavalry. The corridor received heavy foot traffic, considerable dirt; and maintenance is minimal. In January, 1969 the corridor was cleaned thoroughly with alkaline detergent and rinsed with water. A commercial decorative brush-on coating system was then applied. The sealer, applied to the concrete floor, was a polyvinyl acetate emulsion. After this coat had dried, a "wet coat" of acrylic lacquer was brushed on. This was a solution in organic solvent of a blend of polymethyl methacrylate and polycyclohexyl methacrylate. While the "wet coat" was still wet, colored vinyl chips were sprinkled over the lacquer to cover the surface. After the lacquer dried, the floor was swept free of loose vinyl chips and a second "wet coat" was brushed on. After this coat had dried, the floor was swept again and a third "wet coat" applied by brush. The next day the floor was sanded lightly and a final coat of acrylic lacquer was brushed on. After seven months, in August, 1969, the coating was worn through in a number of places but the bond was still good. There was overall pitting, probably due to the vinyl chips being pulled out.

After one year service, late December 1969, the acrylic decorative coating was worn through and the floor was gritty and dirty. The floor was cleaned thoroughly with alkaline detergent, rinsed with clear water, and sanded lightly. After sweeping, the entrance way from the outside door to about 4 feet inside the corridor was covered with abrasive sheet vinyl using latex adhesive. This product is 0.100 inch thick, comes in rolls 6 feet wide, and consists of about 25 percent aluminum oxide abrasive in a matrix of a vinyl composition which consists of about 70 percent vinyl resin and 30 percent plasticizer. The remaining area, about 6 feet square, was covered with a brush-on epoxy coating. The epoxy coating was brushed on in 2-foot wide strips and fine colored mineral aggregate was sprinkled over the wet barrier coat, covering the same. The next day the surface was swept and sanded lightly. After sweeping again the surface was coated with two applications of clear polyurethane glaze. After seven months service, late July 1970, the abrasive sheet vinyl was dirty, damaged somewhat by cigarette burns, and disfigured with chewing gum but had a fairly good overall appearance, was not worn or scratched, and adhesion was good. The epoxy topping was dirty and stained but not worn appreciably.

3.2.2 ARMY COMMISSARY - ACRYLIC EMULSION, ABRASIVE SHEET VINYL, 1969-1970

The commissary is a converted warehouse in Cameron Station, Alexandria, Virginia. The sales area is covered with 35,175 square feet of vinyl asbestos tile, damaged by fork lift trucks which move merchandise from the receiving room to the sales area. The trucks leave black and scuffed skid marks on the tile. The tiles are worn out at the entrance to the sales area leading to the receiving room and loading platform. Some of the tile in the aisles of the sales area is gouged, dirty, scratched, and cannot be cleaned properly. The black marks can be removed with mineral spirits and steel wool but the gouges remain. An attempt was made to restore and protect an area in one of the aisles of the sales area with three coats of acrylic emulsion. The floor was cleaned carefully with alkaline detergent and rinsed with water before applying the finish. After a week the treated areas looked just as bad as the rest of the floor. Also, abrasive sheet vinyl, as described in 3.2.1 was laid in the entrance to the sales area leading to the receiving room. After a week the abrasive vinyl was torn, dirty, and scuffed. After scrubbing the abrasive vinyl with steel wool and mineral spirits, the dirt and black marks were removed but the surface was dull all over, torn, cracked in one place, and there were scuffed and "burned" places. The fork lift truck tires actually "burn" or melt places in the vinyl material.

3.2.3 COMPUTER ACCESS FLOORS, 1967-1970.

The original 2-foot square access panels, covered with 12-inch square vinyl tile, were installed in May, 1967. After two years service, the tile appeared scratched and scuffed and was somewhat hard to clean. Experimental floor coverings were installed during 1969-1970 on panels behind the counter and swinging doors, where foot traffic is heaviest.

	Floor Covering	Installation Date
A.	Original vinyl tile, as Type III, Fed. Spec. SS-T-312	May, 1967
B.	Laminated resin tile with melamine-formaldehyde resin wearing surface	August, 1969

	Floor Covering	Installation Date
C.	Polyester terrazzo tile with marble chips	August, 1969
D.	Conductive vinyl asbestos tile	July, 1970
E.	Acrylic resin tile with fine mineral aggregate	May, 1970

Appearance of Floor Coverings, September, 1970

Floor Covering	Service Period	Appearance at Eye Level	Close-up Appearance
A	3 years	Numerous scratches & scuffs	Numerous scratches & scuffs
B	1 year	Shiny & Clean	A number of fine scratches all over
C	1 year	Shiny & Clean	A few scratches, hard to see
D	6 weeks	Numerous scratches & scuffs	Numerous scratches & scuffs
E	5 months	A few scuffs	A few scuffs

4. OVERLAYS FOR CONTAMINATED CONCRETE FLOORS

As pointed out in Part 3. FIELD STUDIES OF FLOORING, failure of monolithic surfacings in military mess hall kitchens and meat cutting plants have often been attributed to the presence of grease on the concrete substrate. In the field observations on mess hall kitchens in section 3.1.2.1, it was shown that grease may penetrate concrete floors in mess hall kitchens as far as 1/4 inch. The test used to determine grease penetration in mess hall kitchen floors was developed in our laboratories.

A cement mortar panel, 10 inches square and 1 inch thick, was rubbed with fresh lard, using a clean cloth every few days over a period of three weeks. Some one-inch cores were cut out of the treated panel, using a diamond core bit, fed with water, and a drill press. One of the cores was immersed in a solution of one (1) percent Congo Red dye in water for 10 seconds. The core was then rinsed with tap water. The untreated concrete was dyed red and the upper part of the core, about 1/16 inch thick, was gray, not being wet by the aqueous dye solution. A hole was chiseled in the surface of the treated panel with a cold chisel and hammer. The dye solution was poured into the hole, then removed by rinsing with water. Again the untreated cement mortar was dyed red and the greasy upper portion was gray. This procedure was used to test mess hall kitchen floors for grease penetration.

Experiments with cement mortar panels in the laboratory showed that hot lard will penetrate up to 1/8 inch and test panels soaked up as much as the equivalent of a pound of lard to approximately 6 square feet of floor area. (See Note 1, Tables 2 & 4). Paraffin oil or mineral oil penetrated up to 3/8 inch and the test panel soaked up the equivalent of about a gallon to 13 square feet of floor area. Such large amounts of fats, oils and grease on the floor would undoubtedly require removal of the slab unless some topping system or overlay could be found which was compatible with the oily or greasy material. It is very likely that if only surface contamination were removed, the oily material under the surface would "wick up" or penetrate into adhesives or toppings and cause softening and poor bond.

Attempts were made to remove lard from cement mortar panels which had been deeply impregnated with this material. The contaminated panels were washed with hot detergent solution, 10 percent sodium hydroxide solution, trichloroethylene, and combinations of these treatments. None of the treatments were successful in removing even surface contamination. The cleaned panels were not wet with the aqueous dye solution of one (1) percent Congo Red.

4.1 Experimental procedure

A number of laboratory experiments were performed on cement mortar cubes and panels with various overlay systems. The results are reported in Tables 1, 2, 3, and 4.

The tests with cement mortar cubes, reported in Tables 1 and 2, were performed using the technique described by Wolfe [1/]. Further details are found in the Footnotes in Table 1, The statistical analysis of data in Table 2 were performed with OMNITAB by Dr. David Hogben of the Statistical Engineering Section.

Tests with cement mortar panels, described in Tables 3 and 4 were performed by a modification of the pipe cap bond test developed by Mr. C. V. Wittenwyler, Shell Chemical Company, Plastics Technical Center, Post Office Box 700, Woodbury, New Jersey 08096, published as part of a report of Committee 403 of the American Concrete Institute [2/].

1/ Winthrop C. Wolfe, Bonding Adhesives and Paints to Treated Concrete, CSI Monograph 9M1, August 1966, reprinted from the Constr. Specifier, Vol. 19, No. 3, 30-35 (August 1966), The Constr. Specifications Inst., Inc., Wash., D.C. Also reported in NBS Tech Bulletin, Vol. 50, No. 4, pages 58-59, (April 1966)

2/ APPENDIX. FIELD TEST FOR SURFACE SOUNDNESS AND ADHESION, pgs. 1139-1141 of "Guide for Use of Epoxy Compounds with Concrete", Reported by ACI Committee 403, Title No. 59-43, Journal of the Amer. Con. Inst., Proceedings, Vol. 59, No. 9, 1121-1141 (September 1962).

The equipment for performing the test can be obtained from Custom Scientific Instruments, Inc., 13 Wing Drive, Whippany, New Jersey 07981, Model CS-173, Bond Strength Apparatus. This equipment was obtained for field tests but the actual measurements reported in Table 4 were made using a load-strain testing machine. In order to gain some idea of the accuracy and precision of field data, a trial calibration was made of the dynamometer suppled with the commercial kit for performing the field tests. The results are as follows:

Direction of Crosshead	Load cell reading	Dynamometer scale reading	Dynamometer Error
Raised (Increasing load)	200	187	-13
	300	285	-15
	400	378	-22
	500	473	-27
Lowered (Decreasing load)	400	385	-15
	300	295	-5
	200	196	-4
	100	97	-3
Raised (Increasing load)	100	93	-7
	200	192	-8
	300	292	-8
	400	382	-18
	500	477	-23
Lowered (Decreasing load)	400	397	-3
	300	304	+4
	200	204	+4
	100	104	+4

While the error may be as much as 27 lbs. and the dynamometer exhibits some hysteresis, it is not necessary to know the exact bond strength. The results in Table 2 indicate that it is necessary to perform a number of tests on the same floor, say 10 replicates, as the data show condiserable scatter.

Another modification of the pipe cap bond test, besides using a load-strain testing machine, was to core with a notched brass tube, 60-mesh carborundum abrasive, and water. Since this requires drying before cementing the pipe cap, it would not be suitable for field tests. Coring was done in a drill press instead of by means of the portable drill and stand used in the original method. For field trials, a 1/2 inch electric drill was secured to a portable stand, available commercially, with an aluminum base. A circular cut was made in the aluminum base with a hole saw to allow coring in the concrete floor. A commercial carbide coring bit was modified by cutting off, inserting a steel plug and a 1/2 inch shaft to fit into the electric drill.

4.2 Results of bond tests on laboratory specimens

From the laboratory experiments reported in Tables 1, 2, 3, and 4, it appears that the most reliable procedure is to coat the contaminated surface with a sealer or primer consisting of neoprene in hydrocarbon solvent.

According to the quantitative tests with cement mortar cubes, Table 1 and 2, epoxy monolithic surfacings over neoprene sealer bonded well whether the concrete was clean or greasy. Epoxy asphalt surfacing bonded fairly well over asphalt cutback primer with little difference between clean and greasy surfaces. The polyethylene-foil-paper sheet was not as effective a grease barrier as the neoprene sealer or asphalt primer. There is considerable spread in each series of ten tests, so the value of single bond tests is questionable.

Some single or duplicate tests were performed on overlays placed on cement mortar panels, recorded in Tables 3 and 4. The results were not very conclusive and did not always agree with the cement mortar cube tests in Tables 1 and 2. However, the neoprene sealer performed well except for the greasy panel with oil-modified epoxy mix (System D). Neoprene sealer was satisfactory with epoxy asphalt (System F) and with polyester (System G). Asphalt primer performed well with epoxy surfacing (System CB) but not on a greasy panel with epoxy asphalt (System C) or with oil-modified epoxy mix (System CA).

Table 1. Overlay Systems Tested [1/] on Cement Mortar Cubes [2/]

System	Description [3/]
A	Asphalt cutback adhesive [4,5/] - Polyethylene-foil-paper sheet [5,6/] Polyester sand mix [5,7/]
B	Asphalt cutback primer [5,8/] - Asphalt cutback adhesive [4,5/] - Polyethylene-foil-paper sheet [5,6/] - Polyester sand mix [5,7/]
C	Asphalt cutback primer [5,8/] - Epoxy primer [5,9/] - Epoxy asphalt sand mix [5,10/] - Epoxy primer [5,9/]
D	Neoprene sealer [5,11/] - Oil-modified epoxy sand mix [5,12/]
E	Neoprene sealer [5,11/] - Epoxy sand mix [5,13/]

Footnotes to Table 1

1. Overlay systems, which are intended to be used as coatings or toppings for concrete, were tested by making a sandwich between a cement mortar cube and a wooden cube. The system or treatment was applied to the top or troweled surface of the cement mortar cube and the wooden cube was cemented to the upper surface of the overlay system. Usually this was accomplished by pressing the wooden cube into the wet resin mix. In System C, an epoxy primer was added to the overlay and the wooden cube pressed on the wet primer.

2. Specimens for this series of tests were 2-inch cement mortar cubes, cast in modified "Bowen Expansible Cube Molds", U. S. Patent 2,061,137, Bowen and Company, Inc., Bethesda, Maryland. The molds were modified by drilling holes, 17/64 inch in diameter, in a position such that the three completed cubes from each mold would each have a 1/4 inch diameter steel pin through the center of two faces adjacent to the top or troweled surface under test. The pins were inserted through the drilled holes before casting the cement mortar cubes. The cubes were cast according to ASTM C-109 except that a mixture of standard 20-30 and standard graded Ottawa sand was used in place of graded Ottawa sand. The wooden cubes were cut from wood to be 2 inches cube and then holes were drilled through centers of opposite sides for 1/4 inch steel pins, inserted into the holes.

3. Successive treatments were applied to the top or troweled surface of each cement mortar cube in order as described for each system. The first treatment was applied to the cement mortar cube and the last treatment served to cement the wooden cube to the overlay forming a sandwich.

4. Asphalt cutback or solvent type adhesive for asphalt and vinyl asbestos tile was applied with a notched trowel, used for installing tile. The adhesive used was Armstrong S-90, manufacturered and supplied through the courtesy of Armstrong Cork Company of Lancaster, Pennsylvania. See Note 5.

5. Certain commercial products are identified in this report in order to specify the experimental procedure adequately. In no case does such identification imply recommendation or endorsement by the National Bureau of Standards, nor does it imply that the material is necessarily the best available for the purpose.

6. The sheet was SANDURA MOISTURE SHIELD, manufactured and supplied through the courtesy of GAF Corporation, Floor Products Division, 1139 Lehigh Avenue, Whitehall, Pennsylvania 18052. See Note 5. According to the manufacturer, the sheet consists of a sandwich of 2 mils polyethylene, 0.00035-inch foil, and 30-lb. kraft paper. The polyethylene side of the sheet was placed on the asphalt cutback adhesive and the polyester sand mix placed on the upper kraft paper side.

7. The resin used was manufacturered and supplied through the courtesy of Koppers Company, Inc., Pittsburgh, Pennsylvania 15219. The polyester sand mix was made by combining

1,500 grams MARKAY COLORTUFF polyester resin (See Note 5)
25 mils catalyst for above
4,500 grams standard Ottawa sand
4,500 grams standard 20-30 Ottawa sand

in a mechanical mixer used for small batches of concrete. The mix was applied to the surface and troweled smooth with a mason's trowel.

8. Asphalt cutback or solvent type primer, used on porous or dusty underlayments or concrete before installing asphalt or vinyl asbestos tile, was applied by brush. The primer used was Armstrong S-80, manufactured and supplied through the courtesy of Armstrong Cork Company of Lancaster, Pennsylvania. See Note 5.

9. The primer was that supplied for the epoxy asphalt resin described in Note 10 and was applied by brush. Three parts by weight of primer was mixed with one part by weight of hardener. The product was yellow and apparently did not contain asphalt.

10. The resin and primer (Note 9) were manufactured and supplied through the courtesy of Atlas Minerals & Chemicals Division, ESB Inc., Mertztown, Pennsylvania 19539, under the trade name REZKLAD. See Note 5. The epoxy asphalt sand mix was made by combining

250 grams REZKLAD epoxy asphalt resin
250 grams hardener for same (which was black and apparently contained the asphalt)
2,250 grams standard Ottawa graded sand
2,250 grams standard 20-30 Ottawa sand

in a mechanical mixer used for small batches of concrete. The mix was applied to the surface and troweled smooth with a mason's trowel.

11. A neoprene in organic solvent coating was applied by brush. This product was distributed and supplied through the courtesy of Hercules Flooring Company, 247 West 16th Street, New York, New York 10011 and is sold under the trade name HERCULES OIL GARD. See Note 5.

12. The resin used was manufactured and supplied through the courtesy of Shell Oil Company, 50 West 50th Street, New York, New York 10020 under the trade name GUARDKOTE 250. See Note 5. This product is used in compositions for patching pavements and is used to repair highways and bridges. The oil-modified epoxy sand mix was made by combining

250 grams GUARDKOTE 250A
250 grams GUARDKOTE 250B
2,250 grams standard Ottawa graded sand
2,250 grams standard 20-30 Ottawa sand

in a mechanical mixer used for small batches of concrete. The mix was applied to the surface and troweled smooth with a mason's trowel.

13. The resin used was manufactured by Shell Chemical Company, Plastics and Resins Division, New York, New York under the trade name EPON. See Note 5. The epoxy sand mix was made by combining

670 grams epoxy resin EPON 828
330 grams V-25 hardener for same
4,500 grams standard Ottawa graded sand
4,500 grams standard 20-30 Ottawa sand

in a mechanical mixer used for small batches of concrete. The mix was applied to the surface and troweled smooth with a mason's trowel.

Table 2. Adhesion of Overlay Systems to Clean and Greasy [1] Cement Mortar Cubes

Data Group	System Table 1	Surface	No. of Tests	Tensile Bond Strength Average Maximum Stress $x10^3$ n/m^2	psi	Std. Dev. of Mean psi	F_{PROB} [2]
1	A	Clean	10	218.4	31.8	3.45	
2	A	Greasy	10	130.8	19.0	2.51	
1,2	A	Clean, Greasy					0.008
3	B	Clean	10	231.2	33.7	2.82	
4	B	Greasy	10	163.2	23.7	2.60	
3,4	B	Clean, Greasy					0.018
5	C	Clean	10	302.4	43.9	2.88	
6	C	Greasy	10	265.1	38.5	3.28	
5,6							0.232
7	D	Clean	10	554.8	80.3	6.88	
8	D	Greasy	10	505.4	73.4	4.29	
7,8	D						0.406
9	E	Clean	5	826.0	119.8	6.19	
10	E	Greasy	5	721.8	104.6	13.4	
9,10							0.333

1. Cement mortar cubes, prepared as in Note 2, Table 1, were cured under water for 28 days and dried at laboratory temperature and humidity. Owing to delays in the program, the cubes were stored for more than two years. "Clean" cubes were treated as in Note 3, Table 1. "Greasy" cubes were treated with a grease consisting of equal parts of lard, corn oil, and mineral oil, heated and stirred together. The mixture was applied while warm with a brush. This treatment was repeated three times, allowing the grease to soak in for several days after each treatment. Finally the surfaces were rubbed with a soft towel. The amount of grease soaked in was weighed and found to be the equivalent of one pound per 5.58 square feet of surface. Before treating further, the surfaces were cleaned with hot detergent solution. The detergent used

was Detergent, General Purpose, Federal Specification P-D-220A, Type 2, Class 1. One part of detergent was diluted with five parts of hot water; brushed on with a stiff brush; let stand for five minutes; scrubbed with a stiff brush; rinsed thoroughly with hot water. This cleaning treatment was repeated. The "greasy" cubes were treated as in Note 3, Table 1.

2. Probability of rejecting the hypothesis of equal means when, in fact, the means are equal and usual assumptions hold. This means that there is a significant difference between data groups 1 and 2 and between 3 and 4 but not between the other pairs of data. In other words, there is a significant difference in adhesion between clean and greasy specimens containing overlay systems A and B, so that the grease affected the bond significantly. With systems B, C, D and E the grease had no significant effect on the bond. This is a summary of OMNITAB results from Dr. Hogben.

Reference: David Hogben, S. T. Peary, and S. T. Varner, OMNITAB II User's Reference Manual, NBS Technical Note 552, U. S. Government Printing Office, Washington, D.C. 20402.

Table 3. Overlay Systems Tested on Cement Mortar Panels [1/]

System	Description
B[2]	Asphalt cutback primer - Asphalt cutback adhesive - Polyethylene-foil-paper sheet - Polyester sand mix
C[2]	Asphalt cutback primer - Epoxy primer - Epoxy asphalt sand mix
D[2]	Neoprene sealer - Oil-modified epoxy sand mix
AA	Asphalt cutback primer [3,4/] - Asphalt cutback adhesive [4,5/] - Polyethylene-foil-paper sheet [4,6/] - Epoxy sand mix [4,7/]
AB	Asphalt cutback primer [3,4/] - Asphalt cutback adhesive [4,5/] - Polyethylene-foil-paper sheet [4,6/] - Latex adhesive [4,8/] - Abrasive sheet vinyl [4,9/]
CA	Asphalt cutback primer [3,4/] - Oil modified epoxy sand mix [4,10/]
CB	Asphalt cutback primer [3,4/] - Epoxy sand mix [4,7/]
DA	Oil-modified epoxy sand mix [4,10/]
DB	Oil-modified epoxy primer [4,11/] - Oil-modified epoxy sand mix [4,10/]
F	Neoprene sealer [4,12/] - Epoxy primer [9,13/] - Epoxy asphalt sand mix [4,14/]
G	Neoprene sealer [4,12/] - Polyester ssnd mix [4,15/]
HA	Asphalt cutback primer [3,4/] - Asphalt cutback adhesive [4,5/] - Abrasive sheet vinyl [4, 9/]
HB	Neoprene sealer [4,12/] - Latex adhesive [4,8/] - Abrasive sheet vinyl [4,9/]

Footnotes to Table 3

1. Specimens for this series of tests were cement mortar panels, 10 X 10 X 1-inch, cast in steel molds. A batch for four panels

1,600 ml tap water
4,000 grams Type I portland cement
5,100 grams standatd Ottawa sand
5,100 grams standard 20-30 Ottawa sand

was blended in a portable cement mixer. Each panel was about half filled with the mix; tamped with a mason's trowel; struck off with a large plasterer's trowel; and steel trowel to a smooth surface. The panels were cured in a moist room at 80° F, 100 percent relative humidity for 28 days, then allowed to dry for two weeks or more at laboratory temperature and humidity. Each system was applied as under Description, the various treatments in each system in the order given.

2. Same as in Table 1. However, in System C, the top layer of epoxy primer was omitted, as the system is not a sandwich and is treated by the pipe cap bond method.

3. Same as Note 8, Table 1.

4. Same as Note 5, Table 1.

5. Same as Note 4, Table 1.

6. Same as Note 6, Table 1.

7. Same as Note 13, Table 1.

8. Armstrong latex adhesive S-235 for sheet vinyl on concrete floors, on or below grade or suspended, furnished by the manufacturer, Armstrong Cork Company of Lancaster, Pennsylvania.

9. The abrasive-sheet vinyl floor covering used is manufactured by Altro, Ltd. Sales Division of the Adamite Company, Ltd., Caxton Hill, Hertford, Great Britain, under the trade name ALTRO. The product is sold in the U. S. A. by Hercules Flooring Company, 247 West 16th Street, New York, New York, 10011, which furnished the material used in the tests.

10. Same as Note 12, Table 1.

11. Equal parts of GUARDKOTE 250A and GUARDKOTE 250B, applied by brush. See Note 12, Table 1.

12. Same as Note 11, Table 1.

13. Same as Note 9, Table 1.

14. Same as Note 10, Table 1.

15. Same as Note 7, Table 1.

Table 4. Adhesion of Overlay Systems to Clean and Greasy [1/] Cement Mortar Panels

Panel No.	System Table 3	Surface	Maximum Stress Tensile $\times 10^3$ n/m^2	psi
4	B	Clean	1,142	166
8 [2/]	C	Clean	796	116
8 [3/]	C	Clean	1,142	166
7 [2/]	C	Greasy	386	56
7 [3/]	C	Greasy	0	0
20	D	Clean	599	87
19	D	Greasy	142	21
6	AA	Clean	1,092	158
3	AB	Greasy	68	10
5	AB	Greasy	139	20
12	CA	Clean	250	36
11	CA	Greasy	0	0
2	CB	Clean	1,099	159
1	CB	Greasy	994	144
24	DA	Clean	509	74
23	DA	Greasy	176	26
22	DB	Clean	444	64
21	DB	Greasy	142	21
14 [2/]	F	Clean	614	89
14 [3/]	F	Clean	1,117	162
13 [2/]	F	Greasy	638	93
13 [3/]	F	Greasy	827	120
18	G	Clean	846	123
17	G	Greasy	469	68
10	HA	Clean	338	49
9	HA	Greasy	126	18
16	HB	Clean	324	47
15	HB	Greasy	42	6

1. The cement mortar panels were prepared as in Note 1, Table 3. "Clean" panels were treated as in Note 1 without any other treatment. "Greasy" panels were first coated with grease as in Note 1, Table 2.

2. The core was not drilled all the way through the overlay and the test was repeated on the same panel but another core. The first core was approximately in the center of the panel and the second core was to one side.

3. Repeat of previous test in which the core was not drilled all the way through the overlay.

4.3. Qualitative observations on bond tests, Tables 1, 2, 3, and 4

4.3.1. Straight-pull bond tests with cement mortar cubes, Tables 1 and 2

Systems A and B. Failures occurred invariably between the asphalt coating and the polyethylene side of the polyethylene-foil-paper sheet.

System C. Failures occurred between the asphalt primer and the epoxy overlay. In two tests the wooden cubes broke at the steel pins.

Systems D and E. Failures occurred between the neoprene sealer and the epoxy overlay.

4.3.2. Straight-pull bond tests with cement mortar panels, Tables 3 and 4

System B, clean panel. Most of the break was within the epoxy cement used to attach the pipe cap; there was a break at one edge in overlay.

System C, clean panel. In both tests the pipe cap broke loose from the cement used to attach it to the overlay.

System C, greasy panel. In the first test, in which the core was not drilled through the overlay, the pipe cap broke loose from the epoxy cement used to attach it to the overlay. In the second test, there was practically no bond and the specimen fell apart between the overlay and the primer.

System D, clean panel. The pipe cap broke loose from the epoxy cement used to attach it to the overlay.

System D, greasy panel. Failure occurred between the cement mortar panel and the neoprene sealer.

System AA, clean panel. The break was irregular. The overlay failed (cohesion) at the edges and at the center the failure was between the asphalt primer and the polyethylene-foil-paper sheet.

System AB, greasy panels. Both tests failed between the asphalt primer and the polyethylene side of the polyethylene-foil-paper sheet.

System CA, clean panel. The specimen cracked before the bond failed but failure occurred between the asphalt primer and the overlay.

System CA, greasy panel. There was complete failure of bond between the asphalt primer and the overlay.

System CB, clean panel. The break was irregular. The overlay failed (cohesion) at the edges and at the center the failure was between the asphalt primer and the overlay.

System CB, greasy panel. Failure occurred in a fairly straight plane within the overlay (cohesion).

System DA, clean panel. The cement mortar panel broke.

System DA, greasy panel. Failure occurred between the overlay and the panel.

System DB, clean panel. The cement mortar panel broke.

System DB, greasy panel. Failure occurred between the panel and the overlay.

System F, clean panels. In both tests the pipe cap broke loose from the epoxy cement used to attach it to the overlay.

System F, greasy panels. In both tests the pipe cap broke loose from the epoxy cement used to attach it to the overlay.

System G, clean panel. Failure occurred between the panel and the overlay.

System G, greasy panel. Failure occurred in a fairly straight plane within the overlay (cohesion).

System HA, clean panel. Failure occurred within the asphalt adhesive (cohesion).

System HA, greasy panel. Failure occurred within the asphalt adhesive.

System HB, clean panel. Failure occurred within the latex adhesive.

System HB, greasy panel. Failure occurred within the latex adhesive.

4.4. Compressive strength of resin mixes

Compressive strength tests were performed on the resin-sand mixes used as overlays in the bond tests reported in sections 4.2 and 4.3. The results were as follows:

Resin-sand mix

Generic Type	Reference Sect. 4.2, Table 1	Compressive Strength after curing period of 1 day psi	12 days psi
Epoxy	Note 13	1,750	4,969
Oil-modified epoxy	Note 12	669	1,044
Epoxy asphalt	Note 10	225	1,400
Polyester	Note 7	6,044	9,838

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