NBS TECHNICAL NOTE 783

Durability and Maintenance as Related to the Selection of Flooring

NATIONAL BUREAU OF STANDARDS

The National Bureau of Standards [1] was established by an act of Congress March 3, 1901. The Bureau's overall goal is to strengthen and advance the Nation's science and technology and facilitate their effective application for public benefit. To this end, the Bureau conducts research and provides: (1) a basis for the Nation's physical measurement system, (2) scientific and technological services for industry and government, (3) a technical basis for equity in trade, and (4) technical services to promote public safety. The Bureau consists of the Institute for Basic Standards, the Institute for Materials Research, the Institute for Applied Technology, the Institute for Computer Sciences and Technology, and the Office for Information Programs.

THE INSTITUTE FOR BASIC STANDARDS provides the central basis within the United States of a complete and consistent system of physical measurement; coordinates that system with measurement systems of other nations; and furnishes essential services leading to accurate and uniform physical measurements throughout the Nation's scientific community, industry, and commerce. The Institute consists of a Center for Radiation Research, an Office of Measurement Services and the following divisions:

Applied Mathematics — Electricity — Mechanics — Heat — Optical Physics — Nuclear Sciences [2] — Applied Radiation [2] — Quantum Electronics [3] — Electromagnetics [3] — Time and Frequency [3] — Laboratory Astrophysics [3] — Cryogenics [3].

THE INSTITUTE FOR MATERIALS RESEARCH conducts materials research leading to improved methods of measurement, standards, and data on the properties of well-characterized materials needed by industry, commerce, educational institutions, and Government; provides advisory and research services to other Government agencies; and develops, produces, and distributes standard reference materials. The Institute consists of the Office of Standard Reference Materials and the following divisions:

Analytical Chemistry — Polymers — Metallurgy — Inorganic Materials — Reactor Radiation — Physical Chemistry.

THE INSTITUTE FOR APPLIED TECHNOLOGY provides technical services to promote the use of available technology and to facilitate technological innovation in industry and Government; cooperates with public and private organizations leading to the development of technological standards (including mandatory safety standards), codes and methods of test; and provides technical advice and services to Government agencies upon request. The Institute consists of a Center for Building Technology and the following divisions and offices:

Engineering and Product Standards — Weights and Measures — Invention and Innovation — Product Evaluation Technology — Electronic Technology — Technical Analysis — Measurement Engineering — Structures, Materials, and Life Safety [4] — Building Environment [4] — Technical Evaluation and Application [4] — Fire Technology.

THE INSTITUTE FOR COMPUTER SCIENCES AND TECHNOLOGY conducts research and provides technical services designed to aid Government agencies in improving cost effectiveness in the conduct of their programs through the selection, acquisition, and effective utilization of automatic data processing equipment; and serves as the principal focus within the executive branch for the development of Federal standards for automatic data processing equipment, techniques, and computer languages. The Center consists of the following offices and divisions:

Information Processing Standards — Computer Information — Computer Services — Systems Development — Information Processing Technology.

THE OFFICE FOR INFORMATION PROGRAMS promotes optimum dissemination and accessibility of scientific information generated within NBS and other agencies of the Federal Government; promotes the development of the National Standard Reference Data System and a system of information analysis centers dealing with the broader aspects of the National Measurement System; provides appropriate services to ensure that the NBS staff has optimum accessibility to the scientific information of the world. The Office consists of the following organizational units:

Office of Standard Reference Data — Office of Technical Information and Publications — Library — Office of International Relations.

---

[1] Headquarters and Laboratories at Gaithersburg, Maryland, unless otherwise noted; mailing address Washington, D.C. 20234.
[2] Part of the Center for Radiation Research.
[3] Located at Boulder, Colorado 80302.
[4] Part of the Center for Building Technology.

Durability and Maintenance as Related to the Selection of Flooring

Winthrop C. Wolfe,
Robert E. Roberts

Center for Building Technology
Institute for Applied Technology
National Bureau of Standards
Washington, D.C. 20234

and

Mortimer Russell

Veterans Administration
Washington, D.C. 20420

U.S. DEPARTMENT OF COMMERCE, Frederick B. Dent, *Secretary*
NATIONAL BUREAU OF STANDARDS, Richard W. Roberts, *Director*

Issued August 1973

National Bureau of Standards Technical Note 783

Nat. Bur. Stand. (U.S.), Tech. Note 783, 68 pages (Aug. 1973)

CODEN: NBTNAE

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402
(Order by SD Catalog No. C13.46:783). Price $0.90

TABLE OF CONTENTS

ABSTRACT

This report is addressed to the problem of selection and maintenance of flooring to the best advantage in terms of durability, type and severity of service, appearance, comfort, and safety. The selection of flooring is discussed with respect to service life, maintenance, obsolescence, and trade-off advantages. Two articles by maintenance administrators include information and discussion helpful in determining maintenance cost, trade-offs, and selection of flooring for different types of service. Field observations and preliminary field tests by the National Bureau of Standards indicate areas in which research is needed, as in laboratory tests for wear and slip resistance. Observations and field tests are impracticable to use for procurement.

This report is helpful in the selection and maintnenace of flooring and floor finishes. More important, it points up areas in which research is needed to develop information for this purpose.

KEY WORDS; Carpets; durability; economics; field studies; flooring; floor coverings; life-cost; maintenance; selection; user needs.

1. Introduction

by Winthrop C. Wolfe

Materials and Composites Section; Structures, Materials, and Life Safety Division; Center for Building Technology; Institute for Applied Technology; National Bureau of Standards.

Flooring may be defined as the wearing element of the floor assembly on which people walk and on which furniture is placed. It may be considered as a sub-element of the Floor-Ceiling Built Element [1]* and is usually not a structural component, although sometimes concrete constitutes the flooring or wearing element.

Flooring may be classified into four basic types: hard, resilient, textile, and wood. Hard flooring may be defined as rigid flooring which is not readily indented or scratched, at least not to an appreciable depth or width. This includes various types of ceramic tile, such as mosaic, quarry, and paver tile; concrete, with or without coating or surfacing; monolithic surfacings; terrazzo; brick; and natural stone. Monolithic surfacing is a composition applied to a floor to provide an improved wearing surface. Terrazzo is flooring made by embedding decorative stone in a matrix (of concrete or synthetic resin) and then polishing (grinding) smooth.

Resilient flooring is semi-rigid or plastic and is therefore subject to a certain amount of scratching and indenting but is usually designed to recover from indentation and to have a limited defined scratch resistance. Resilient flooring or floor covering includes such products as asphalt tile, vinyl asbestos tile, rubber tile, vinyl tile, sheet vinyl floor coverings, linoleum, and bituminous based sheet floor covering

Textile floor covering is that made from fibers, filaments, or yarns and is usually referred to as carpets and rugs. Most textile floor coverings have a woven or tufted loop or cut pile but some are nonwoven,

---

*Numbers in brackets indicate references at the end of this report.

flat, felt-like products made by the needlepunch process. There are also other types, such as knitted or braided rugs.

Wood flooring is most commonly tongue and grooved strip oak or pine but may be of other species. Plank, parquet, and block flooring are also used.

The first article in this report, "Factors in Selection of Flooring" is a discussion of how life-cost, annual-cost, and trade-offs may be applied to the selection of flooring. Following are two articles on selection and maintenance of flooring in government buildings. These articles provide some detail on the maintenance factor of life-cost, background on problems under various service conditions, and information on the selection of flooring for different types of service. Selection of flooring is sometimes dictated by the type and severity of service but should also be based on a trade-off between desirable features and life-cost or annual-cost.

Observations on the performance of flooring follow an earlier study, published in 1968, which was based mostly on military installations. Types of flooring studied include monolithic surfacings, resilient floor coverings, carpet, and wood flooring. Also reported are field experiments by the National Bureau of Standards, Center for Building Technology. Flooring and floor finishes were applied under conditions known and controlled as far as possible. The performance of these products was observed and recorded.

2. Factors in Selection of Flooring

by Winthrop C. Wolfe

Materials and Composites Section; Structures, Materials and Life Safety Division; Center for Building Technology; Institute for Applied Technology; National Bureau of Standards

Economic decision making has been applied to a variety of activities, including purchase of machinery and equipment, stock transactions, design and construction of buildings and dams, mining operations, water supply, and sewage disposal. This decision making can be based on annual-cost comparisons [2]. This type of analysis can be applied to interior

finishes as well as to the design and construction of buildings. It should be possible to apply the concept of annual-cost to flooring [3].

Flooring is an important item in building econimics for several reasons:

(1) The care of flooring is a large item in the annual budget for maintenance of buildings.

(2) The floor is the part of the building which receives most of the wear from human activities.

(3) Like other interior finishes, it contributes to appearance and must be considered in interior design and construction.

(4) Unlike most interior finishes, flooring contributes to such factors as comfort, fatigue, and noise reduction.

(5) Flooring has special problems, such as slipperiness, indentation, and static charge, and presents more of a cleaning problem than most interior finishes.

(6) Flooring is more frequently replaced by new products which have appeared on the market, such as carpet of synthetic fibers, replacing resilient flooring in many areas. Reasons for increasing use of carpet include appearance, desire for greater comfort (less fatigue), and reduction of distracting noise. However, carpet introduces some problems, which will be discussed later.

We are attempting to apply the principle of life-cycle costing in the application of building economics to Federal construction. Since a large fraction of building maintenance is cleaning, finishing, and replacing flooring, it would be important to apply life-cycle costing to flooring. Life-cost of flooring may be considered to be the sum of first cost plus in-use cost, including operation, maintenance, repair, replacement, and improvement. In-use cost of flooring may be called OMRI, an abbreviation of the factors mentioned. Replacement of flooring is sometimes necessitated by actually wearing out so the subfloor is exposed. More commonly the flooring becomes so unattractive or possible unsafe that it is highly desirable or even necessary to replace it. Since the value of flooring is largely aesthetic or "subjective" [3], it is often replaced because the building is being redecorated or there is a desire

for a more attractive or more comfortable floor than is in place. New improved products are constantly coming on the marekt and it may be desirable to take advantage of these improvements. In other words, flooring may be replaced because of obsolescence.

In an analysis of maintenance cost, it is important to consider trade-offs between labor, materials, and equipment. As a rule, cleaning materials and floor finishes, such as sealer, waxes, and polishes, are the least expensive items. Hence the trade-off is usually between labor and equipment. It may be advantageous and result in lower annual-cost to invest in floor cleaning and polishing machinery, especially in large buildings.

Maintenance is the constant struggle to keep floors sanitary, clean, attractive, and with other desirable properties as long as possible and at the least cost. Maintenance costs depend on the type of flooring, the kind and severity of service, the desired level of maintenance, and maintenance problems. In most government buildings, it is necessary to compromise the desired appearance level with budgetary limitations. Considerable though and experimentation is devoted to reducing maintenance cost, improving and standardizing maintenance procedures, and improving the desirable properties of flooring in government buildings. Various floor finishes, cleaning materials, and machines have been tried in an effort to lower cost and improve appearance and other properties. Elaborate cleaning schedules have been worked out and an effort has been made to analyze maintenance cost. New floor coverings are often used in an effort to reduce maintenance cost or to secure trade-off advantages, such as resilience and quietness, associated with carpet.

Color, pattern, and texture of flooring have a bearing on maintenance cost. Some patterns and colors show dirt and some conceal it. Textured and embossed flooring may trap dirt and be more difficult to clean, hence raise maintenance cost.

Carpeting may reduce the first-cost of the floor assembly. For example, concrete floors do not require as much finishing if wall-to-wall carpeting is to be laid over the floor. Finished wood flooring might be eliminated from wood construction because wall-to-wall carpeting can be laid on underlayment grade plywood.

Economic decision making involves more than life-cycle costing. In addition to maintenance, wear, and other OMRI factors, it is important to consider trade-off factors. These factors are important in the selection and use of flooring and consideration of trade-offs may take precedence over life-cost considerations. Some of these factors were discussed in an article [3] in which performance requirements for flooring were grouped in three categories; Health and Safety; Comfort; Convenience and Efficiency; and Economics. Factors under Economics are those which would be considered in life-cycle costing, while the other factors are trade-offs. Fire safety is an important consideration, especially with carpeting. Slip resistance is important in the selection and use of resilient and hard flooring. Cleanability and sanitation must be considered in any situation, especially in hospitals. Air pollution has been under consideration recently and certain fibers used in carpeting and possibly other flooring may be allergenic or toxic. Resistance to build-up of static charge must be considered in the selection, use, and treatment of carpets and is essential where flammable gases or vapors may be present. Noise reduction and foot comfort, on the other hand, are claimed to be advantages of carpeting. In hospitals, offices, and other locations where wheeled vehicles or chairs are used, the resistance to movement of such vehicles must be considered.

3. Maintenance of Floors at the National Bureau of Standards

by Robert E. Roberts, Chief, Janitorial Services

The National Bureau of Standards has about 2,285,000 gross and about 1,600,000 net square feet of floor area*, including about 62,480 square feet of corridors. Most of the flooring is vinyl asbestos tile and there is roughly 25,000 to 35,000 square feet of terrazzo or similar flooring. The cleaning staff at present numbers 123, of which 12 men are permanently assigned to spray buffers. We estimate that floor care of all types represents about 40 percent of the janitorial budget and that labor cost is about 90 to 93 percent of the total janitorial budget. Wages average about $3.50 per hour. Our buildings are largely laboratories and hence floor care accounts for a larger percentage of the janitorial budget. For an office building, floor care represents about 30 percent of the budget. Estimates of total costs and of percentage costs for various operations depend on the mode of operation, the level of maintenance, the type of equipment used, the kind of flooring, and the degree of traffic. Cleaning costs depend largely on cleaning schedules and frequency of the various operations, such as mopping, sweeping, polishing, etc. Over-emphasis on productivity may lead to losses from accidents, breakage, damage to equipment, spillage, etc. Also, it is difficult to estimate the amount of time spent on some operations, as sweeping, rug cleaning, buffing, and other operations in the same room or hall. For example, in each of our auditoriums we have a combination of carpet, vinyl asbestos tile, and wood flooring and it would be easier to analyze costs and also cheaper to maintain if there were only one type of flooring in each auditorium.

Most of our resilient tile is maintained by what is known to the trade as spray-buffing, an almost dry method of cleaning. In this method, a synthetic polymer finish is first sprayed on the floor as a fine mist.

---

* Gross space is all livable interior space with corresponding floor area. Net space is space cleaned on a scheduled basis, as every night, every week, etc. Net floor area is that of the net space.

The finish is then agitated by a buffing 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 the old finish and dirt into the pad. This results in a clean, bright, and shiny finish. It has been found that the customary wet cleaning with scrubbing is harmful to resilient tile, which is one reason for using the spray-buffing process. We have also found that the spray-buffing process saves maintenance cost. This process does not completely eliminate stripping and refinishing but greatly extends the time between these operations. Mops and buckets are not used as extensively as would be the case if there were a scheduled program of stripping and refinishing. The spray-buffing process also allows more frequent cleaning of resilient tile areas. However, spray-buffing must be done repetitively or the advantages of the process are lost. If spray-buffing is not repetitive, it may be necessary to start all over again and re-strip and refinish the floors.

Cleaning terrazzo floors is a simple operation which is done by means of battery-powered scrubbing and vacuum machines. The area is dust mopped before wet cleaning. Three or four clear water applications per week are made, the floor is scrubbed, then the water is picked up. We have found that sealers and other finishes generally involve considerable cost in labor and materials and are not necessary. Some types of terrazzo sealers also show traffic patterns and some show scuff marks. An initial permanent phenolic base sealing is desirable on terrazzo surfaces. Yearly touch-up may be necessary in traffic lanes. We have studied replacing or covering our resilient and hard flooring with carpet because it apparently offers certain advantages. It presents to most people a more pleasing and aesthetic appearance to an area; it is more conducive to study for people who need a quiet work environment; and it absorbs more distracting and disturbing noise. It is safer with respect to slip resistance but may present an annoyance or even a hazard from generation of static electricity. Carpet installation in our buildings is a disadvantage because we have

used our flooring for only eight years and resilient tile has an expected service life of 18 years or more, depending on use. It is more advantageous to make decisions about flooring in a new building or when the flooring needs replacing to obviate the cost of resilient tile installation. Our studies indicate that cleaning cost of carpet is less than that of resilient tile but this estimate must be modified by such variables as quality of carpet, cleaning schedule, spillage, and traffic. Moreover, the initial installed cost of carpet is higher and the service life is shorter as compared to resilient tile. It is more advantageous to purchase a better grade of carpet, as the increased service life offsets the greater initial cost and results in a life-cost or annual-cost which may be about the same as that for resilient flooring. However, in order to save on cleaning cost, it is necessary to cover most of our flooring with carpet in order to phase out the expensive mopping, waxing, polishing, and spray-buffing equipment and operation. Utility areas with very heavy traffic or which are excessively dirty are not suitable for carpet but such areas are usually bare concrete and receive minimal floor care. Elevators are relatively clean but receive heavy traffic and wear, due to twisting and turning of feet, so we have found that a good medium grade of carpet lasts us for only three years. Such areas may be regarded as marginal with respect to carpet life.

It may be advantageous to install carpet in 27-inch strips, sewn or taped on the job, which is how the carpet in our red and green auditoriums was installed. This enables the owner to switch worn strips of carpet in travel lanes and strips of carpet in less travelled areas, thus increasing the service life.

Carpet is sometimes sold on a janitorial contract or an annual-cost basis. In this type of contract, 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.

In general, carpet, from a cleaning cost and aesthetic basis can be said to be superior to resilient flooring; however, many variables interdict a flat comparison statement or conclusion. Previous studies

[4,5] of the annual-cost of carpet as compared to resilient flooring do not agree, which shows the need for an impartial study of the subject.

4. Maintenance of Floors in Hospitals

by Mortimer Russell, Chief,
Environmental Sanitation Division, Building Management Service (137), Veterans Administration, Washington, D. C. 20420

The Veterans Administration operates a system of 166 hospitals throughout the country, ranging from one to fifty years old. A variety of flooring is used in the hospitals, including wood, linoleum, asphalt and vinyl asbestos tile, homogeneous vinyl tile, sheet vinyl, terrazzo, etc. The type of flooring for various areas is prescribed according to the Veterans Administration guide for finishes. This guide is mandatory for new construction and is recommended for modernization.

Cleaning of floors in hospitals is different from that in other buildings. This is because of the necessity to wet clean with detergent-disinfectants to reduce the bacterial level on the floors and to use non-buffable floor finishes to limit air turbulence and noise from buffing machines. However, the use of detergent-disinfectants is not without problems, as they can remove floor finishes if not prepared properly and tiles can be loosened if too much water is used. Careless floor cleaning can remove insecticide from baseboards. In operating rooms, some detergents can adversely affect the conductivity of conductive flooring. In small areas preliminary dry vacuum pick-up is recommended if necessary. The next procedure is to spray detergent-disinfectant on the floor, followed by wet vacuum pick-up. Battery-powered vacuum scrubbers are recommended for large areas. This spray and vacuum technique has been shown to be the most effective in reducing floor bacteria levels. However, it takes longer than the mop and bucket method and some maintenance men are reluctant to change to the spray and vacuum procedure. The success of spray and vacuum depends on the quality and training of the maintenance staff and the availability of modern equipment and supplies. There is some difficulty in obtaining a uniformly satisfactory "metal cross-linked acrylic polymer finish", used in the spray and vacuum process.

The use of insecticide preparations is another flooring problem and insecticides should be applied only to the baseboards and not to the floor. The oil base of such insecticides will damage certain types of resilient flooring such as asphalt tile.

In addition to sanitation and reducing bacterial levels, the safety aspects of the flooring are also important from the standpoint of patients, hospital personnel, and visitors. There must be no indented places in the flooring, no water or liquid deposits remaining on the floor and the floor finish should not be slippery.

Carpeting may be used in place of other floor coverings in certain areas in hospitals. In our facilities, it is used mainly in administrative areas. Carpeting is not used in patient areas because the question has not been resolved regarding sanitation or the effect of carpet on the biological environment, including bacterial levels on the carpet and in the air.

Fire safety is another question which has limited the use of carpeting in hospitals. In some areas carpeting is acceptable if it complies with the now legally binding "Pill test [6] and in other areas only if it has a certain rating when subjected to the ASTM E-84 test for flammability [7].

Static charge is also a problem with carpeting. Incorporation of stainless steel fibers into the carpeting has not always been successful. Some, but not all, antistatic sprays are effective for varying periods of time.

Because of poor experience with compressed or needlepunch polyolefin carpeting, it is not recommended for use in hospitals. The wearing characteristics are poor and it shows marked traffic patterns. It is also hard to clean and is susceptible to burns from cigarettes.

We have had varying success with monolithic or seamless floors. Sometimes mops tear on the chips used in one such type of flooring. In other instances, breaks occur and stains are not easily removed. Some seamless floors are very good but expensive.

A new floor tile has been installed in two of the hospitals but it has subsequently been taken off the market. This tile is based on acrylic resin and does not require a floor finish or as much maintenance as other flooring. However, these tiles must be installed over a very good subfloor.

5. Field Observations and Experiments on Performance of Flooring

by Winthrop C. Wolfe

Materials and Composites Section; Structures, Materials and Life Safety Division; Center for Building Technology; Institute for Applied Technology; National Bureau of Standards

A field study by the National Bureau of Standards on floor coverings was published in 1968 [8]. This study was sponsored by the Department of Defense and covered mostly military installations. The specific purpose of the study was to solve the problem of resurfacing concrete floors in World War II temporary buildings. The overall purpose was (1) to evaluate types of floor coverings, (2) to assist the Department of Defense with flooring problems, and (3) to gain background experience in floor coverings for defining areas of research designed to improve standards and specificiations.

Since this study was published, the National Bureau of Standards has continued the field study of flooring but with a wider purpose and scope. The scope now includes assisting all government agencies with flooring problems and covers all types of flooring. Also, the purpose and scope not only relates to improved standards and specifications but also to better informed economic decision making in the purchase and maintenance of flooring.

Observations reported in the earlier study and continued observations are combined in this report. A complete description of the observations is found in Appendix A. Observations on flooring are summarized by materials in Table 1 and by locations in Tables 2 and 3. Locations are classified in Table 2 by type of exposure and by usage. Appendix B is an account of field experiments on flooring by the author. Recommendations in Table 4 are based on field observations and experiments.

5.1 Comments on Field Observations Reported in Appendix A

The performance of flooring in military installations has already been discussed in a previous article by the author [8], which dealt largely with monolithic surfacings. On the basis of Tables 1-3 and Appendix A, it appears that polyester resin-based trowel-on monolithic surfacings perform better in military kitchens than those based on epoxy resins. It is difficult to apply monolithic surfacings successfully to concrete floors in laundries, due to the problems caused by flooding with hot water and solutions of detergents and starch. Both epoxy and polyester trowel-on surfacings were successful in barracks latrines and shower rooms, which indicates that these surfacings can be used in "wet" areas. Thin-set or resin-based terrazzo is likely to crack in areas exposed to the weather or over substrates that are subject to vibration. Brush-on polyurethane surfacings do not appear promising in heavy traffic areas or in areas subjected to severe treatment with hot water, chemicals, and grease. However, polyurethane coatings are satisfactory in residential kitchens and on wood floors in homes. Surfacings based on portland cement and acrylic latex may cause trouble in heavy traffic areas. Surfacings based on portland cement and asphalt are not suitable where oils and greases are spilled, as these substances will soften the topping and asphalt will be tracked into other areas by foot traffic.

Resilient floor coverings, known to perform well in office buildings, were found to be successful in animal rooms. Polyester tile requires a smooth, level and plane subfloor, as it is too rigid to conform to the average concrete floor surface.

Quarry tile with epoxy or furan bed and joints may or may not perform well in kitchens, depending on the amount of heat to which it is subjected and the soundness of the subfloor. Sometimes it is possible to use it over plywood but this is not recommended.

Carpeting is satisfactory for areas where there is not too much spillage, careless use of cigarettes and matches, or extremely heavy traffic.

Of great interest in the rehabilitation of housing was the successful application of an epoxy-polyurethane brush-on system, No. 65, over old asphalt tile and mastic on a concrete floor in a housing project.

5.2 Comments on Field Experiments Reported in Appendix B

From the test on the barracks corridor, it appears that a brush-on monolithic surfacing with vinyl chips does not perform well in heavy traffic. A surfacing with sand filler wore satisfactorily and so did sheet vinyl with abrasive filler. However, the sheet vinyl was damaged by cigarettes and matches. Resilient floor coverings did not perform well in a military commissary where fork lift trucks were used and it was not practicable to protect the resilient floor tile with a floor finish. Polyester terrazzo floor tile or panel performed better in a busy computer facility than did vinyl and vinyl asbestos tile. Filled acrylic tile* wore almost as well as the polyester terrazzo tile! Floor tile or panel with melamine-formaldehyde resin wear layer appeared better than vinyl or vinyl asbestos tile for the first year of service but showed noticeable wear after 2-1/2 years and is not recommended for this application.

6. Summary, Conclusions and Recommendations

by Winthrop C. Wolfe

Materials and Composites Section; Structures, Materials and Life Safety Division; Center for Building Technology; Institute for Applied Technology; National Bureau of Standards

Economic decision making may be applied to the selection of flooring on the basis of life-cost or annual-cost and trade-offs. Both life-cost and annual-cost are functions of operation, maintenance, repair, replacement, and improvement or OMRI.

Maintenance cost is largely labor, with appreciable equipment cost and negligible material cost. It is advantageous to invest in cleaning machines for large buildings for this reason.

---

* This product has been withdrawn from the market and is no longer available.

Selection of flooring should be based on properties which affect first-cost and maintenance cost. Carpeting as the permanent type of flooring may reduce first-cost when finished flooring is eliminated. Embossed and porous flooring will trap dirt and cause increased maintenance cost. In general, ease of cleaning is the property which is most related to maintenance cost.

Flooring is often replaced before it wears out because of obsolescence due to loss of appearance or because of the introduction on the market of new products and style changes.

In addition to appearance, trade-offs such as comfort and reduction of distracting noise have led to the replacement of resilient flooring by carpet in many buildings.

Some trade-offs are matters of health and safety. Resilient flooring and floor finishes should be slip-resistant to avoid accidents. Increased use of carpeting has focused attention on fire safety, a very serious problem with some carpets. Certain carpeting will build up static charge when people walk over it under conditions of low relative humidity and cause annoying electrical shocks. Certain carpet fibers have been suspected of being allergenic and it is possible that carpet might trap irritating dirt particles.

Mr. Roberts of the National Bureau of Standards reported that floor care represents about 40 percent of the maintenance budget and that NBS has a staff of 123 to clean 1,600,000 sq. ft. on a scheduled basis or about 13,000 sq. ft. per man.

For general maintenance of resilient tile, which covers most areas in office buildings, wet cleaning and waxing has been largely replaced by the spray-buffing method. The spray-buffing process involves special equipment and acrylic polymer finish. This saves maintenance cost because it is not necessary to strip and refinish the floors as often and permits more frequent cleaning of resilient tiles. However, the spray-buffing process must be repeated periodically or it becomes necessary to strip and refinish the floors.

According to Mr. Russell of the Veterans Administration, wet cleaning with detergent-disinfectant is used in hospitals to reduce bacterial levels. However, careless cleaning may damage floor tiles and finishes and remove insecticides from baseboards.

Carpeting is being used more and more in office buildings and in corridors and administrative areas of hospitals. However, Mr. Russell reported that the Veterans Administration has not used carpeting in patient areas largely because of the question of bacterial contamination. Other problems which have limited the use of carpet in hospitals are fire safety and static charge build-up. The use of stainless steel fibers and antistatic sprays have not been entirely successful. Needlepunch carpeting was not successful in Veterans Administration hospitals because of poor wear, difficulty in cleaning and cigarette burns. Mr. Roberts pointed out that narrow carpet strips permit replacement of only part of the carpet in traffic lanes, thus lowering replacement cost. The use of carpet squares in some areas has accomplished the same purpose. Carpet is often sold on a janitorial contract or annual-cost basis. Under this type of contract, the maintenance firm has a five-year contract for cleaning and furnishes the carpet without additional cost.

The Veterans Administration has tried monolithic surfacings or seamless floors and has found that good floors of this type are too expensive. Cleaning problems and failures are also a problem with some of this type of flooring.

Table 1. Summary of Observations on Flooring by Materials

	Types of Flooring	Total Installations		Failures		Fairly Satisfactory		Satisfactory	
		No.	Life[a]	No.	Life	No.	Life	No.	Life
A	Epoxy monolithic - all types	14	3.7	6	3.4	2	1.3	6	4.5
	(a) Brush-on, roll-on	2	0.5	1	0.1			1	1.0
	(b) Trowel-on industrial	9	4.3	5	4.0	2	1.3	2	6.5
	(c) Thin-set terrazzo	3	4.3					3	4.3
B	Polyester monolithic - all types	21	1.8	4	1.9	6	2.7	11	1.3
	(a) Trowel-on industrial	14	1.5	2	1.0	2	2.8	10	1.4
	(b) Thin-set terrazzo	7	2.4	1	4.0	5	2.4	1	0.5
C	Polyurethane monolithic - all types	18	2.0	8	1.9	4	2.1	4	2.2
	(a) Brush-on, roll-on	15	2.1	6	1.8	3	2.4	4	2.2
	(b) Trowel-on industrial	3	1.7	3	1.7				
D	Various resin monolithic	5	2.6	1	0.1	2	3.0	2	3.5
	(a) Vinyl-acrylic brush-on	2	3.0			2	3.0		
	(b) Epoxy-polyamide-polyurethane brush-on	1	2.0					1	2.0
	(c) Vinyl trowel-on industrial	1	5.0					1	5.0
	(d) Furan trowel-on industrial	1	0.1	1	0.1				
E	Portland cement with additives	6	2.6	2	2.8	3	3.3		
	(a) Acrylic latex additive	2	9.0			2	9.0		
	(b) Epoxy emulsion additive	1	1.0			1	1.0		
	(c) Styrene-butadiene latex additive	1	0.5	1	0.5				
	(d) Asphalt additive	2	5.0	1	5.0			1	b
F	Alumina cement with neoprene latex	7	3.2	1	0.2	1	5.0	5	3.3

a. Average period in years over which installation was observed or after which it failed

b. No data

Table 1 - continued

	Types of Flooring	Total Installations		Failures		Fairly Satisfactory		Satisfactory	
		No.	Life[a]	No.	Life	No.	Life	No.	Life
G	Resilient floor coverings	3	11.2			1	0.7	2	16.5
	(a) Asphalt tile	1	28.0					1	28.0
	(b) Sheet vinyl	1	5.0					1	5.0
	(c) Polyester tile	1	0.7			1	0.7		
H	Quarry tile	5	9.2			2	9.0	3	9.3
	(a) with epoxy bed and joints	2	6.5			1	8.0	1	5.0
	(b) with furan bed and joints	3	11.0			1	10.0	2	11.5
I	Carpet	8	3.0	1	5.0	5	2.6	2	3.0
	(a) Acrylic, medium-level looped pile, without cushion	1	3.0			1	3.0		
	(b) Nylon, low-level looped pile, with sponge rubber cushion	3	3.7	1	5.0	1	4.0	1	2.0
	(c) Wool, looped pile, without cushion	3	2.0			3	2.0		
	(d) Wool, velvet twist, over hair-jute pad	1	4.0					1	4.0

Table 2. Classification of Locations Where Observations on Flooring Were Made[a]

A. Classification by Exposure

Interior Dry[b] Areas		Interior Wet[c] Areas		Exterior Areas
Clean[d]	Subject to Spillage[e]	Clean	Subject to Spillage	Exterior Areas
Airline terminal	Bakery	Latrines	Animal rooms	Concrete sun decks
Church	Barracks	Showers	Corridor between animal rooms	Stairs outside barracks
Concrete floors, residential	Hospital nursing units		Fire station	Walk ramp
Entrance to laboratory building	Meat cutting plants		Kitchens	
	Plumbing shop		Laboratory	
Entrance to office building	Supermarket		Laboratory glass washing facility	
Hospital operating suites			Laundries	
Office buildings				
Recreation area				
Storeroom				
Wooden floors, residential				

Table 2 - continued

B. Classification by Usage[f]

Light Traffic	Medium Traffic	Heavy Traffic
Church	Animal rooms	Airline terminal
Concrete floors, residential	Bakery	Barracks
Concrete sun decks	Corridor between animal rooms	Entrance to office building
Hospital operating suites	Entrance to laboratory building	Fire station
Kitchens, residential	Laboratory glass washing facility	Hospital nursing units
Laboratory	Meat cutting plants	Kitchens, military
Storeroom	Recreation area	Latrines and shower rooms
Wooden floors, residential	Plumbing shop	Laundries
	Showers in hospital	Office buildings
		Stairs outside barracks
		Supermarket
		Walk ramp

Notes to Table 2

a. Classifications by exposure and by usage. These classifications are on the basis of the author's experience and some overlapping is to be expected.

b. Dry areas in Table 2 are those not normally exposed to water spillage. In Table 3, dry areas include only "clean" areas, as in Note d.

c. Wet areas are those normally exposed to water spillage. In Table 3, wet areas include all exterior areas and those subject to other spillages, as in Note e.

d. Areas not subject to spillage except of water.

e. Areas subject to spillage besides water, as of grease, chemicals, or other materials which soil, stain, or otherwise damage the floor.

f. Light, medium, and heavy traffic are relative terms. Areas of light traffic are used occasionally, as in a church, or by a limited number of people, as in a home, hospital operating room, laboratory. Heavy traffic areas are used by the public or undergo intensive use, as a fire station or military kitchens, latrines, shower rooms. Medium traffic areas are in between.

Table 3. Service Life of Flooring in Various Locations

Type of Flooring[a]	Type of Location																	
	Interior Dry Areas[b]									Wet Areas Including Exterior[c]								
	Traffic[d]									Traffic								
	Light			Medium			Heavy			Light			Medium			Heavy		
	No.[e]	Life[f]	Fail[g]	No.	Life	Fail	No.	Life	Fail	No.	Life	Fail	No.	Life	Fail	No.	Life	Fail
A (a)	--	---	---	--	---	---	--	---	---	--	---	---	1	1.0	0	1	0.1	1
A (b)	--	---	---	--	---	---	--	---	---	--	---	---	1	5.0	0	8	3.8	5
A (c)	--	---	---	--	---	---	--	---	---	--	---	---	2	5.0	0	2	3.0	0
B (a)	--	---	---	--	---	---	--	---	---	--	---	---	1	2.0	1	13	1.0	1
B (b)	--	---	---	--	---	---	1	1.5	0	4	2.6	1	1	4.0	0	1	0.5	0
C (a)	2	3.0	0	1	4.0	0	1	0.2	0	2	3.0	0	2	3.0	1	7	1.5	5
C (b)	--	---	---	--	---	---	--	---	---	--	---	---	--	---	---	3	1.7	3
D (a)	--	---	---	--	---	---	--	---	---	--	---	---	--	---	---	2	3.0	0
D (b)	1	2.0	0	--	---	---	--	---	---	--	---	---	--	---	---	--	---	---
D (c)	--	---	---	--	---	---	--	---	---	--	---	---	1	5.0	0	--	---	---
D (d)	--	---	---	--	---	---	--	---	---	--	---	---	--	---	---	1	0.1	1
E (a)	--	---	---	--	---	---	--	---	---	--	---	---	--	---	---	2	9.0	0
E (b)	--	---	---	--	---	---	--	---	---	--	---	---	--	---	---	1	1.0	0
E (c)	--	---	---	--	---	---	--	---	---	--	---	---	--	---	---	1	0.5	1
E (d)	1	h	0	--	---	---	--	---	---	--	---	---	1	5.0	1	--	---	---
F	2	4.5	0	--	---	---	--	---	---	--	---	---	3	3.7	1	2	2.5	0
G (a)	--	---	---	--	---	---	1	28.0	---	--	---	---	--	---	---	--	---	---
G (b)	--	---	---	--	---	---	--	---	---	--	---	---	1	5.0	0	--	---	---
G (c)	--	---	---	1	0.7	0	--	---	---	--	---	---	--	---	---	--	---	---
H (a)	--	---	---	--	---	---	--	---	---	--	---	---	--	---	---	2	6.5	0
H (b)	--	---	---	--	---	---	--	---	---	--	---	---	--	---	---	3	11.0	0
I (a)	--	---	---	--	---	---	--	---	---	--	---	---	--	---	---	1	3.0	0
I (b)	--	---	---	--	---	---	1	4.0	0	--	---	---	--	---	---	2	3.5	1
I (c)	--	---	---	--	---	---	--	---	---	--	---	---	--	---	---	3	2.0	0
I (d)	1	4.0	0	--	---	---	--	---	---	--	---	---	--	---	---	--	---	---

Notes to Table 3

a. See Table 1.

b. Dry areas are those not normally exposed to spillage of water, grease, chemicals, or other materials which soil, stain, or otherwise damage the floor.

c. Wet areas include all exterior areas and those interior areas normally exposed to spillage of water, grease, chemicals, or other materials which soil, stain, or otherwise damage the floor.

d. Traffic is divided into light, medium, and heavy traffic. See Table 2 for examples.

e. Number of locations in this category.

f. Average period in years over which installation was observed or after which it failed.

g. Number of installations in this category which failed.

h. No data on service life or period of observation.

Table 4. Flooring Recommended for Various Types of Service[a]

Light traffic in wet or dry areas, with or without spillage

- Epoxy brush-on
- Polyurethane brush-on
- Epoxy-polyurethane brush-on[b]

Moderate traffic in dry, clean areas

- Carpet

Heavy traffic in dry, clean areas

- Asphalt tile
- Epoxy trowel-on and thin-set terrazzo
- Polyester trowel-on and thin-set terrazzo

Heavy traffic in wet areas without exposure to heat or spillage of grease and chemicals

- Epoxy trowel-on and thin-set terrazzo

Heavy traffic with exposure to spillage of grease and chemicals

- Vinyl asbestos tile

Heavy traffic with exposure to heat and spillage of grease and chemicals

- Polyester trowel-on and thin-set terrazzo
- Quarry tile

Pedestal floors, as in computer areas

- Polyester terrazzo tile

Rehabilitation over old asphalt tile[b]

- Brush-on epoxy-polyamide-polyurethane system

---

a. The author'e experience was used, together with the data in this report, as a basis for these recommendations.

b. Federal Specification TT-C-001685, May 10, 1971

Caution must be taken in the interpretation of the comments and recommendations in this report. The following qualifications should clarify and prevent misinterpretation of these recommendations:

1. Recommendations and comments are based on the studies included in this report in the light of the author's judgment and experience.

2. The products included in the observations and experiment are not well defined and therefore the recommendations are only tentative and are intended only as rough guidelines.

3. Other types of flooring may be suitable for applications described in Tables 1-4.

4. Some types of carpet may be suitable for "wet" areas, areas of high spillage, and for heavy traffic but the author has not received sufficient evidence to recommend carpeting for such areas.

5. Some epoxy trowel-on surfacings may be suitable for heavy traffic in "wet" areas subjected to spillage but epoxy based formulations could not be recommended for such usage on the basis of present evidence.

As a general conclusion, the author has made qualified recommendations based on the data in this report and present knowledge. Further studies of this kind should be undertaken to improve the state of the art of performance evaluation as the author has outlined [3], [9], [10].

References

1. Felix Y. Yokel and Norman F. Somes, "Performance Criteria for Innovative Housing Systems", Engineering Education, vol. 61, No. 2, 105 (Nov., 1970).

2. George A. Taylor, Managerial and Engineering Economy, van Nostrand Reinhold Co., New York, 1964, Chapters 6 and 7.

3. W. C. Wolfe, "Performance Tests for Floor Coverings", ASTM Matls. Res. and Stds., vol. 10, No. 7, 15 (July, 1970).

4. George M. Parks, The Economics of Carpeting and Resilient Flooring, University of Pennsylvania Press, Philadelphia, Pa. 19104, 1966.

5. David G. Martens, "Hardwood? Carpet" or Tile?", U. S. Department of Agriculture Forest Service, Research Paper NE-200, 1971.

6. Notice of Proposed Flammability Standard, Federal Register, vol. 34, No. 242, 19812, Thursday, December 18, 1969. Notice of Standard, op. cit., vol. 35, No. 74, APPENDIX I, 38, Thursday, April 16, 1970. See also Federal Specification DDD-C-95, CARPETS AND RUGS, WOOL, NYLON, ACRYLIC, MODACRYLIC, POLYESTER, POLYPROPYLENE, INTERIM AMENDMENT-2, 4.5.13.

7. ASTM E 84-70, Test for SURFACE BURNING CHARACTERISTICS OF BUILDING MATERIALS.

8. Winthrop C. Wolfe, "Field Studies of Floor Coverings", Flooring, vol. 74, No. 11, 52 (Nov., 1968).

9. Winthrop C. Wolfe and William C. Cullen, "Performance Testing of Floor Coverings", page 85, "Performance of Buildings - Concept and Measurement", Building Science Series 1, National Bureau of Standards, January, 1970.

10. Winthrop C. Wolfe, "Performance Tests for Finish Floors. State-of-the-Art", page 799, vol. I, National Bureau of Standards Special Publication 361: Performance Concept in Buildings; Proceedings of the Joint RILEM-ASTM-CIB Symposium, May 2-5, 1971, Philadelphia (Issued March 1972).

APPENDIX A

Detailed Report on Field Observations

A.a. Observations on Flooring by Case Histories

BARRACKS LATRINE, 1968, No. 1. Concrete slab on grade.
A previous epoxy coating was removed, revealing old paint and a rough surface in the center for the room. A trowel-on polyester coating was applied to the floor, apparently while the room was cold (poorly heated during January). After about a week, there were blisters and cracks all over the floor.

BARRACKS LATRINE, 1959-1968, No. 2
A 1/8-inch trowel-on coating was installed over a latex coating which had been installed over a plywood subfloor. Pretreatment consisted of a primer coat and a glass mat. A surface coating was applied over the trowel-on topping. After more than 8 years service the floor was still in good condition.

LAUNDRY, SECTION NEXT TO WINDOWS, 1963-1964, No. 3.a.
The surfacing was removed after one month service.

LAUNDRY - TWO SECTIONS, EACH BETWEEN WASHERS AND DRIERS, 1963-1968.
Nos. 3b, 3c. Concrete slab on grade.
The old concrete floor was acid washed, cleaned with detergent, rinsed with water, and dried with a torch. Primer was applied with a rubber squeegee. While the primer was still tacky, a 1/4-inch layer of green polyester mix was applied. After five years, the floor was still in good condition, although dirty and faded.

MESS HALL KITCHEN, 1959-1962, No. 4
A 3/16-inch trowel-on coating was applied over concrete with a pretreatment consisting of a primer coat and a glass mat. A surface coat was applied over the trowel-on topping. After a few weeks, the coating began to separate from the concrete and became soft. After a year, the top coat was worn off around the dishwashing area. Finally, the bond between coating and concrete failed completely around the stoves and drains. The floor was removed after about three years.

MESS HALL KITCHEN, 1959-1962, No. 5

The concrete subfloor had badly eroded areas at all drains and a few cracks. Grease spots were cleaned with solvent and a solvent-based primer was brushed on. The epoxy coating was troweled on over the primer. The floor gradually disintegrated over a three-year period and a large area around the drain broke loose.

MESS HALL KITCHEN, 1959-1968, No. 6

The installation procedure was as follows:

1) The concrete floor was cleaned with hydrochloric acid.
2) Epoxy resin was brushed into the concrete as a binder.
3) A bed of epoxy mortar and hardener was laid 5/8 to 3/4 inch thick.
4) Abrasive quarry tile, 6- by 6- by 1/2-inch, was set down, not pressed into the bed.
5) The joints were filled with epoxy mortar.

In about six months, some tiles were loose at the corners near the range. The epoxy bed and joints gradually disintegrated under the stoves and hot water heater. After about five years, the tile on the range pads was replaced, using cement mortar. The epoxy under the hot water heater was almost gone. After about 8 years, the black epoxy joints were worn and there were some holes.

MESS HALL KITCHEN, 1959-1965, No. 7a.

An epoxy coating about 1/8-inch thick was troweled on over concrete. After about a year, the coating loosened under the sink, near the range and at the dishwashing area. This was attributed to grease on the original surface. After about six years, the coating was worn and bare concrete showed at three small spots.

MESS HALL KITCHEN, 1959-1968, No. 8

After 9 years, the floor was in fair condition, except for disintegration, roughness, and worn appearance around the floor drain and sink, and a number of fine cracks all over the floor. The floor was dirty and hard to clean.

MESS HALL KITCHEN, 1967-1968, No. 9

After about one year, most of the floor appeared to be in satisfactory condition, but a number of small places around the dishwasher, drain, and hot water heater had become loose and were patched with epoxy composition.

MESS HALL KITCHEN, 1967-1968, No. 10

After six months service, the floor was in excellent condition, smooth and clean looking.

MESS HALL KITCHEN. First installation, 1960-1961, No. 11.a

The coating was removed after five months service.

MESS HALL KITCHEN. Second installation, 1961-1966, No. 11.b. Plywood subfloor.

A latex floor topping had been removed after five months service. Non-skid red quarry tile was installed, using epoxy bed and joints. The installation steps were:

1) A plywood subfloor was installed with 1/4 inch joints between sheets.
2) An epoxy mortar was applied to the plywood subfloor with a notched trowel to 1/4-inch thickness, working the mortar into the plywood joints.
3) The quarry tile was set into the bed, leaving 1/4-inch joints.
4) The joints between the tiles were filled with the mortar used for the bed. The surface was squeegeed and the excess removed with the rubber squeegee. The surface was finally cleaned with wet rags and sponge.

After five years, the joints were in good condition. The tile was in good condition except for some broken by impact - two around the center of the kitchen, one near the stove, and several near the floor drain. Apparently this tile was not affected by heat.

MESS HALL KITCHEN, 1957-1968, No. 12

Red quarry tile was installed over plywood. After about 10 years, the building was closed and broken tiles were being replaced. Several tiles had cracked from impact.

MESS HALL KITCHEN, 1965-1968, No. 13

The concrete floor was installed in 1958. It was still in good condition in 1965. There was some spalling around the drain and dishwashing areas, a few cracks and spalling on the pad under the ranges but no major cracks. The floor was prepared by acid wash; scrubbing with steel wool; scarifying with a machine; another acid wash; and a hose rinse. A polyester primer was placed on the concrete, with a little sand sprinkled on the wet primer. The final polyester coating was placed 1/4-inch thick and was white with green and black chips. After three years, the floor was in excellent condition.

MESS HALL KITCHEN, 1965-1968, No. 14

Quarry tile, 1/2-inch thick, was installed over plywood. After about 13 years, the floor was in excellent condition, except for a few cracked tiles.

MESS HALL KITCHEN, 1957-1968, No. 15

Quarry tile, 1/2-inch thick, was applied over plywood with furan adhesive and mortar joints. The workmanship was poor, the adhesive was not spread thoroughly over the plywood, and the joints looked sloppy. After about three months, 24 tiles cracked, probably due to impact from heavy trash cans; otherwise the installation was satisfactory. After ten years, the tiles were badly cracked. Finally, the broken tiles were replaced where damaged by trash cans, using portland cement grout.

SHOWERS AND DRESSING ROOM IN HOSPITAL, 1960-1966, Nos. 16, 17

The floors were in service for about six years and the space was then converted to classrooms.

SALT SPRAY LABORATORY, 1967-1968, No. 18

The concrete floor was cleaned, acid etched, and rinsed. A polyester prime coat was applied, then the resin topping the same day. The topping consisted of resin, catalyst, marble dust, and crushed granite. The mix was troweled on to about 1/4-inch. About half the thickness was removed with a terrazzo grinder. After 8 months the floor was in satisfactory condition but dirty.

ENTRANCE BETWEEN OUTSIDE DOOR AND LABORATORIES, NEXT TO STAIRS, 1967-1968, No. 19

Polyester tile was installed on the concrete floor, using a 3/32-inch layer of adhesive, applied with a notched trowel. The new installation had cracks between the tiles and some tiles were higher than others, indicating an uneven subfloor. After about 8 months, most of the tiles appeared tight superficially but on close inspection some tiles near the staircase in low traffic areas were loose at the corners. There were cracks between the tiles. The tiles seemed to have leveled off; they were all at the same level. The floor was rather dirty.

ENTRANCE - STAIR LANDING BETWEEN OUTSIDE DOOR AND DOOR TO INSDIE CORRODOR OF OFFICE BUILDING, 1967-1968, No. 21

A polyurethane brush-on coating with vinyl chips was applied to the concrete floor. After about three months the floor was in serviceable condition but looked slightly worn and dirty in traffic areas.

BAKERY, 1966-1967, No. 22

After about three months there were some breaks in the floor and evidence of crumbling in the coating. The floor was removed, the concrete scarified, and the same material was applied again. After about three months, there were several loose places and some flaking. Most of the floor appeared to be in satisfactory condition.

BARRACKS LATRINES AND SHOWER ROOMS (4), 1966-1967, Nos. 23-26, incl.

After about one year service, most of the floor, in each case, was in good condition over most of the area, but there were loose places and blisters at various positions, especially around the drains and toilets.

MESS HALL KITCHEN, 1966-1968, No. 27

A 1/4-inch polyester coating was troweled on over concrete. After 1-1/2 years service, no defects were reported.

BARRACKS LATRINES AND SHOWER ROOMS (2), 1965-1968, Nos. 28, 29

The coatings, about 1/16-inch thick, were in satisfactory condition after three years, except for peeling around the drinking fountain in one latrine and peeling in the back part of the shower room in the other latrine.

BARRACKS LATRINE, 1966-1967, No. 30

After ten months service the floor was rough but satisfactory.

BARRACKS LATRINES AND SHOWER ROOMS (5), 1966-1968, Nos. 31-35, incl.

All floors were in satisfactory condition after about one year service.

MESS HALL KITCHEN, 1966-1968, No. 31

After one year, the floor was in good condition.

MESS HALL KITCHEN, 1967, No. 37

After about six months service, the floor was in good condition, but rough and uneven, with indentations; its condition was attributed to poor troweling.

MEAT CUTTING PLANT, 1965-1967, No. 38. Concrete slab on grade.

The coating was loose and peeling off after two years service, although the same materials and application method was used as in the laundry, No. 39.

LAUNDRY, 1965-1967, No. 39. Concrete slab on grade.

The floor was in good condition after two years service.

BARRACKS LATRINES AND SHOWER ROOMS (2), 1966-1968, Nos. 40, 41

Soon after installation, the floors appeared rough, porous, stained, and hard to clean. After sealing, the floors were satisfactory and no trouble was reported during the first year of service.

LAUNDRY AREA NEXT TO WINDOWS BETWEEN WASHERS AND DRIERS. First installation, January-March 1964, No. 42.a.(1)

The concrete floor was cleaned thoroughly with caustic, the loose concrete was removed, and the floor thoroughly dried. Holes were filled with a polyurethane coating containing a small amount of sand. Four coatings were applied with a roller and the last two were sprinkled with sand. The total thickness was about 3/16 inch. The coating began to lose bond around the edges after about six weeks and was removed after about four months because of bond failure.

LAUNDRY AREA NEXT TO WINDOWS BETWEEN WASHERS AND DRIERS. Second installation, May 1964-November 1966, No. 42.a.(2)

A coating of 1 part sand to 3 parts epoxy resin was rolled on the cleaned concrete. Then two successive coatings of polyurethane resin were applied and a white, pigmented polyurethane composition was troweled on.

After drying, the coating was wetted with solvent to make it tacky and a polyurethane mix with walnut shell flour, brick color, was troweled on to 1/4-inch thickness. After about two years, the coating disintegrated, became soft and loose, and was peeling off in large sections. Pools of water were standing on the uneven floor.

LAUNDRY, THIRD BAY FROM WINDOWS. First installations, 1964, No. 42.b(1). (The second installation, 1964, was a polyurethane coating No. 42.b.(2).) The concrete floor had become eroded and spalled due to impact from heavy equipment, rolling friction of steel wheels, and the action of hot water, starch, and detergents. The floor was acid etched, rinsed with water, and dried. A solvent-based epoxy primer was rolled on. Cracks, holes, and joints were filled with an epoxy patching compound. Three 10-mil coats of gray epoxy composition were rolled on. After about a month, the floor was removed because of poor bond. Some of the floor coating had already peeled off.

LAUNDRY, THIRD BAY FROM WINDOWS. Second installation, 1964-1966. No. 42.b.(2). (The first installation, 1964, No. 42.b.(1), was an epoxy coating). The coating was applied in the same manner and with the same composition as the previous installation in the area next to the windows, between washers and driers, No. 42.a.(2), but the test color was white and the mix had a sand filler. This disintegrated and peeled after about two years service.

MESS HALL KITCHEN, No. 43

An epoxy coating had peeled off in large sections during approximately three years service.

MESS HALL KITCHEN, 1964. No. 44. Concrete slab on grade.

The original wood floor had been removed and the space had been graded with a compacted fill. A concrete floor was then poured over the fill. Subsequently an epoxy coating was troweled on. This coating proved hard to clean.

STOREROOM, 1966, No. 45. Concrete slab on grade.

The topping was applied over rough, spalled concrete. After a few weeks, while fork lift trucks were operating over the floor, the topping was in good condition except for some gouges.

PLUMBING SHOP, 1964-1969, No. 46. Concrete slab on grade.

After two years the floor was in good condition except for some structural cracks. After five years service the general appearance was poor, with long cracks and gouges. When wet, workmen track in black marks into the office and locker room. 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 or surfacing is satisfactory.

STAIRS OUTSIDE BARRACKS, 1966-1969, No. 47. Steel stairs outside brick building covered with a concrete roof.

A polyurethane brush-on coating with fine stone aggregate in blue, white and black colors was used on the steel stairs from the first to the second floor. This was applied to the treads; a thick layer was used on the upper part of the stairs. Soon after application, some wear was noticeable, especially on the lower part of the stairs, where the paint was worn off the steel nose pieces. Considerable metal was worn away. There was less wear on the upper part of the stairs, where the steel nose pieces were scarcely worn and the white paint was still intact. After about 18 months, the stairs were still in satisfactory condition. However, after three years service the coating was badly worn all over.

WALK RAMP OUTSIDE COMMISSARY, 1967-1969, No. 48

Non-slip, trowel-on epoxy coating was in good condition after 8 months service, but somewhat worn and smooth in traffic areas. After two years service only a little of the coating was left and most of the loose material was removed.

FIRE STATION, 1966-1969, No. 49. Concrete slab on grade.

Holes in the concrete floor were patched with concrete and troweled. The floor was acid washed and cleaned with alkaline detergent. An epoxy based primer was applied and then three coats of urethane based finish. Reclaimed vinyl chips were used as a filler. The first coat was sanded. The total thickness was between 1/16 and 1/8 inch. After about two months, the coating yellowed at the entrance where it was exposed to direct sunlight. The floor also showed damage from the sharp edges of trash cans, although it was not affected by pick-up trucks being driven over it. After about 19 months, the floor showed more impact damage and

it was necessary to apply a fresh seal coat. 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 fire trick, and the area near the back door, were refinished due to lack of bond. Overall, there is some scuffing and there are some chipped places. However, the refinishing and recoating do not seem excessive compared to repainting a painted floor, which would be necessary about every six months.

MESS HALL KITCHEN, 1959-1960, No. 50

An epoxy coating was applied over a concrete floor in a 200 sq. ft. dishwashing area. The concrete surface was acid etched and a sealer coat was applied. A red epoxy coating was troweled on about 1/4 inch thick. After 24 hours a red, pigmented skim coat was applied. After 16 months there was no sign of bond failure or erosion but the floor was unattractive and there were a number of chipped places due to impact from trays, etc.

MESS HALL KITCHEN, DISHWASHING AREA, 1967, No. 51. Concrete slab, 4 inches thick, over a wooden subfloor.

The floor is subjected to hand trucks. The surface was chipped in heavy traffic areas and was dirty but otherwise it was in satisfactory condition.

RESIDENCES - KITCHENS AND LIVING QUARTERS, (2), 1966-1969. Nos. 52, 53.

Polyurethane brush-on decorative coating with vinyl chips was applied over vinyl asbestos tile in the kitchens of two homes. Clear polyurethane finish on the wood floors in both homes was in excellent condition with no yellowing or darkening and without refinishing. Both kitchen floors were in fair to good condition after three years service. The brush-on decorative coating in No. 52 kitchen was in excellent condition except for separation around the edges against the painted wood 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 probably harder to clean than a perfectly smooth surface. Also, scouring

powder had been used to clean the floor, which would account for at least some of the scratches [8] and a scratched floor would be still more difficult to clean because dirt is likely to collect in the scratches.

INTENSIVE CARE UNIT, No. 54.a, and CIRCULAR OPERATING WING, No. 54.b, 1964-1968 (2)

The floors were reported to be in satisfactory condition after about four years.

ANIMAL OPERATING ROOMS AND HALL, 1963-1968, No. 55

Epoxy terrazzo with granite chips was in good condition after five years service.

ANIMAL ROOM - "CLEAN ROOM", 1963-1968, No. 56.a. Concrete slab on grade. The floor was in good condition after five years service.

ANIMAL ROOM - "CLEAN ROOM", 1963-1968, No. 56.b. Concrete slab on grade. Epoxy terrazzo with granite chips was in good condition after five years service.

ANIMAL ROOM - "CLEAN ROOM", 1966-1968, No. 56.c. Concrete slab on grade. A one-component polyurethane composition was applied in two coats over a similar coating in 1966. The appearance was gray and shiny. The floor was in good condition after two years service.

ANIMAL ROOM - "CLEAN ROOM", 1963-1968, No. 56.d. Concrete slab on grade. Fiberglass-reinforced epoxy trowel-on coating was in good condition after five years service.

ANIMAL ROOM - "CLEAN ROOM", 1963-1968, No. 56.e. Concrete slab on grade. The floor was in good condition after five years service.

ANIMAL ROOM - "CLEAN ROOM", 1966, No. 56.f. Concrete slab on grade. Three coatings of epoxy composition were rolled on over a rough polyester coating. Total thickness is about 20 mils. After about a year the coating seemed to be in satisfactory condition.

CENTER CORRIDOR BETWEEN ANIMAL "CLEAN" ROOMS, 1963-1968, No. 56.g. The floor appeared to be in good condition after five years.

OPERATING SUITE, 1963-1968, No. 57

Conductive neoprene latex terrazzo flooring was installed in January 1963. After about five years, the conductivity has remained about the same. The floors look dull. In the operating rooms, there is some

pitting in the middle of the room where the operating table is placed. There were also gouges in the corridor near a steel nose piece.

LABORATORY GLASSWARE WASHING FACILITY, 1966-1970, No. 58. Concrete slab on grade.

The floor had been covered with asphalt or vinyl asbestos tile, using asphalt adhesive. The tile and mastic were removed and decorative polyurethane brush-on coating was applied. The coating consisted of a primer and three finish coats with vinyl chips. Some sand was broadcast onto the surface before complete setting or hardening to skidproof the coating. The new floor was subjected to pipe fitting operations. After about 18 months, the floor was serviceable but unattractive. The floor was stained in places with dye. One place was etched and discolored with a sulfuric acid-dichromate mixture used to clean laboratory glassware. The floor was hard to clean and the finish was worn and dull. After four years service most of the floor was still in fairly good condition even around all but one of the sinks. However, the area around the sink where sulfuric acid-dichromate mixture was used had failed. The coating around this sink was destroyed to the bare concrete floor. A rubber mat around this sink would have solved this problem.

CONCRETE SUN DECK IN HOSPITAL, 1966-1970, No. 59

The sun deck roof was refinished with a concrete topping, then covered with a 1/4-inch thick polyester thin-set terrazzo. After 16 months, the deck covering was in good condition but contained long, structural cracks (repaired with a caulking compound), and stained with rust from a down-spout. After four years service the floor was dirty and badly stained with many cracks caulked with a white sealant. The installation should have had expansion joints.

RECREATION BUILDING, 1966-1970, No. 60

A polyurethane decorative coating was applied over 1/2-inch particle-board, laid over a wood floor, using a primer and three coats. After about a year, the floor was worn in places and there were some cracks, with evidence of peeling adjacent to the cracks. The floor was rather dirty, probably due to poor maintenance. After four years service the floor was still in fair condition with an overall dull appearance and cracks in some places and pitted in some areas. However, areas outside

the traffic pattern were in good condition and looked new under the pool table and ping pong table.

MEAT CUTTING PLANT, 1966-1970, No. 61

After about three months service the floor was in excellent condition. However, after four years service there were a number of rough places and whitish areas, probably due to pulling away of aggregate from the resin matrix, (which might result from applying a fresh batch of mix and troweling). Otherwise the floor was in good condition and there were no bonding problems.

AIRLINE TERMINAL, 1967-1969, No. 62

Polyester thin-set terrazzo, 1/4-inch thick was installed over new concrete in 1967. After 1-1/2 years service there were 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. The area covers about 30,000 sq. ft. and the floor base is a 3-inch composite steel deck with bar-joint suspension. The building is adjacent to an older terminal and suffers vibrations from aircraft.

FIRE STATION, 1968-1971, No. 63. Concrete slab on grade.

Thin-set epoxy terrazzo with green and white marble chips was installed in 1968 over a 2-inch concrete slab on fill, originally coated with gray deck enamel. Procedure for preparation of the surface and installation of the terrazzo was as follows:

1) Paint remover and rags were used to remove the deck enamel.
2) The floor was ground lightly, using a hand grinder with horizontal axis, and the floor was rinsed with water. Grinding and rinsing were repeated twice. The floor was allowed to dry overnight.
3) A skim coat of epoxy primer was troweled on.
4) While the primer was still wet and tacky, the terrazzo mix was troweled on about 1/4-inch thick.
5) The floor was ground with a terrazzo grinder beginning the next day.

The floor area, about 225 sq. ft., is 11- by 19-ft. plus a 2- by 7-ft. area under the stairs. The largest span is 16 ft. There are no divider strips. The room is used as a vestibule and is the main entrance to the living quarters upstairs and to a classroom, which is used occasionally. The traffic is moderate. After about three years the floor appears to be in perfect condition. The floor is cleaned and waxed regularly.

CONCRETE SUN DECKS IN HOSPITAL, 1967-1970, Nos. 64a, 64b

Two concrete sun decks had originally been covered with quarry tile on coal tar pitch beds. The quarry tile was in bad condition and was removed in 1967 and a polyester thin-set terrazzo was installed at that time. After three years service, both decks were in fairly good condition. However, there were some white spots due to faulty application and some fine hairline cracks on both sun decks. One of the decks was in worse condition. On this deck there was a wide structural crack; the floor was much dirtier, with rust stains; and the area near the drain was patched because the floor was toohigh and did not drain.

APARTMENT IN HOUSING PROJECT, 1969-1971, No. 65

On March 25, 1969, a monolithic surfacing or seamless floor system was applied to the floor of an apartment dwelling unit in which there had been a fire with damage to the asphalt tile. Some of the tile had been removed but most of it was intact. Over the asphalt tile and the mastic of the removed tiles was brushed on a base coat of epoxy-polyamide emulsion in water. After about two hours, an epoxy-polyamide resin based "wet coat" was applied, into which was sprinkled decorative vinyl chips. Another "wet coat" was applied, followed by several "glaze coats" of moisture-cured polyurethane. After two years, on March 24, 1971, the coating was in excellent condition with no complaints from the tenants. There were a few scars near the door from movers and a few seams from the old tile showed through. A new toilet had been installed in the bathroom which was narrower than the old one and exposed linoleum underneath which had served as a base for the coating in the bathroom. There was no sign of peeling at the edges.

MASS HALL KITCHEN, 1970-1971, No. 66. Concrete slab on grade.

The original wood floor was removed; a concrete block wall was installed; the space under the floor was filled in; and a concrete slab on grade

was placed over the fill. The concrete slab deteriorated and eroded with use. A concrete topping and then an epoxy topping were tried but failed because of poor bond. On February 12, 1970, the concrete surfacing with epoxy additive was applied. The surface was prepared by acid etching, followed by thorough rinsing with water. After air drying for 17 hours, the hairline cracks in the concrete floor were sealed with a proprietary floor sealer, probably based on acrylic resin. Three coats of sealer were applied over the cracks and two coats over the entire floor. A two-inch thick topping was then applied, using a proprietary portland cement mix, modified with an additive of emulsified epoxy resin. Application was started while the primer or sealer was still tacky, after two or three hours. Six months later, in August 1970, two coats of floor sealer were applied to seal hairline cracks which appeared in the topping or surfacing. On October 12, 1970, after eight months service, the floor showed many irregular fine cracks and whitish places near the sink, probably due to the effect of moisture on the sealer or "blushing". The floor was somewhat slippery, which is probably due to the sealer. There were some rough places near one of the sinks. There was a traffic pattern at the serving line where the sealer had visibly worn off. The storeroom area was in good condition with no cracks. On February 4, 1971, after about one year service, the floor was about the same and generally in good contion, very smooth and even, but with some hairline cracks.

OFFICE BUILDING, 1943-1971, No. 67

The original flooring was asphalt tile, laid on concrete, 3/16-inch thick in the corridors and 1/8-inch thick in the offices. Over half of this is still in use, especially in the corridors. Some offices now have vinyl asbestos tile, which is generally light colored. The original asphalt tile is almost black. There are about 30,000 employees in the building but there are many entrances, including six public entrances. Most people (probably 85 percent) carry bag lunches, so that the noon traffic is not very heavy. Most of the traffic is one way in the morning and the reverse in the evening. Two of the public exits are the most widely used. There are two men assigned to repair and replacement and 385 men on the general maintenance staff. There is about 6,000,000

gross and 3,600,000 net square feet of floor area*. There is a noticeable traffic pattern in the corridors over the entire width except by one tile width at each wall. The asphalt tile appears badly worn with seams obliterated, gouges, and scarred places, but is not yet worn through in most places. However, there are some bare places near entrances where the tile is worn through to the concrete. The tile has been replaced in front of drinking fountains. The original asphalt tile does not indent as badly as the vinyl asbestos tile used in some of the offices but it is more susceptible to scratches. In some corridors new 1/8-inch asphalt tile is somewhat lower than the original 3/16 asphalt tile and in other corridors the new tile is about level with the original tile, so that the overall wear may or may not be as much as 1/16 inch. Some of the tile was replaced on the first floor where the tile was laid on concrete slab on grade. The concrete slab was laid on a swamp with no vapor barrier and this resulted in water seepage, causing damage from efflorescence. Originally there was a white, powdery residue on the tiles from efflorescence and later gouges appeared.

SUBURBAN PRIVATE HOSPITAL - CORONARY CARE UNIT, 1966-1968, No. 68

A commercial low-level looped pile nylon carpet with sponge rubber cushion was installed in the coronary care unit, which has relatively little traffic and spillage. The head nurse said that the 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 only been vacuumed, not shampooed. The carpet was in service for about two years, then the unit was transferred to another floor and the carpet was removed.

CITY PRIVATE HOSPITAL, 1969-1972, No. 69

The carpet was installed in 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, cemented wall-to-wall without cushioning.

*Gross space is all livable interior space with corresponding gross floor area. Net space is space cleaned on a scheduled basis, as every night, every week, etc. Net floor area is that of the net space.

According to measurements by the National Bureau of Standards, the pile height was 0.219 inch; total thickness 0.365 inch; weight of yarn 58.9 ounces per square yard. Tests performed by the Bureau's Office of Flammable Fabrics indicated that the carpet passed the U. S. Department of Commerce Proposed Flammability Standard of 1969, essentially the same as the Standard of 1970 [5]. Acoustics tests by the Bureau's Building Research Division, before and after installation, showed reduction in noise level but it was not established that the noise level reduction was 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 that for resilient tile. The carpet is shampooed about every three months and vacuumed daily. Patients' rooms are shampooed after check-out. We have observed the installation periodically and the appearance of most of the carpet during the three year period of service is fair to good. It does not appear worn near the elevators or stairs and is still in place in the corridors, patients'; rooms, bathrooms, and stair landings. However, the carpet has been replaced by embossed sheet vinyl in the nurses' station, adjacent closet, and in the serving room or kitchen area because of wear or unsatisfactory appearance. The overall appearance is somewhat dull and there are some stains and black marks. The carpet appears a little matted and the pile needs brushing periodically. Extensive spotting is necessary and there are numerous stains in the corridors from coffee, soft drinks, etc., although these are not very noticeable. There are noticeable stains in the patients' rooms and also cigarette burns, so that a number of repairs have been made by cutting circular sections and cementing in patches. Some of the nurses have complained about the persistent odor due to spillage of food and body fluids, which was difficult to remove even by thorough shampooing. The

overall impression is that the carpet is satisfactory for corridors but not for patients' rooms, bathrooms, kitchen or serving areas, or nurses' stations.

URBAN SUPERMARKET, 1967-1972, No. 70

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 appeared firm and food carts could 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, in August 1970, the carpet in the worst areas around the vegetable bins, meat and seafood counters, was replaced with the same type of carpet of a different color. The original carpet around the check-out areas was noticeably worn and the original carpet in the rest of the store had deteriorated in appearance. After about five years service, in 1971, the carpet was replaced with another low-level, looped pile, nylon carpet (without cushion) which was cemented to the floor. The manufacturer's specifications were: 22 ounces/sq. yd. face weight; 56 ounces/sq. yd. total weight; 3 ply nylon; 7 rows per inch; 270 pitch. The new carpet was inspected in February 1972, and appeared to be in good condition but with some stains and adhered chewing gum. Mats were placed over the carpet near the storeroom and entrance but not near any of the bins, counters, or freezers. The carpet seemed firmer and it was easier to push food carts, which could be moved readily even by frail elderly people. The general impression was that, while the original carpet was in service for five years, it should have been replaced earlier and could not be maintained economically in a satisfactory condition even with the use of mats and partial replacement.

PRIVATE OFFICE BUILDING - CORRIDORS, 1966-1970, No. 71

A sponge rubber backed low-level, looped pile, woven nylon carpet was cemented over resilient tile in 1966 in the corridors of a 12-story office building. 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 the adhesion and with seams which scrubbing tends to open. Sponge rubber cannot be obtained in widths greater than 54 inches, so there are more seams than there would be with broadloom carpet with foam rubber cushion. In 1970 the carpet was still in good condition and was clean without stains. However, some areas appeared to be patched and there was 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 they are not shampooed.

ARMY BARRACKS, 1968-1970, Woven looped pile wool carpet without cushion, LOBBY OF MEN'S BARRACKS, No. 72a

There were some problems initially with fuzzing but the carpet appears to be in good condition after two years of service. There are a few cigarette burns and some depressions due to an uneven pad. The carpet is vacuumed daily but is not shampooed.

LOBBY OF WOMEN'S BARRACKS, No. 72.b

The carpet was in good condition after two years of service except for a number of stains. The carpet needs shampooing and spotting.

DAY-ROOM, WOMEN'S BARRACKS, No. 72.c

A number of cigarette burns were noted after one year of service but otherwise the carpet was in good condition. After two years of service the carpet appeared dirty, with a number of stains and cigarette burns but was otherwise in good condition. The carpet needs shampooing and spotting.

SUBURBAN CHURCH, 1967-1971, No. 73

A dull blue, wool velvet-twist carpet was installed in the sanctuary, April 1967. Installation was by the tackless method over a combination hair-jute pad, in rows 15 ft. wide, with the pad on the bias. The sanctuary is irregular in shape and a good deal of cutting and fitting were required. The carpet was stretched over 6-inch tackless strips

about 6 inches apart and seamed with paper-plastic tape, using a hot iron. The carpet was finally shrunk to shape with water. After the installation the carpet was dirty but the appearance was restored by cleaning. Some of the carpet was examined and the tufts were easily pulled out by hand, suggesting possible damage by children. According to Federal Specification DDD-C-95, the tuft bind for single level cut pile twist, Table II, Class 2, is 16 ounces, a rather low figure. Although the tufts pull out easily, the carpet probably conforms to DDD-C-95 with respect to tuft bind and cannot be considered substandard. The installation was examined four years later in April 1971. The overall appearance was very good and smooth except for the aisle on the left hand side facing the altar, where there was some buckling in places, indicating a need for re-stretching. The carpet was clean and there was no sign of wear. The staff had not noticed any appreciable extra work in maintenance. The only noticeable defect except for the buckling was indentation where kneeling benches rest on the carpet. These indentations were deep and permanent.

A.b. Observations on Flooring by Materials[a]

Epoxy Monolithic Surfacings (14)

(a) Brush-on or roll-on type (2)

FAILURES (1)

Laundry, No. 42b(1) - concrete slab on grade - loss of bond - water, starch, detergents (1 mo.)

SATISFACTORY INSTALLATION (1)

Animal room, No. 56f - concrete slab on grade (1 yr.)

(b) Trowel-on industrial type (9)

FAILURES (5)

Mess hall kitchens (4), Nos. 4, 5, 7a, 43 - concrete subfloor - loss of bond, crumbling - hot water, detergents, grease (3-6 yrs.)

---

a. After each installation is indicated type of subfloor. In case of failure or "fairly satisfactory" installation, the type and probable cause of failure or defect are listed. Service period observed is in parentheses in each case.

Walk ramp outside commissary, No. 48 - steel substrate - wear - foot traffic (2 yrs.)

FAIRLY SATISFACTORY INSTALLATIONS (2)

Mess hall kitchen, No. 44 - concrete slab on fill - hard to clean

Mess hall kitchen, No. 50 - concrete subfloor - unattractive, chipped (16 mos.)

SATISFACTORY INSTALLATIONS (2)

Barracks latrine, No. 2 - plywood subfloor (8 yrs.)

Animal room, No. 56d - concrete slab on grade (5 yrs.)

(c) Thin-set Terrazzo (3)

SATISFACTORY INSTALLATIONS (3)

Animal operating rooms and hall, No. 55 - concrete subfloor (5 yrs.)

Animal room, No. 56b - concrete slab on grade (5 yrs.)

Fire station, No. 63 - concrete slab on grade (3 yrs.)

Polyester Monolithic Surfacings (20)

(a) Trowel-on industrial type (14)

FAILURES (2)

Barracks latrine, No. 1 - concrete slab on grade - blisters and cracks - low temperature (1 week)

Meat cutting plant, No. 38 - bond failure - grease on concrete subfloor (2 yrs.)

FAIRLY SATISFACTORY INSTALLATIONS (2)

Laundry sections, Nos. 3b, 3c - concrete slab on grade - dirty and faded - maintenance and pigment used in mix (5 yrs.)

Mess hall kitchen, No. 37 - concrete subfloor - rough and uneven - poor troweling (6 mos.)

SATISFACTORY INSTALLATIONS (10)

Barracks latrines and shower rooms (7), Nos. 31-35, incl., 40-41 - concrete slabs on grade (1 yr.)

Laundry, No. 39 - concrete slab on grade (2 yrs.)

Mess hall kitchens (2), Nos. 13, 27 - concrete subfloors (1-1/2 yrs, 3 yrs.)

(b) Thin-set Terrazzo (6)

FAILURE (1)

Concrete sun deck, No. 59 - concrete subfloor - cracks - expansion and contraction from weather (4 yrs.)

FAIRLY SATISFACTORY INSTALLATIONS (5)

Airline terminal, No. 62 - concrete slab over steel deck - cracks - vibrations from aircraft (1-1/2 yr.)

Salt spray laboratory, No. 18 - concrete subfloor - dirty - poor maintenance (8 mos.)

Concrete sun decks (2), Nos. 64a, 64b - concrete subfloors - whitish spots - faulty application
crack - structural, from movement of subfloor (3 yrs.)

Meat cutting plant, No. 61 - concrete slab on grade - rough spots, whitish areas - faulty application (4 yrs.)

SATISFACTORY INSTALLATIONS (1)

Mess hall kitchen, No. 10 - concrete subfloor (6 mos.)

Polyurethane Monolithic Surfacings (16)

(a) Brush-on or roll-on type (13)

FAILURES (6)

Barracks latrines and shower rooms (4), Nos. 23-26, incl. - concrete slabs on grade - bond failure, blisters - moisture (1 yr.)

Laboratory glassware washing facility, No. 58 - concrete slab on grade - disintegration - acid cleaning mixture (4 yrs.)

Stairs outside barracks, No. 47 - steel substrate - wear - foot traffic (3 yrs.)

FAIRLY SATISFACTORY INSTALLATIONS (3)

Fire station, No. 49 - concrete slab on grade - bond failure, chipping - impact from hoses, cans (3 yrs.)

Entrance, No. 21 - concrete subfloor - worn and dirty - poor maintenance, possibly not best material for installation (3 mos.)

Recreation area, No. 60 - particleboard over wooden floor - cracks, some peeling, dull and pitted - not best material for installation (4 yrs.)

SATISFACTORY INSTALLATIONS (4)

Barracks latrine, No. 30 - concrete slab on grade (10 mos.)

Animal room, No. 56c - concrete slab on grade (2 yrs.)

Residences, Nos. 52, 53 - vinyl asbestos tile in kitchen and wooden floors in other rooms (3 yrs.)

(b) Trowel-on industrial type (3)

FAILURES (2)

Laundry, No. 42a(2), 42b(2) - concrete slab on grade - bond failure, disintegration - water, starch, detergents (2 yrs.)

FAIRLY SATISFACTORY INSTALLATION (1)

Mess hall kitchen, No. 9 - concrete subfloor - bond failures around dishwasher, drain, hot water heater, water, heat (1 yr.)

Various Resin Monolithic Surfacings

(a) Vinyl-acrylic brush-on type (2)

FAIRLY SATISFACTORY INSTALLATIONS (2)

Barracks latrines and shower rooms (2), Nos. 28, 29 - concrete slab on grade - bond failure in wet areas - moisture, improper installation (3 yrs.)

(b) Epoxy-polyamide polyurethane brush-on type (1)

SATISFACTORY INSTALLATION (1)

Apartment No. 65 - concrete subfloor with damaged asphalt tile and old mastic (2 yrs.)

(c) Vinyl trowel-on industrial type (1)

SATISFACTORY INSTALLATION (1)

Animal room, No. 56e - concrete slab on grade (5 yrs.)

(d) Furan trowel-on industrial type (1)

FAILURE (1)

Laundry, No. 3a - concrete slab on grade - unknown (1 mo.)

Monolithic Surfacings Based on Portland Cement and Additives (6)

(a) Acrylic latex additive (2)

FAIRLY SATISFACTORY INSTALLATIONS (2)

Mess hall kitchen, No. 8 - concrete subfloor - fine cracks, wear and crumbling around floor drain and sink, dirty - water, heat, faulty installation, poor maintenance (9 yrs.)

Mess hall kitchen, No. 51 - concrete slab over wooden subfloor - some chipping - heavy traffic

(b) Epoxy emulsion additive (1)

FAIRLY SATISFACTORY INSTALLATION (1)

Mess hall kitchen, No. 66 - concrete slab on grade - fine cracks filled in with sealer, which made floor slippery and caused whitish places and traffic patterns from wear, some rough places near sink - faulty application, improper choice of materials (1 yr.)

(c) Styrene-butadiene latex additive (1)

FAILURE (1)

Mess hall kitchen, No. 11a - concrete subfloor - unknown (5 mos.)

(d) Asphalt additive (2)

FAILURE (1)

Plumbing shop, No. 46 - concrete slab on grade - cracks, gouges, contamination of adjacent areas - improper choice of materials (5 yrs.)

SATISFACTORY INSTALLATION (1)

Storeroom, No. 45 - concrete slab on grade

Monolithic Surfacings Based on Alumina Cement and Neoprene Latex Additive (8)

FAILURE (1)

Bakery, No. 22 - concrete slab on grade - crumbling - improper application or mixing (3 mos.)

FAIRLY SATISFACTORY INSTALLATION (1)

Operating suite, No. 57 - concrete subfloor - dull appearance, some pitting, gouging - possibly not best material for installation (5 yrs.)

SATISFACTORY INSTALLATIONS (6)

Mess hall kitchen, No. 36 - concrete subfloor (1 yr.)

Showers and dressing room in hospital, Nos. 16, 17 - concrete subfloor (6 yrs.)

Intensive care unit, No. 54a and Operating wing, No. 54b - concrete subfloors (4 yrs.)

Corridor between animal rooms, No. 56g - concrete slab on grade (5 yrs.)

Resilient Floor Coverings (3)

(a) Asphalt tile - SATISFACTORY INSTALLATION

Office building, No. 67 - concrete subfloors, on and above grade (28 yrs.)

(b) Sheet vinyl - SATISFACTORY INSTALLATION

Animal room, No. 56a - concrete slab on grade (5 yrs.)

(c) Polyester tile - FAIRLY SATISFACTORY INSTALLATION

Entrance to laboratories, No. 19 - concrete subfloor - cracks, uneveness, some bond failures, dirty floor - improper material for installation, faulty application (concrete should have been leveled with mastic), poor maintenance (8 mos.)

Quarry Tile (5)

(a) with epoxy bed and joints (2)

FAIRLY SATISFACTORY INSTALLATION (1)

Mess hall kitchen, No. 6 - concrete subfloor - bond failures near range, joint failures near stoves, hot water heater - improper materials for installation (8 yrs.)

SATISFACTORY INSTALLATION (1)

Mess hall kitchen, No. 11b - plywood subfloor (5 yrs.)

(b) with furan bed and joints (3)

FAIRLY SATISFACTORY INSTALLATION (1)

Mess hall kitchen, No. 15 - plywood subfloor - poor joints, cracking - poor workmanship in installation, impact from abuse of floor, possibly not best choice of materials for installation (10 yrs.)

SATISFACTORY INSTALLATIONS (2)

Mess hall kitchens, Nos. 12, 14 - plywood subfloor (10, 13 yrs.)

Carpet (8)

FAILURE (1)

Low-level, looped pile, nylon with sponge rubber cushion

Urban supermarket, No. 70 - concrete slab on grade - dirty, stained, worn - improper choice of material for installation (5 yrs.)

FAIRLY SATISFACTORY INSTALLATIONS (5)

Medium-level, looped pile, acrylic without cushion

Hospital nursing unit, No. 69 - suspended concrete slab - stains, cigarette burns, persistent odor, wear in some places - improper choice of material for certain locations, as nurses' station, food serving area, bathrooms, patients' rooms (3 yrs.)

Low-level, looped pile, nylon with sponge rubber cushion

Office building, No. 71 - suspended concrete slabs - some patching, split seams - faulty installation (4 yrs.)

Looped pile wool without cushion (3)

Army barracks (3), Nos. 72a, b, c - concrete slabs on grade - cigarette burns, stains, dirt - abuse, poor maintenance, possibly not best choice of material for location (2 yrs.)

SATISFACTORY INSTALLATIONS (2)

Low-level, looped pile, nylon with sponge rubber cushion

Hospital coronary care unit, No. 68 - suspended concrete slab (2 yrs.)

Wool, velvet twist, over hair-jute pad

Suburban church, No. 73 - concrete slab on grade (4 yrs.)

A.c. Observations on Flooring by Locations

Location	Type of Flooring	Service Time	Rating
Airline terminal			
	Polyester thin-set terrazzo, No. 62	1-1/2 yrs.	FAIRLY SATISFACTORY
Animal rooms			
	Epoxy brush-on, No. 56f	1 yr.	SATISFACTORY
	Epoxy trowel-on, No. 56d	5 yrs.	SATISFACTORY
	Epoxy thin-set terrazzo, Nos. 55, 56b	5 yrs.	SATISFACTORY
	Polyurethane brush-on, No. 56c	2 yrs.	SATISFACTORY
	Vinyl trowel-on, No. 56e	5 yrs.	SATISFACTORY
	Sheet vinyl, No. 56a	5 yrs.	SATISFACTORY
Bakery			
	Alumina cement - neoprene latex, No. 22	3 mos.	FAILURE
Barracks, military			
	Carpet, Nos. 72a, b, c	2 yrs.	FAIRLY SATISFACTORY
Church			
	Carpet, No. 73	4 yrs.	SATISFACTORY
Concrete floors, residential			
	Epoxy-polyamide-polyurethane brush-on No. 65 (over old asphalt tile)	2 yrs.	SATISFACTORY
Concrete sun decks			
	Polyester thin-set terrazzo		
	No. 59	4 yrs.	FAILURE
	No. 64a, b	3 yrs.	FAIRLY SATISFACTORY
Corridor between animal rooms			
	Alumina cement - neoprene latex, No. 56g	5 yrs.	SATISFACTORY
Entrance to laboratory building			
	Polyester tile, No. 19	8 mos.	FAIRLY SATISFACTORY
Entrance to office building			
	Polyurethane brush-on, No. 21	3 mos.	FAIRLY SATISFACTORY
Fire station			
	Epoxy thin-set terrazzo, No. 63	3 yrs.	SATISFACTORY
	Polyurethane brush-on, No. 49	3 yrs.	FAIRLY SATISFACTORY
Hospital nursing units			
	Alumina cement - neoprene latex, No. 54a	4 yrs.	SATISFACTORY

Location	Type of Flooring	Service Time	Rating
Hospital nursing units (cont.)			
	Carpet		
	No. 69	3 yrs.	FAIRLY SATISFACTORY
	No. 68	2 yrs.	SATISFACTORY
Hospital operating suites			
	Alumina cement - neoprene latex		
	No. 57	5 yrs.	FAIRLY SATISFACTORY
	No. 54b	4 yrs.	SATISFACTORY
Kitchens, military			
	Epoxy trowel-on		
	Nos. 4, 5, 43	3 yrs.	FAILURE
	No. 7a	6 yrs.	FAILURE
	No. 44	--	FAIRLY SATISFACTORY
	No. 50	16 mos.	FAIRLY SATISFACTORY
	Polyester trowel-on		
	No. 37	6 mos.	FAIRLY SATISFACTORY
	No. 13	3 yrs.	SATISFACTORY
	No. 27	1 1/2 yrs.	SATISFACTORY
	Polyester thin-set terrazzo, No. 10	6 mos.	SATISFACTORY
	Polyurethane trowel-on, No. 9	1 yr.	SATISFACTORY
	Portland cement - acrylic latex		
	No. 8	9 yrs.	FAIRLY SATISFACTORY
	No. 51	--	FAIRLY SATISFACTORY
	Portland cement - epoxy emulsion, No. 66	1 yr.	FAIRLY SATISFACTORY
	Portland cement - styrene-butadiene latex		
	No. 11a	5 mos.	FAILURE
	Alumina cement - neoprene latex, No. 36	1 yr.	SATISFACTORY
	Quarry tile with epoxy bed and joints		
	No. 6	8 yrs.	FAIRLY SATISFACTORY
	No. 11b	5 yrs.	SATISFACTORY
	Quarry tile with furan bed and joints		
	No. 15	10 yrs.	FAIRLY SATISFACTORY
	No. 12	10 yrs.	SATISFACTORY
	No. 14	13 yrs.	SATISFACTORY

Location	Type of Flooring	Service Time	Rating
Kitchens, residential			
	Polyurethane brush-on, Nos. 52, 53	3 yrs.	SATISFACTORY
Laboratory, salt spray			
	Polyester thin-set terrazzo, No. 18	8 mos.	FAIRLY SATISFACTORY
Laboratory glassware washing facility			
	Polyurethane brush-on, No. 58	4 yrs.	FAILURE
Latrines and shower rooms, military			
	Epoxy trowel-on, No. 2	8 yrs.	SATISFACTORY
	Polyester trowel-on		
	No. 1	1 week	FAILURE
	Nos. 31-35, 40-41 (7)	1 yr.	SATISFACTORY
	Polyurethane brush-on		
	Nos. 23-26 (4)	1 yr.	FAILURE
	No. 30	10 mos.	SATISFACTORY
	Vinyl-acrylic brush-on, Nos. 28, 29	3 yrs.	FAIRLY SATISFACTORY
Laundries			
	Epoxy brush-on, No. 42b(1)	1 mo.	FAILURE
	Polyester trowel-on		
	Nos. 3b, 3c	5 yrs.	FAIRLY SATISFACTORY
	No. 39	2 yrs.	SATISFACTORY
	Polyurethane trowel-on, Nos. 42a(2), 42b(2)	2 yrs.	FAILURE
	Furan trowel-on, No. 3a	1 mo.	FAILURE
Meat cutting plants			
	Polyester trowel-on, No. 38	2 yrs.	FAILURE
	Polyester thin-set terrazzo, No. 61	4 yrs.	FAIRLY SATISFACTORY
Office buildings			
	Asphalt tile, No. 67	28 yrs.	SATISFACTORY
	Carpet, No. 71	4 yrs.	FAIRLY SATISFACTORY
Recreation area			
	Polyurethane brush-on, No. 60	4 yrs.	FAIRLY SATISFACTORY
Shop, plumbing			
	Portland cement - asphalt emulsion, No. 46	5 yrs.	FAILURE

Location	Type of Flooring	Service Time	Rating
Showers in hospital			
	Alumina cement - neoprene latex, Nos. 16, 17	6 yrs.	SATISFACTORY
Stairs outside barracks			
	Polyurethane brush-on, No. 47	3 yrs.	FAILURE
Storeroom			
	Portland cement - asphalt emulsion, No. 45	--	SATISFACTORY
Supermarket			
	Carpet, No. 70	3-5 yrs.	FAILURE
Walk ramp			
	Epoxy trowel-on, No. 48	2 yrs.	FAILURE
Wooden floors, residential			
	Polyurethane brush-on, Nos. 52, 53	3 yrs.	SATISFACTORY

APPENDIX B

Report on Field Experiments

At the end of the 1968 report on the field study of floor coverings [7], the author suggested a program of field experiments, in which the materials and installation conditions would be known and could be controlled as closely as practicable. As a step in this direction, three experiments were conducted by the author to determine the suitability of flooring and floor finishes for certain applications and to determine the relative wear of these flooring products. The results to date follow:

B.a. Comparison of Durability of Monolithic Surfacings and Abrasive Vinyl in Army Barracks Corridor, 1969-1971

Two brush-on monolithic surfacings and an abrasive sheet vinyl were tested in a corridor of an Army barracks, about 10 ft. long and 6 ft. wide, running from the outside door to the orderly room. The corridor receives heavy foot traffic with considerable dirt tracked in and receives minimal maintenance.

Test of Decorative Acrylic Surfacings with Vinyl Chips

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. A polyvinyl acetate emulsion was applied to the concrete floor as a sealer. After this coat dried, a "wet coat" of acrylic lacquer was brushed on. This lacquer was a solution in organic solvent of polymethyl methacrylate and polycyclohexyl methacrylate, as determined by infrared spectra observations at the National Bureau of Standards. 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" was 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,

December 1969, the acrylic decorative coating was worn through and the floor was gritty and dirty.

Test of Brush-On Epoxy Coating with Sand Filler and of Abrasive Sheet Vinyl

In December 1969, the above corridor 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. The abrasive sheet vinyl 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. Information about the composition was obtained from measurements and analyses in our laboratories. 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 appearance otherwise. It was not worn or scratched, and adhesion was good. The epoxy surfacing was dirty and stained but not worn appreciably. After more than a year service, in February 1971, the corridor was inspected again and the dirty floor was cleaned with water and a mop. The abrasive sheet vinyl material appeared to be in satisfactory condition except for numerous cigarette burns all over the area. The epoxy surfacing was stained and dirty but was not worn. The bond was excellent even at the edge where it was feathered to the exposed bare concrete.

B.b. Test of Acrylic Floor Finish and Abrasive Sheet Vinyl in Army Commissary, 1969-1970

The test was performed in the sales area in an Army commissary, which was covered with about 35,000 sq. ft. of vinyl asbestos tile. The tile was damaged by fork lift trucks which move merchandise from the

receiving room to the sales area. The trucks left black and scuffed skid marks on the tile. The tiles were 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 were gouged, dirty, scratched, and could not be cleaned properly. The black marks could be removed with mineral spirits and steel wool but the gouges remained.

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 floor finish. 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.

Abrasive sheet vinyl, as in 5.1, 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 scuffed and "burned" places were observed. The fork lift truck tires actually "burned" or melted places in the abrasive vinyl as they did with the vinyl asbestos tile.

B.c. Test of Resilient Tiles in Computer Facility, 1967-1972

A test of resilient floor tiles was performed in front of the counter, partition, and swinging doors of a computer facility. The area behind the counter, partition, and swinging doors is occupied by the equipment and staff of the facility. The test area is illustrated in Figure I.

In Figure I, the access panels covered with test tiles are numbered and the test tiles are indicated by letters A through E. The original tile corresponds to letter A. The 2-foot square access panels, covered with 12-inch square vinyl tiles were installed in May 1967. After two years of service, the tile appeared scratched and scuffed and were somewhat hard to clean. Following is a table of the kinds of resilient tiles used in the test area and the dates of the installation:

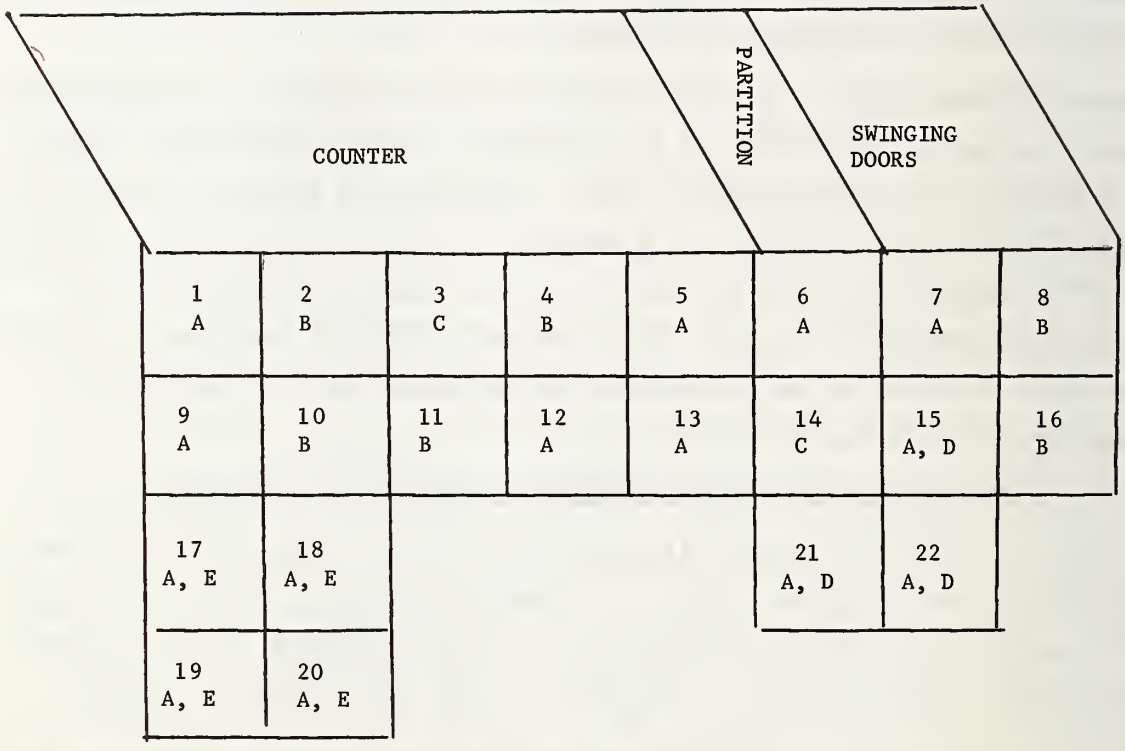

Figure I. Computer Test Area Flooring Layout

Table I. Tiles Used in Computer Room Test Area

Tile Symbol	Resilient Tile	Installation Date
A	Original vinyl tile, as Type III, Fed. Spec. SS-T-312, four 12-inch squares on each access panel	May 1967
B	Laminated resin tile with melamine-formaldehyde wear layer, 2-foot squares, one on each panel	August 1969
C	Polyester terrazzo tile with marble chips, four 12-inch squares on each access panel	August 1969
D	Conductive vinyl asbestos tile, four 12-inch squares on each access panel	July 1970
E	Acrylic resin tile with fine mineral aggregate, 2-foot squares, one on each panel	May 1970

The resilient tiles were examined periodically and the appearance after each examination is recorded in the following tables:

Table II. Appearance of Tiles, September 1970

Tile Symbol	Service Period	Appearance at Eye Level	Close-Up Appearance
A	3 years	Numerous scratches and scuffs	Numerous scratches and scuffs
B	1 year	Shiny and clean	A number of fine scratches all over
C	1 year	Shiny and clean	A few scratches, hard to see
D	6 weeks	Numerous scratches and scuffs	Numerous scratches and scuffs
E	5 months	A few scuffs	A few scuffs

Table III. Appearance of Tiles, March 1971

Tile Symbol	Service Period	Appearance at Eye Level	Close-Up Appearance
A	3-1/2 yrs.	Numerous scratches and scuffs	Numerous scratches and scuffs
B	1-1/2 yrs.	A few mars, scratches, and scuffs	A few mars and scuffs, numerous scratches
C	1-1/2 yrs.	Shiny and clean	Some scratches; marble chips gone in two places; dull appearance near counter
D	6 months	Numerous scratches and scuffs	Numerous scratches and scuffs
E	11 months	Some scuffs	Some scuffs and fine scratches

Table IV. Appearance of Tiles, April 1972

Tile Symbol	a. Observations at Eye Level
A	Numerous mars and scratches; same appearance at all positions.
B	Numerous fine scratches; long black mark in No. 2 position, next to counter.
C	Shiny and clean. However, in No. 3 position, next to counter, appearance was much lighter at the edge of the panel next to the counter, indicating darkening in traffic areas.
D	Scratches and mars all over; about the same as A; same appearance at all positions.
E	Mostly shiny and clean but a few mars, one black mark, and one piece of adhering chewing gum.

Tile Symbol	b. Close-Up Observations
A	Numerous mars and scratches; scratches practically cover the entire surface; overall dull appearance; same appearance at all positions.
B	Fine scratches and dull all over; traffic pattern and obviously worn streaks at No. 2 and No. 4 positions, next to counter. Some dirty places at No. 8 position, next to swinging doors.
C	No. 14 position, away from counter: Overall good appearance but slightly dull; some chipping of tile at edges of panel. No. 3 position, next to counter: Fine scratches and dull over most of the panel in marked contrast to edge near counter, which was shiny and clean.

Table IV. Appearance of Tiles, April 1972 (continued)

Tile Symbol	b. Close-Up Observations
D	Same as A.
E	A number of faint mars and scratches, not highly visible.

Table V. Periods of Service of Resilient Floor Tiles as of April 1972

Tile Symbol	Tile	Period
A	Vinyl tile	5 years
B	Laminated tile with melmaine-formaldehyde wear layer	2-1/2 years
C	Polyester terrazzo tile	2-1/2 years
D	Conductive vinyl asbestos tile	2-1/4 years
E	Acrylic tile with fine aggregate	2 years

FORM NBS-114A (1-71)

U.S. DEPT. OF COMM. BIBLIOGRAPHIC DATA SHEET	1. PUBLICATION OR REPORT NO. NBS-TN-783	2. Gov't Accession No.	3. Recipient's Accession No.

4. TITLE AND SUBTITLE

Durability and Maintenance as Related to the Selection of Flooring

5. Publication Date: August 1973

6. Performing Organization Code

7. AUTHOR(S): W.C. Wolfe, R.E. Roberts, M Russell

8. Performing Organization

9. PERFORMING ORGANIZATION NAME AND ADDRESS

NATIONAL BUREAU OF STANDARDS
DEPARTMENT OF COMMERCE
WASHINGTON, D.C. 20234

10. Project/Task/Work Unit No.: 4616165

11. Contract/Grant No.

12. Sponsoring Organization Name and Address

Same as No. 9.

13. Type of Report & Period Covered: Final 1972

14. Sponsoring Agency Code

15. SUPPLEMENTARY NOTES

16. ABSTRACT (A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)

This report is addressed to the problem of selection and maintenance of flooring to the best advantage in terms of durability, type and severity of service, appearance, comfort, and safety. The selection of flooring is discussed with respect to service life, maintenance, obsolescence, and trade-off advantages. Two articles by maintenance administrators include information and discussion helpful in determining maintenance cost, trade-offs, and selection of flooring for different types of service. Field observations and preliminary field tests by the National Bureau of Standards indicate areas in which research is needed, as in laboratory tests for wear and slip resistance. Observations and field tests are impracticable to use for procurement.

This report is helpful in the selection and maintenance of flooring and floor finishes. More important, it points up areas in which research is needed to develop information for this purpose.

17. KEY WORDS (Alphabetical order, separated by semicolons) Carpets; durability; economics; field studies; flooring; floor coverings; life-cost; maintenance; user needs

18. AVAILABILITY STATEMENT	19. SECURITY CLASS (THIS REPORT)	21. NO. OF PAGES
[x] UNLIMITED.	UNCLASSIFIED	68
[ ] FOR OFFICIAL DISTRIBUTION. DO NOT RELEASE TO NTIS.	20. SECURITY CLASS (THIS PAGE) UNCLASSIFIED	22. Price 90 cents

USCOMM-DC 66244-P71

NBS TECHNICAL PUBLICATIONS

PERIODICALS

JOURNAL OF RESEARCH reports National Bureau of Standards research and development in physics, mathematics, and chemistry. Comprehensive scientific papers give complete details of the work, including laboratory data, experimental procedures, and theoretical and mathematical analyses. Illustrated with photographs, drawings, and charts. Includes listings of other NBS papers as issued.

Published in two sections, available separately:

- **Physics and Chemistry (Section A)**

Papers of interest primarily to scientists working in these fields. This section covers a broad range of physical and chemical research, with major emphasis on standards of physical measurement, fundamental constants, and properties of matter. Issued six times a year. Annual subscription: Domestic, $17.00; Foreign, $21.25.

- **Mathematical Sciences (Section B)**

Studies and compilations designed mainly for the mathematician and theoretical physicist. Topics in mathematical statistics, theory of experiment design, numerical analysis, theoretical physics and chemistry, logical design and programming of computers and computer systems. Short numerical tables. Issued quarterly. Annual subscription: Domestic, $9.00; Foreign, $11.25.

TECHNICAL NEWS BULLETIN

The best single source of information concerning the Bureau's measurement, research, developmental, cooperative, and publication activities, this monthly publication is designed for the industry-oriented individual whose daily work involves intimate contact with science and technology—*for engineers, chemists, physicists, research managers, product-development managers, and company executives.* Includes listing of all NBS papers as issued. Annual subscription: Domestic, $6.50; Foreign, $8.25.

NONPERIODICALS

Applied Mathematics Series. Mathematical tables, manuals, and studies.

Building Science Series. Research results, test methods, and performance criteria of building materials, components, systems, and structures.

Handbooks. Recommended codes of engineering and industrial practice (including safety codes) developed in cooperation with interested industries, professional organizations, and regulatory bodies.

Special Publications. Proceedings of NBS conferences, bibliographies, annual reports, wall charts, pamphlets, etc.

Monographs. Major contributions to the technical literature on various subjects related to the Bureau's scientific and technical activities.

National Standard Reference Data Series. NSRDS provides quantitative data on the physical and chemical properties of materials, compiled from the world's literature and critically evaluated.

Product Standards. Provide requirements for sizes, types, quality, and methods for testing various industrial products. These standards are developed cooperatively with interested Government and industry groups and provide the basis for common understanding of product characteristics for both buyers and sellers. Their use is voluntary.

Technical Notes. This series consists of communications and reports (covering both other-agency and NBS-sponsored work) of limited or transitory interest.

Federal Information Processing Standards Publications. This series is the official publication within the Federal Government for information on standards adopted and promulgated under the Public Law 89–306, and Bureau of the Budget Circular A–86 entitled, Standardization of Data Elements and Codes in Data Systems.

Consumer Information Series. Practical information, based on NBS research and experience, covering areas of interest to the consumer. Easily understandable language and illustrations provide useful background knowledge for shopping in today's technological marketplace.

BIBLIOGRAPHIC SUBSCRIPTION SERVICES

The following current-awareness and literature-survey bibliographies are issued periodically by the Bureau:

Cryogenic Data Center Current Awareness Service (Publications and Reports of Interest in Cryogenics). A literature survey issued weekly. Annual subscription: Domestic, $20.00; foreign, $25.00.

Liquefied Natural Gas. A literature survey issued quarterly. Annual subscription: $20.00.

Superconducting Devices and Materials. A literature survey issued quarterly. Annual subscription: $20.00. Send subscription orders and remittances for the preceding bibliographic services to the U.S. Department of Commerce, National Technical Information Service, Springfield, Va. 22151.

Electromagnetic Metrology Current Awareness Service (Abstracts of Selected Articles on Measurement Techniques and Standards of Electromagnetic Quantities from D-C to Millimeter-Wave Frequencies). Issued monthly. Annual subscription: $100.00 (Special rates for multi-subscriptions). Send subscription order and remittance to the Electromagnetic Metrology Information Center, Electromagnetics Division, National Bureau of Standards, Boulder, Colo. 80302.

Order NBS publications (except Bibliographic Subscription Services) from: Superintendent of Documents, Government Printing Office, Washington, D.C. 20402.

U.S. DEPARTMENT OF COMMERCE
National Bureau of Standards
Washington, D.C. 20234

OFFICIAL BUSINESS

Penalty for Private Use, $300

POSTAGE AND FEES PAID
U.S. DEPARTMENT OF COMMERCE
COM-215