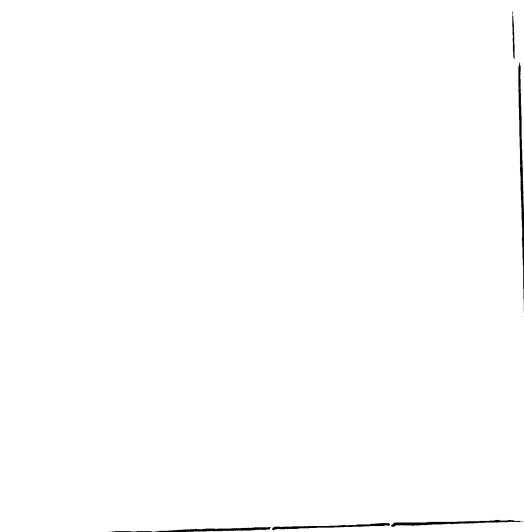


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THESIS



FACTORS IN THE SELECTION AND MAINTENANCE OF
INSTITUTIONAL FLOORS

By

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A PROBLEM

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PREFACE

This manual was written for housekeepers, custodians, and management specialists interested in floor selection and maintenance. In 1953, when I became Building Supervisor of a group of Residence Halls, which were then under construction, I knew little of floor maintenance and began searching for a manual of this type. Although there were many publications with sections devoted to floor maintenance, none provided adequate information on that subject, or would serve as a guide for selection of a floor.

The factual material presented in this report is based upon information from the various trade associations listed in the appendix, articles from the trade magazines, work with other Building Supervisors, classes of Hospital Housekeepers and School Custodians. I have taught and my own experience as a Building Supervisor for six years.

The usefulness of this manual to the reader, depends upon his degree of interest in flooring problems. For one sincerely concerned in learning more about floor maintenance and selection, this manual can be of value whether he is a novice or has had twenty years experience.

Floor maintenance materials and methods may change in the future. Manufacturers are constantly developing new machines and new products. I have tried to list maintenance methods in general terms with the thought that what is presented as true today will be valid in the future.

INTRODUCTION

Whenever a new building is designed or an old building is rehabilitated the selection of proper flooring for each area is of prime importance. This is particularly true of institutional buildings since floors usually account for 3 to 10 percent of the initial building cost and receive at least 80 percent of the wear.

Flooring problems have no cure-all. There is seldom one floor which will meet all service requirements in a particular institution; a flooring may perform well under certain conditions and fail under others. Intelligent selection by area and use is essential for maximum utility and life.

Too often, floors are purchased on initial cost alone and low installation expense is the sole determining factor in selection. A more reliable method of determining the true cost of a floor is to consider the initial cost, the expected life of the floor, cost of maintenance and the cost of repairs. Cloyes (12) has suggested a formula based on these factors for comparison of flooring costs:

$$\frac{F + YM + YR}{Y} = \text{Cost per square foot per year}$$

F = First cost of flooring installed

Y = Expected life of flooring in years

M = Cost of maintenance per year

R = Cost of repairs

The application of this formula frequently provides concrete evidence that the purchase of the cheapest floor on basis of initial cost is false economy. The least expensive flooring is often the most expensive to maintain.

Unfortunately, lack of money may be the executioner after intelligent planning has included careful consideration of initial cost, utility, expected life, maintenance and repairs. Since the architect must remain within the building appropriation, flooring specifications usually bear the brunt of a budget reduction. Asphalt tile may be substituted for terrazzo or ceramic tile and grease-proof asphalt tile may replace the initial specifications for quarry tile. No material should be expected to do the job it was not designed to do and it is seldom economical to buy the cheapest floor simply because of low initial cost.

The purpose of this manual is to provide information for intelligent selection and efficient maintenance of flooring materials. To select the one best material is not the intention of this report, but rather to point out the more important advantages and disadvantages of common types of hard and soft flooring and to discuss their manufacture, installation, cost and maintenance.

COMMON TYPES OF FLOORS AND FLOOR COVERINGS

The first floors were tamped earth covered with textiles or skins; later, different types of stone pavings were introduced. During the Roman Empire (205 B.C. - A.D. 180) small pieces of marble were imbedded in cement to form terrazzo and at the same time mosaic tile and marble floors appeared. In the late 12th and 13th centuries tile floors became usual in churches and other important buildings while wood floors were common in homes.

An early forerunner of modern floor covering was floor oil cloth, which had its origin in a coarse fabric woven of hemp or flax coated with oil or paint (23). Later, the cloth was sized with liquid glue, rye flour, or varnish and the surface was rubbed with pumice to make it smooth. A coat of colored clay was next applied to the surface which was then scraped and evened to the desired thickness. Floor oil cloth, however, was not satisfactory. The patterns faded rapidly and the cloth frequently had to be replaced. The industry, therefore, set about designing new materials which would be more satisfactory.

The development of resilient floor coverings such as linoleum, asphalt, cork, rubber and vinyl has been recent compared to marble, terrazzo and tile. The linoleum industry dates back to 1860 with the invention by Frederick Walton of the process for oxidizing linseed oil. Rubber and cork floorings were first manufactured around 1900, asphalt tile was introduced in

1922 and vinyl floors made their public debut at the Chicago World Fair in 1933. Mass production of the currently popular asphalt tile and vinyl floorings did not begin until the time of World War II.

Resilient Floor Coverings

There are five basic types of resilient floor coverings. These are: asphalt tile, cork, linoleum, vinyl, rubber and combinations of the basic types. The wide use of resilient floor coverings has been due to these product characteristics:

- (1) Easy and economical installation.
- (2) Availability of wide variety of sizes, colors and patterns.
- (3) Maximum floor comfort.

Asphalt tile

There are probably more square feet of asphalt tile in institutional, industrial and commercial buildings today than any other kind of resilient flooring. This is primarily due to ease of installation and low initial cost.

The continuous growth of the asphalt tile industry is shown by the increase in annual production from an estimated 3 million square yards in 1930 to 41 million square yards in 1947. The 1952 production of 80 million square yards accounted for an estimated 10-12 percent of the resilient floor industry.

Manufacture and cost. Commercial manufacture of asphalt tile began in 1922 when a midwestern manufacturer of asphalt roofing products started the production of asphalt tile. An early process involved a heavy asphalt solution containing mineral fillers troweled smooth and allowed to harden by evaporation of the solvent (23). At first, tile colors were limited to

black, red, brown and green. Production of individually molded tiles was practiced initially, but this was soon superseded by the present process of sheeting and cutting to size.

Asphalt tile is a thermoplastic material consisting of asbestos fibers, mineral coloring pigments, inert fillers, asphaltic and resinous binders. These constituents are mixed, calendered, sheeted and cut. The binder materials determine the physical properties of the tile such as flexibility, resistance to indentation and resistance to heat and light (23). The binders also affect the chemical properties of the tile such as resistance to alkalis, acids, greases and moisture. The fillers consist of asbestos in fibre form and mineral aggregate (clay, ground limestone, and ground sand). Different formulations produce different qualities of the manufactured tile. The pigments used are generally selected for light fastness, alkali and acid resistance, as well as to produce the desired color in the tile.

Asphalt tile is sold in a series of color groupings, A, B, C or D which are described in Table I. A and B usually contain asphalt binders while C and D have the resin binders (9). Asphalt tile is also furnished in a grade designated as Greaseproof. In the case of dark colors, the binder is Gilsomite asphalt. One of the paradoxes in product naming is found in the case of the intermediate and light colors of asphalt tile: color groups C and D contain little or no asphalt since resins are the binders.

TABLE I
ASPHALT TILE COLOR GROUPINGS

Group	Colors	Description
Color Group A	Black, dark red	Plain colors only
Color Group B	Background colors black, dark brown and dark red mottled with any one or more of the following colors: white, red, yellow and green.	Marbelized colors only
Color Group C	Dark green, light green, light gray, light red, medium red, tan and buff.	Plain colors
	Seven background colors corresponding to the plain colors listed above, mottled with any one or more colors to make seven color patterns.	Marbelized colors
Color Group D	Cream, white, blue	Plain colors
	Three background colors corresponding to the plain colors listed above mottled with any one or more colors to make three color patterns.	Marbelized colors

Asphalt tile is regularly available in sizes 9 by 9 inches, 12 by 12 inches, and 18 by 24 inches with either 1/8-inch or 3/16-inch thickness (3). The 3/16-inch thickness is often used in industrial establishments where floors receive a great deal of wear and abuse. The 9 by 9 inch tile is the most commonly used.

While the cost of asphalt tile has increased with rising prices generally, it is still the least expensive of the resilient floor coverings. The initial cost of the asphalt tile varies with the colors selected.

Group A colors are usually lowest in cost.

Group B colors are usually next lowest.

Group C colors are usually next lowest.

Group D colors are the most expensive.

Of all the resilient floors, conventional asphalt tile is the least expensive to install. Installed price ranges are, however, difficult to quote because there are so many factors that affect cost in addition to purchase price of floor covering material. Installation is often a major variant in floor covering costs (19). For example, a floor in a single color and styling laid wall to wall is less costly than a complex, custom designed floor that involves exceptional craftsmanship and additional time to lay. Other items affecting installation cost are subfloor conditions and local labor rates.

Installation. Asphalt tile can be installed on nearly any kind of subfloor almost anywhere, but it is not recommended for outdoor installations (35). The subfloor, must be solid, level, smooth, and free of wax and oils. If painted, the old paint should be removed and the subfloor must be dry and not at any time subjected to excessive moisture.

If the subfloor is concrete, and if any dusting exists, a priming of asphalt should be applied. No under layment is required if the installation is to be over a wood floor (4). The wood subfloor must be solid and smooth, free of cupped or broken boards. Sanding is sometimes necessary. The asphalt tile adhesive should be applied in a thin film and spread evenly with a cement finisher trowel of the type suggested by the asphalt tile manufacturer.

The Asphalt Tile Institute recommends a 70° F. room temperature for a period of 48 hours before and during installation followed by a 48 hour period at this same temperature after installation. Newly installed asphalt tile should not be scrubbed for at least 14 days so that the cement bonds the tile tightly to the subfloor and the tile sets solidly.

Complete information covering the installation of asphalt tile has been published by the Asphalt Tile Institute, 101 Park Avenue, New York City, New York.

Utility. The chief advantages of asphalt tile, low initial cost and ease of installation, have already been cited. Universal popularity may also be attributed to:

- 1) Wide range of available colors and patterns.
- 2) Ample choice of tile sizes and gauges (thicknesses).
- 3) Fair resistance to alkali.
- 4) Easy replacement of damaged areas.

Disadvantages of asphalt tile are readily apparent in an institutional floor:

- 1) High maintenance cost.
- 2) Poor resistance to grease.
- 3) Poor resiliency compared to rubber.
- 4) Susceptibility to indentation.
- 5) Susceptibility to cracking or breaking when cold and brittle.
- 6) Color fading caused by highly alkaline cleansers.
- 7) Softening and warping of the tile and loosening of the adhesive caused by excessive use of hot water.

Maintenance. The basic steps in the maintenance of asphalt tile are dry cleaning, wet cleaning, and, waxing and polishing.

- 1) Sweeping, vacuuming or dust mopping are the usually dry cleaning methods.
No floor should be scrubbed until it has been dry cleaned by one of these three methods. Oil and its derivatives can soften and disintegrate asphalt tile. Care should be taken not to use an oily dust mop or sweeping compound.
- 2) Wet cleaning. Three operations (stripping, scrubbing, wet mopping) comprise the wet cleaning process.
 - a) Stripping. The removal of all soil and wax from the floor with a soap or detergent and mechanical agitation such as a power scrubber.
 - b) Scrubbing. The removal of all soil but wax. Many custodians use this term synonymously with stripping.
 - c) Wet mopping. The use of a mop and water on the floor. Soap, detergent, or wax may be added to the water. When wax is added to clean mop water, this is sometimes referred to as track mopping.

Certain precautions should be observed in all three phases of the wet cleaning process.

- a) New floors should not be flooded with water until they have set properly, which may require from 7 to 14 days.
 - b) The excessive use of hot water or too much water may cause warping or softening of the tile. The water may also loosen the tile from the mastic which binds it to the subfloor.
 - c) Highly alkaline soaps can cause bleeding or loss of color by damaging the pigment binders.
 - d) Rough steel wool can scratch the tile.
- 3) Waxing and polishing. Only good water emulsion waxes or plastic coatings should be used on asphalt tile. Solvent waxes will soften and deteriorate asphalt. The wax should always be applied in thin coats and the floor should be machine buffed after each coat is dry. If a slip hazard exists, slip resistant waxes are available.

Cork tile

Although cork tile has been manufactured since 1900 it constitutes a relatively small part of total industry production (23). This may be due to the restricted use and high price of cork floor coverings.

Manufacture and Cost. Cork comes from the outer bark of the cork oak tree found in Spain and Portugal and is composed of numerous 14 sided cells which are empty. The bark is converted into shavings, cleaned, ground, molded in large hydraulic presses and sheeted. The sheeted material is then

baked at a high temperature to melt the natural resins which bind the mass together. Some manufacturers add certain resinous binders of lower melting point to reduce the baking temperature. The surface of this sheeted material is given a heavy coat of melted wax and the sheeting is cut in various sizes and sold as cork tile.

Cork tile is available in light or dark brown tones and in a variation of shading which is fabricated by mixing dark and light particles of cork in the same tile. The tile may be purchased in squares or rectangular planks and is usually installed in alternating shades.

Of the resilient floor coverings only pure vinyl tile is more expensive than cork. Rubber tile is nearly equal to cork in price but linoleum, asphalt tile and vinyl asbestos tiles are cheaper.

Installation. Cork tile should be installed only on floors which are above ground and ventilated underneath (45). Most basement installations are not feasible since cork tile should not be laid on subfloors in direct contact with the ground or over concrete floors subjected to moisture. While the cork components of the flooring are not affected by ordinary moisture, the resinous binders and the cement which attaches the tile to the subfloor are likely to deteriorate from prolonged contact with moisture.

Cork tile is flexible and will bend several degrees before breaking. The natural tendency of the tile to promptly resume its original shape makes it less adaptable to uneven surfaces than other resilient floorings. When an installation is made over an uneven subfloor, sanding of the cork may be required to avoid an undulating appearance and normally the tile will loosen.

For a satisfactory installation certain precautions are essential. Plywood or masonite ($\frac{1}{4}$ -inch) should be nailed to old subfloors with screw type nails on 6-inch centers and on 3-inch centers along the joints. In the case of new wood subfloors the boards should be well seasoned and well dressed, not more than 3 inches wide and laid perfectly smooth with all joints tight and well nailed. Wright (43) has recommended that an asphalt saturated paper with butt joints be laid across the boards and cemented down. A newly sanded wood subfloor may be given a coat of penetrating floor sealer to insure better adhesion of the cement which attaches the cork to the subfloor. Cork tile should not be laid over a single-layer floor since some single-layer floors may flex under pressure and thereby loosen the tiles.

Professional installation of cork tile is advisable even though specifications and directives are available from manufacturers.

Utility. Cork is the luxury floor of the resilient

floor coverings. It is similar in composition to linoleum but it is lighter, more resilient and less durable. Because of composition cork tile is extremely flexible, very quiet, soft and easy underfoot and for these reasons is used where comfort and quietness are primary factors. Cork is not recommended for such areas as kitchens and dining rooms.

In the selection of an institutional floor the advantages and disadvantages of cork tile should not be overlooked.

Advantages

- 1) Comfortable for standing or walking.
- 2) Absorption of traffic noises.
- 3) Easy replacement of damaged tile.
- 4) Good coefficient of friction; normally slip resistant.
- 5) Good insulator against heat and cold.
- 6) Resistant to mild acids.

Disadvantages

- 1) High initial cost.
- 2) Expensive and difficult maintenance.
- 3) Poor resistance to solvents and grease.
- 4) Easily indented.
- 5) Easily damaged by excessive hot water.
- 6) Scratching from abrasive cleaners or gritty soil.
- 7) Deterioration by highly alkaline cleaners.

Maintenance. Cork tile is not designed for rugged

usage, but may, if properly cared for, last for thirty years in areas such as offices or homes (45). On the other hand, abuse, neglect or incorrect maintenance may limit the life to less than five years in areas such as hallways or ballrooms. Cork tile should not be scrubbed for 7 to 14 days after installation and then with a rather neutral soap.

Remember that:

1. Vacuuming, sweeping, or dustmopping may be used in dry cleaning cork tile.
2. In wet cleaning, use only enough soapy water to loosen the soil and remove immediately with a wet vacuum pickup.
3. Cork tile may be waxed with either solvent or water emulsion wax, buffing after each coat.
4. Machine buffing with #00 steel wool is sometimes employed for the cleaning process.

Do not:

1. Use harsh alkaline cleaners.
2. Use harsh abrasive cleaners.
3. Clean with naphtha, gasoline or similar solvents.
4. Use oily dust mops or oily sweeping compounds.
5. Coat with a varnish or lacquer.
6. Concentrate heavy loads on small areas.
7. Use excessive water.
8. Allow grit, sand or cinders to accumulate on floor.

Linoleum

Linoleum, a term originally coined by the Englishman Frederick Walton for a material of his own invention, is now used indiscriminately to describe almost all floor coverings having a base of solidified oil adhering to a jute canvas or some other foundation (23).

The earliest patent in 1636 for "Painting with oyle cullers upon wollen-cloath," was recorded in England (24). In 1754 Nathan Smith established a factory at Knights Bridge for the manufacture of floor cloth by applying a mixture of rosin, pitch, Spanish Brown, beeswax and linseed oil in a melted state to canvas and rolling it in by pressure (23). Ninety years later Elijah Galloway softened India rubber by heating, incorporated it with cork dust, and rolled the resulting mass into sheets which were marketed as "Kamptulicon". Owing to the high price of rubber, the floor covering proved to be costly; and in 1860 Frederick Walton invented a process (Eng. Pat. 209) for oxidizing linseed oil to produce a cheap, rubber-like substitute (23). In principle, the methods used today are essentially the same as those covered by his inventions.

Production of linoleum was well under way in England and Europe by the latter part of the nineteenth century. In the United States the linoleum industry has tripled production during the last forty years to an estimated current production

of nearly 100,000,000 square yards in 1958. It is computed that the world's output of linoleum is more than 200,000,000 square yards per year.

Manufacture and cost. The principle ingredients for the manufacture of the surface of linoleum are oxidized drying oils (linseed and soya bean) incorporated with rosin or resins and cork or wood flour (23). From the drying oils linoleum receives wearing qualities while the resins act as a binding material. Resiliency and heating properties are obtained from the cork and wood flour.

The manufacturing processes for linoleums are essentially the same as those invented by Walton and involve the following operations:

1. The production of solidified linseed oil.
2. The manufacture of the cement.
3. The incorporation of ground cork or wood flour and pigment with the cement.
4. The application of this mixture to a backing of burlap, cotton or asphalted felt.
5. Seasoning or curing of the sheeted material.
6. The painting of the underside to preserve the canvas.
7. The trimming of the finished cloth.

The first operation consists of a process whereby the oil, driers, rosin and added gums are heat-fluxed and then placed in a horizontal, totally enclosed, jacketed, steel cylinder called a Bedford kettle. Conditioned air is introduced through a port and high-speed agitation is provided by a horizontal shaft equipped with radial rods. The resulting mass emerges in a jelled form and is dumped onto a wood-flour

covered floor in layers approximately two inches thick. After cooling, cutting into small, rubber-like slabs, and a suitable aging period, the linoleum is ready to use.

The next stage of the process involves the incorporation of the cement with cork dust or wood flour, whiting, and pigments in a steam-jacketed internal mixer. The mixture then passes through a series of large grinders and the extruded product is fed into the "scratcher", a machine consisting of two rolls, one steam-heated and the other cold, to which the material adheres. Adjacent to the "scratcher" is a third roll, fitted with hundreds of sharp spikes, which revolves at a high speed scratching off small particles of the linoleum material and converting it into granular flour. These granules or "scratch" provide the basis for all types of linoleum (23).

The various products made from "scratch" can be divided into three broad classes: plain, inlaid and printed.

Plain linoleum is all one color and has been popular for institutional use in the "battleship" type. This was referred to as "battleship" linoleum because it was first used on the deck of warships. The original "battleship" linoleums were $\frac{1}{4}$ -inch to $\frac{1}{2}$ -inch thick, today the usual thickness is one-eighth inch.

Inlaid linoleum, sometimes referred to as embossed inlaid, is often produced with imitation tile patterns. Since the design and color go entirely through the backing, the

pattern remains intact during the life of the covering. It is often used in offices.

Printed linoleums are not practical for institutional use since the design is stamped or applied with heavy lacquers on the surface. They do not stand up in heavy traffic areas.

Linoleums are available in two, three, four and six yard widths; thickness is usually between .0625 and .125 of an inch. Most linoleums are manufactured in rolls six feet wide and ninety feet long to permit installation with as few seams as possible (24). Occasionally the sheets are cut in tile form.

The installed cost of linoleum varies with the type of subfloor and the style of linoleum. If the subfloor is rough the necessary adhesive and felt liner increase the cost. In general, linoleum is the second cheapest floor covering in terms of initial cost. In most areas of the United States only asphalt tile flooring can be installed at less expense.

Installation. Linoleum can be installed over almost any kind of smooth, solid, dry subfloor except concrete which is in direct contact with the ground. The natural alkali in concrete when activated by moisture tends to emulsify the oil content of the linoleum. The resulting seepage can cause disintegration of the backing material and slow disintegration of the linoleum itself. Since dampness is detrimental to linoleum, the subfloor should be at least 18 inches above the ground for necessary ventilation (24).

A solid subfloor is essential because a foundation which flexes under pressure may cause the linoleum to break. Holes, cupped boards or other imperfections in the subfloor will soon become evident after the linoleum has been laid. Such a subfloor requires sanding.

If linoleum is installed over single wood floors, hardwood or plywood should be laid first; if over a double wood subfloor, the top floor should be tongue-and-groove. Cracks wider than one-eighth of an inch and holes larger than one-fourth of an inch should be completely filled with a good plastic wood or snugly fitting pieces of wood. Loose boards should be nailed down and the nail heads countersunk.

Lining felt is often used when burlap-backed linoleum is installed over wood subfloors. Linoleum adhesive is applied to the subfloor, spread out with a saw-toothed trowel and the lining felt pressed down. After the floor has been covered with the felt and the edges have been carefully butted, a heavy roller is used to level the surface. When the lining is firmly set, the adhesive is spread over the surface. Linoleum should be laid carefully in the same direction as the lining felt but the linoleum seams should not cover the seams of the felt. After installation the linoleum should be rolled to insure thorough adhesion.

Wright (43) has recommended that linoleum be stored at a temperature of 70° F. for at least 24 hours before installation and that the room temperature during installation be at least 70° F.

Before installation of linoleum on old floors the quarter round moldings should be removed, the floor should be stripped of paint, varnish and floor wax, scrubbed and thoroughly dried.

Utility. After one hundred years of use as a floor covering, linoleum, the original resilient flooring, ranks high in popularity with the residential building trades and has maintained qualified acceptance for institutional floors. Many public buildings have not replaced the old "battleship" linoleum floorings which were produced in $\frac{1}{2}$ -inch thickness years ago.

In addition to durability, resiliency and quietness linoleum has the following advantages:

1. Low initial cost.
2. Easy installation.
3. Availability of many types, patterns, and gauges.
4. Underfoot comfort.
5. Resistance to indentation.
6. Resistance to grease and mild acids.

The disadvantages of linoleum are readily apparent in certain institutional floor layouts:

1. Linoleum with burlap backing can seldom be installed on concrete.
2. Linoleum can be ruined by strong alkalies.
3. Worn areas cannot be easily patched.
4. Rough spots in the subfloor may damage the linoleum.
5. Abrasive cleaners may scratch linoleum.
6. Some types break or crack rather easily at low temperatures.

Maintenance. The same rules governing the use of cleaners apply to nearly all types of linoleum (37).

Strong alkalis should not be used on linoleum. The linseed oil component of linoleum is a vegetable fat saponifiable by alkali; consequently, alkalis of all kinds are injurious to linoleum. Even the natural alkali in concrete, when activated by moisture, can disintegrate linoleum.

Too much moisture is detrimental to linoleum. According to some linoleum people more linoleum floors are washed out than are worn out. Newly installed linoleum should not be scrubbed until the adhesive cement has set which may require five or more days. In washing or scrubbing only enough water should be used for effective cleaning. Water may seep under the linoleum and cause the backing to rot and the surface to buckle and break.

Except in extreme cases abrasive cleaners are not practicable for linoleum. Mild abrasives are sometimes used for stain removal or to cut wax deposits.

Steel wool is occasionally employed for stripping old wax, but may scratch the linoleum surface.

Either water or paste wax will provide a protective finish for linoleum floors; neither type of wax should contain any alkali.

Maintenance precautions can be briefly summarized:

1. Beware of highly alkaline cleaners.
2. Use only neutral soaps or detergents.
3. Be sure to remove all soap or cleaner after scrubbing the floor.

4. Do not:

- a. Use harsh scouring compounds.
- b. Use sweeping compounds containing oils, sand or abrasives.
- c. Use sealing compounds except those recommended by linoleum manufacturers for restoring the appearance of an old linoleum.
- d. Use too much water in cleaning linoleum floors.
- e. Leave water or washing solutions of the floor for any length of time.

5. Linoleum should be protected against indentation by glides and supports.

Rubber

The English word rubber was coined by Joseph Priestley, the discoverer of oxygen, from its use in rubbing out pencil marks. The term India rubber was given because it was first brought to Europe from the West Indies.

A factory for the production of rubber was in operation in France in 1803. However, the real development of rubber manufacturing began in England in 1820. Thomas Hancock, often referred to as the "Father of the Rubber Industry", opened a shop in London in 1820 and is credited with many of the early developments in rubber manufacturing.

Rubber was first manufactured in the United States in 1832 but production was limited. In 1870, B. F. Goodrich, the discoverer of vulcanization established a factory at Akron, Ohio. With the exception of World Wars I and II, rubber has been in continuous production ever since.

Rubber flooring was first manufactured around 1900 and

production has gradually increased from one million square yards in 1939, to around fifteen million square yards in 1958. However, rubber still constitutes a relatively small percentage of the resilient floor coverings.

Manufacture and cost. When the Japanese cut the crude supply of rubber from the Far East after Pearl Harbor, natural rubber floors went temporarily off the market. Before World War II much of the crude rubber had been imported from Malaya, Borneo, Sumatra and Java.

Germany had developed a synthetic rubber in World War I but since it was inferior to natural rubber, interest waned when the war was over. Little work was done in the United States on synthetic rubber until 1940 when B. F. Goodrich and Standard Oil each developed a synthetic rubber. The real impetus for development of synthetic rubber in the United States dates to December 7, 1941. Numerous synthetic rubbers have been developed since 1941; three important types are:

1. GR-2. (78 parts butadiene, 22 parts styrene)
2. Butyl. (97 parts isobutylene, 3 parts isoprene)
3. Neoprene. (monovinylacetylene)

Some of the ingredients in synthetic rubber might also be found in plastic vinyl floor coverings. In fact, it might be argued that synthetic rubber is a plastic, since it can be fabricated by procedures used in manufacturing plastics. However, synthetic rubber is not considered part of the plastics industry even though the preparation of the polymeric rubber

molecule is similar to the processes used in the development of resinous polymers.

The manufacturing process for rubber flooring involves the mixing of ingredients (clay, rubber, colors and accelerators) in a Banbury mixer and/or in a differential-speed, two-roll mill. The mass then passes through sheeter rolls. The sheeted material is vulcanized in platen presses to obtain a high surface gloss and is then cut to die presses. The final sanding operation controls the gauge and roughens the back surface for adhesion during installation. Variations in pattern depends upon the method of calender feed-preparations; i.e., the system for overlaying contrasting color stocks to a base-colored stock in the form of sheets (23).

Recent improvements in rubber tile production include (1) a catalyzing agent which hastens the vulcanizing process and consequently cuts manufacturing costs; and (2) the discovery of several ingredients which guard against oxidation and deterioration by ultraviolet rays of the sun (18). Some authorities disagree on the effectiveness of the latter development.

The two main types of rubber flooring are rubber tile blocks and sheet rubber which comes in rolls and is laid in a manner similar to linoleum. Rubber flooring is usually available in thicknesses of one-eighth inch, three-sixteenth inch, one-fourth inch and three-eighths inch.

Rubber flooring has many of the advantages of pure

vinyl and is usually more economical. The initial cost of rubber floors is generally medium to medium high compared with the other resilient floors.

Installation. Rubber tile can be installed satisfactorily over any solid, smooth, dry, ventilated subfloor, provided the subfloor is free of dust, oil, grease, floor wax or other foreign matter which may prevent proper adhesion (43). For years, the recommendation has been made that no rubber should be installed on subfloors in direct contact with the ground. Concrete has always been an extremely poor base since the alkali in the concrete may attack the adhesive which binds the tile to the subfloor. However, a new adhesive has recently been developed which is satisfactory for binding rubber to concrete in basements (40).

Rubber tile is usually installed in much the same manner as asphalt tile. After the adhesive has been spread and set, the method for laying tile is the sequence for most resilient tile floorings:

1. Make a chalk-line from the center of each wall to the opposite wall. This forms a cross, the center of which, is the center of the room.
2. The tiles are laid along the line, beginning in the center. Follow the line to each of the two adjoining walls but do not cement the tile down.
3. After the same margin has been obtained on all sides of the room the tile is cemented down.
4. One quarter of the floor should be completed at a time.
5. The entire floor should be leveled with a roller.

Additional information on installation is available from the Rubber Manufacturers Association, 444 Madison Avenue, New York 22, N.Y.

Utility. Rubber has for a long time been considered the aristocrat of floors, and this is for good reason. Rubber tile seldom gives cause for complaints for slipperiness. Rubber flooring is resistant to cracking or crazing and high tensile strength prevents excessive contraction and expansion, thus eliminating the tendency to buckle. Rubber tile will withstand 200 pounds per square inch, whereas 25 pounds is considered the limit for asphalt tile, 40 for cork tile, and 75 for plain linoleum (43).

Vinyl plastic at the present is a real competitor of rubber tile despite the greater resiliency and lower price of rubber. To distinguish rubber from pure 100 percent vinyl is difficult; smelling is one test. Rubber has a particularly characteristic odor when even a small amount of natural rubber is used, while pure vinyl has practically no odor. The chief merits of rubber are:

1. Relative quietness due to a low sound factor.
2. Resilience for underfoot comfort.
3. Good service life when properly maintained.
4. Easy installation.
5. Possible replacement of damaged tiles.
6. Availability of wide range of colors, sizes and thicknesses.

7. Good recovery from indentation.
8. Moderate resistance to acids, alkalis and staining.

Rubber tile floors also have disadvantages. The National Bureau of Standards exposed 60 samples of rubber flooring near a window for six months. A summary of the data gives evidence that sunlight can be harmful to rubber floors:

An examination at the end of this period showed that every sample had lost its gloss and in most cases the surface had chalked as is most often observed on painted surfaces exposed to sunlight. In addition, most of the colors had faded to a greater or less degree and in several cases, there was surface checking. . . .¹

Two other disadvantages of rubber for institutional floors should be mentioned:

1. Poor resistance to grease and solvents.
2. Cracking due to prolonged air exposure.

Maintenance. Rubber floors, when correctly maintained, will give years of satisfactory service from the standpoint of appearance, durability and economy. Correct maintenance is a vital requirement for full enjoyment of this type of floor.

Present day synthetic rubber tile is more resistant to abuse than the pre-war natural rubber product, but is susceptible to injury from improper care. Maintenance rules for the old type floors are applicable to the new synthetic floorings.

¹Brenn, Earl. Floor maintenance manual. Huntington, Indiana. The Huntington Co. p. X-1.

Rubber floors should not be scrubbed until they have been laid for several days. While the adhesive is setting the flooring should be protected against traffic. Heavy paper overlays can help prevent scratching or the tracking in of dirt, grime and plaster. After the rubber tile is thoroughly set the surface should be cleaned with a detergent approved by the Rubber Manufacturers Association. Certain types of cleaners and waxes have proved their suitability for use on rubber floors and appear in List No. 15 from this Association (36).

Clear water mopping is a common method of daily maintenance for rubber tile since the plate finish offers little refuge for dirt. However, when detergents are necessary they could be selected from the approved List No. 15 prepared by the Rubber Manufacturers Association in the publication, Approved Maintenance Methods for Rubber Floors.

Practically all manufacturers of rubber floors recommend waxing with a water emulsion wax; paste or solvent waxes are not practical. A good water emulsion wax will brighten the colors of the tile, add to the gloss and make the floor easier to clean and keep clean. The main purpose of wax is the protection of the floor from wear since wax is easier to replace than the flooring. A good wax coating will also safe-guard rubber against two enemies, sunlight and air. The daily buffing of a waxed floor with a polishing machine removes much of the soil and revives the appearance. Ordinary traffic dirt and stains do not readily penetrate a good film of wax.

Because of the sensitiveness of rubber to oils and greases, oil-treated dust mops or sweeping compounds should never be used.

Any type of varnish or lacquer will cause hardening or breaking of rubber and should not be applied.

Although rubber floors do not indent as readily as some resilient floors, casters and glides should be used on furniture.

Further information on the maintenance of rubber floors is available from the Rubber Manufacturers Association, 444 Madison Avenue, New York, N. Y.

Vinyl

Hundreds of plastic materials have been developed since John W. Hyatt discovered a synthetic plastic, celluloid, in 1868 (23). Although the first vinyl plastic floor was installed in 1933, this type of flooring has been popular only since World War II.

The initial development of plastic-type floors was slow due to the high cost of synthetic resins but the increased utilization of resins in floor coverings and other products has helped reduce prices. In 1941 23 million pounds of vinyl resin were produced at a price of 77 cents per pound. It has been estimated that over 500 million pounds were produced in 1958 and the price has decreased to less than 40 cents per pound. The floor covering industry currently uses about 15 to 20 percent of vinyl resin production.

No official figures are available for total production of plastic floor coverings. Some manufacturers have utilized vinyl resins in improving conventional products, thus disguising the total impact of the new materials. Some estimates have been that total production of all vinyl-type floor coverings currently amount to more than half the yearly production of asphalt tile.

Manufacture and cost. The term vinyl covers a wide variety of floor types. Vinyl plastic, or resin, is a definite material made from acetylene and hydrochloric acid which is frequently used in combination with other raw materials. These may include asbestos, asphalt, certain mineral fillers and even ground cork (43).

The physical and chemical properties of vinyl resins are very adaptable to floor coverings. These resins are produced in powdered form capable of blending with plasticizers, coloring pigments, stabilizers, and similar substances in a Banbury mixer. This differential-speed, two-roll mixer is the same type as that used in the rubber industry. After calendering, the product is pressed on a base; neither heat curing nor vulcanization is necessary. Plastic coverings are made both in the integral and membrane forms. The membrane base consists of asphalt-saturated felt, fabric, cork, or sponge rubber.

Pure, 100 percent vinyl floors have many desirable qualities and are the most expensive of the resilient floors.

Consequently, some of the less essential virtues of pure vinyl may be relinquished to produce other types of vinyl floors at competitive prices.

Vinyl plastic floor coverings manufactured at present include (22):

1. Rotogravure printed yard goods is made by printing a photographed design with vinyl ink on a heavy paper which is in turn water-proofed, laminated to an asphalt saturated base, and finally covered with a transparent layer of vinyl plastic.

A commercial product sold under the brand name of Sandran is representative of rotogravure printed yard goods.

2. Calendered vinyl flooring is the counterpart of conventional inlaid linoleum. In this type of plastic flooring the oxidized drying oils or linoxyn are replaced by vinyl resin and plasticizer. Calendered vinyl flooring is produced in both tile and yard goods form.

Gold Seal Vinyl-Floor is one brand available.

3. Semi-rigid vinyl base tile is comparable to asphalt tile except that vinyl type resins replace the asphalt, coumarone-indene or other cheaper resins. Semi-rigid vinyl tile is generally a little more flexible and resilient than asphalt tile.

Two examples are Terraflex and Koroseal.

4. Flexible vinyl tile, sometimes referred to as pure or 100 percent vinyl is similar to rubber tile in its flexible properties and is difficult to distinguish from rubber in appearance. This type usually contains a minimum of asbestos fiber, if any, and a lower loading of inert pigment and extended filler. Some manufacturers are laminating flexible vinyl type material to a backing material.

Wingfoot and Lifetime Vinyl are two brands of this type of flooring.

5. Vinyl print yard goods is similar to conventional felt base linoleum except that the enamel for printing the surface is made of vinyl resin.

Vinoflor, one brand, is available only in yard goods.

The tile sizes normally available are 9 by 9 inches, 12 by 12 inches and 18 by 24 inches. The calendered vinyl and roto-gravure can be obtained in 6 foot rolls. The available gauges of vinyl tile are one-eighth inch, three-sixteenth inch and one-fourth inch.

Custom vinyl cork tile and 100 percent vinyl tile are the most expensive in initial cost of the resilient floors. The price of vinyl flooring varies with the gauge of the tile, the percentage of vinyl and the other substance with which the vinyl is combined. Vinyl cork and flexible vinyl rate high in initial cost; vinyl asbestos is in the medium price range. In the opinion of many operators the superlative qualities of vinyl flooring justify the higher price.

Installation. Due to similarity of composition, installation of vinyl tile is practically identical to rubber. The subfloor must be smooth, solid and dry since semi-flexible tiles may break if placed over a rough or uneven floor. Even though a good adhesive might hold flexible tile, the irregularities in the subfloors should be sanded until smooth. For certain types of uneven subfloor a troweled underlayment such as oxychloride may be applied.

Single plywood subfloor construction may flex under pressure and cause the tiles to loosen or crack. A layer of strong plywood nailed to the subfloor should prevent flexing.

Until recently, vinyl flooring could not be laid successfully on concrete in contact with the ground. Several manufacturers of vinyl floors have now produced adhesives which are immune to the alkali and moisture in concrete (43).

The procedure for laying vinyl and rubber tiles is similar. A limited section of the subfloor should be coated with adhesive at one time. An underlayment of asphalt-saturated paper or felt requires roller leveling and a second coat of adhesive before the tiles are attached. The adhesive is applied to the subfloor with a notched trowel which has a saw-toothed edge. The trowel, scraped edgewise, applies the adhesive in small parallel ridges.

The preceding method can be used for either vinyl tile or vinyl sheeting but is not used for one type of vinyl flooring. This type of flexible vinyl tile is relatively thick, grilled on the underside to resemble a waffle and can be laid without adhesive. The many small suction cups formed by the grill hold the tile to the subfloor. This type of flooring may be removed and installed elsewhere (43).

Utility. The top quality of the vinyl plastics, flexible vinyl tile, resembles rubber in appearance and is almost as flexible and resilient (40). Flexible vinyl tile has excellent

wearability and is resistant to indentation, oils, grease, solvents, alkalis and many acids. Compared to other resilient floors, maintenance is economical and easy but the initial cost is high and flooding with water may loosen the adhesive cement.

The popularity of vinyl-asbestos tile is increasing. Although vinyl-asbestos resembles asphalt tile, it possesses several advantages over asphalt tile. These advantages are greater resistance to solvents, oils, greases and alkalis. However, vinyl-asbestos is more expensive than asphalt tile.

The general advantages of vinyl plastic tile floor coverings are:

1. Easy and economical maintenance.
2. Availability of wide range of colors, sizes, thicknesses and designs.
3. Excellent service life.
4. Glossy appearance.
5. High resistance to grease, alkali, solvents and most acids.
6. Resiliency.
7. Good resistance to indentation.
8. Excellent color stability.
9. Easy repair of damaged areas.
10. Installation is not difficult.

The disadvantages of vinyl plastic floor coverings are limited:

1. High initial price.
2. Subject to scratching from harsh abrasives.
3. Resistance to conformity to uneven subfloors.
4. Loosening of adhesive from constant flooding with water.

Maintenance. The maintenance of vinyl tile is a controversial subject. Some manufacturers of vinyl tile claim

that only sweeping and clear water mopping are necessary; none warn against use of mild detergents or floor wax (43). Those who do not recommend detergents or waxing report that such maintenance items are unnecessary expense since wax will not adhere readily to the flooring. The implication is made that vinyl floors are much more economical to maintain than the other resilient floors. This is usually true; however, from certain studies the consensus of opinion is that detergents and waxing are necessary for proper maintenance of vinyl floor coverings.

In 1953 the Chemical Specialties Manufacturing Association employed a research laboratory to study the problem of waxing vinyl floors (22). The technicians conducted numerous tests, analyzed the data and presented an opinion which follows:

To summarize, our study of the effects produced by the use of three types of floor wax on five brands of vinyl tile disclosed the following:

1. The appearance of the tile, as judged by gloss measurement, is greatly improved by waxing.
2. The use of wax does not significantly change the coefficient of friction or slip properties of the tile.
3. The soiling tendency of vinyl tile may be substantially decreased by waxing.
4. Soil removal by scrubbing is greatly facilitated where vinyl tile has been previously waxed.
5. Pronounced protection against marring of the surface results from waxing.

6. Some difficulty may be encountered in waxing new tile with emulsion type waxes because of poor wetting and spreading. However, experience indicates that after a period of use this condition disappears.²

In these respects vinyl floorings do not differ from other types of flooring for which decades of usage have amply proved the need for and desirability of waxing.

In 1955, Sanitary Maintenance Magazine contacted several vinyl flooring manufacturers for recommendations on cleaning with steel wool and waxing. The replies of thirteen manufacturing companies showed that nine recommended waxing while four replied that waxing was not necessary. Eight companies recommended occasional dry buffing with steel wool.

Obviously, vinyl tile floors should be maintained in a manner similar to asphalt tile. The small expense of maintenance materials may add years of life to a floor.

Nothing exists which will not in time, succumb to the wear and tear of friction. The constant beating and scraping of feet will eventually take toll on the vinyl surface (43). Waxing provides a protective coating, adds to the appearance of the floor and helps nullify the abrasive action of friction. Wax also retains surface soil and absorbs scuffs and mars which can often be buffed out.

Though solvent type waxes may be safely used on most types of vinyl tile, the water emulsion waxes seem most suitable

²Kimball, C. S. Waxing vinyl floors. Reprinted from Soap and Sanitary Chemicals. June, 1953.

(43). Water emulsion waxes do not spread easily on a new vinyl floor but after the floor has been in use the application of wax becomes less of a problem.

Information on vinyl floor maintenance is furnished in a report Waxing Vinyl Floors, which may be secured from Chemical Specialties Manufacturers Association, Inc., 50 East 41st Street, New York 17, New York.

Non-resilient Floors

Marble, tile, terrazzo and wood comprised the floors of the Egyptian, Greek and Roman Empires and also the Middle Ages; cement, as used today, and oxychloride for floors have received universal acceptance more recently. These floors all have two properties in common but in varying degrees: all are wear resistant and lack resiliency. Their popularity is due to qualities of permanence and resistance to wear and abuse.

Concrete

Concrete construction was known to the Romans; cement at that time was a material known as "puzzolan" cement. The term concrete comes from the Latin word concretus, that which is grown together.

Only since the invention of Portland Cement, first patented in 1824 by Joseph Aspdin of Leeds, England, did concrete as a basic material of construction gain importance. The name Portland Cement indicated the similarity of hardened cement and stone found on the Isle of Portland. Natural elements were first combined for use in England about 1756, but large scale manufacture did not begin until invention of the rotary kiln in 1892 (14).

Manufacture and cost. Concrete is a compound of gravel, broken rock or other aggregates, bound together by means of hydraulic cement, coal tar, asphaltum or other cementing

materials. The aggregates are separated into coarse, diameter of particles more than $\frac{1}{4}$ -inch, and fine, diameter of particles less than $\frac{1}{4}$ -inch, aggregates. If only fine aggregates are used the material is termed mortar.

When water is added to the cement and aggregates a paste is formed due to the chemical reaction between the cement and the water. Even the smoothest appearing concrete floors have rough surfaces when examined microscopically and all finished concrete floors contain a small amount of material which can be dissolved in water.

There are two types of concrete floors, monolithic and granolithic. The monolithic types makes good structural concrete, but the surface does not stand up well under severe wear. The granolithic type is differentiated from monolithic by the following characteristics:

- (1) The water-cement ratio in the mix.
- (2) The method of removing the excess water once the aggregate has been poured.
- (3) Type of aggregate.
- (4) The troweling operation.
- (5) The curing process.

Although the initial cost may be as much as 30 percent higher than monolithic, granolithic concrete produces a surface with greater density, strength, toughness and wear resistance (31).

Concrete is the least expensive floor which can be installed; asphalt tile is the only floor covering which is

comparable in terms of low initial cost. The type of concrete, reinforcement, depth of wearing finish and addition of coloring pigments determine the cost of a concrete floor. The pigments should be resistant to alkalis and should conform to the specifications of the American Society for Testing Materials or the Federal Government Specifications. A wide range of color is obtainable through mineral coloring pigments mixed with the concrete finish. From five to nine pounds of pigment per sack of cement are required depending upon the shade desired.

Installation. The Portland Cement Association has listed the following requirements for installation of a concrete floor:

- (1) Use only suitable materials.
- (2) Use not more than $3\frac{1}{2}$ to 4 gallons of mixing water per sack of cement when machine floating is used and $4\frac{1}{2}$ to 5 gallons of water when floating is done by hand. These amounts include water used as surface moisture on the aggregates.
- (3) Use mixtures and construction methods which will not permit segregation resulting in free water and fine material on the top surface.
- (4) Prevent early evaporation of water by keeping the concrete wet as long as practicable.

The wearing finish of concrete floors should never be less than 1-inch thick, whether it is placed at the same time as the structural slab or after the concrete in the structural slab has hardened.

The chemical reactions which cause the cement to

harden continue indefinitely if moisture is present and temperature is favorable (33). Through this curing process the internal structure of the concrete is built up to provide strength, resistance to wear and water-tightness. Floor finishes present such a large surface area that loss of moisture through evaporation takes place rapidly unless preventative measures are taken. Rapid drying not only stops the chemical reactions, but may cause dusting and cracking of the surface due to shrinkage taking place at a time when the concrete has little strength.

To prevent drying out, water for curing should be applied to the new concrete as soon as possible without marring the surface. The concrete should remain wet or the moisture retained by covering the floor with waterproof paper or a membrane curing compound. The longer the curing period can be extended, the stronger, harder and more impervious will be the concrete. The curing period should be at least a week for normal cement and 3 days for high early strength cement. Special attention should be given areas near radiators or other sources of heat to prevent evaporation during the curing period.

Utility. Few floors or floor coverings can withstand the abuse and heavy punishment to which concrete is often subjected. The Eastman Kodak Company in Rochester, New York, reported concrete floors in trucking rooms in excellent condition after 25 years of wear; concrete floors of the

platforms in Grand ~~Trunk~~ Central Terminal in New York City are still in use after 25 years (33).

Some of the advantages of concrete floors are:

- (1) The initial cost is low.
- (2) Concrete will withstand heavy usage.
- (3) When properly sealed and waxed concrete is relatively easy and economical to maintain.
- (4) Hot water used in cleaning has little effect on concrete.
- (5) Resistance to indentation is good.

The following disadvantages should be considered:

- (1) Concrete has minimal resiliency.
- (2) Damaged areas cannot be easily replaced.
- (3) Concrete will absorb some oils and solvents even after sealing.
- (4) Highly alkaline salts used in cleaning may damage the surface.
- (5) Acids exert a solvent action.

Maintenance. That concrete floors are indestructible and immune to wear and abuse is a common fallacy. The durability of concrete floors depends upon the observance of fundamental rules in making, placing, curing, finishing, and maintaining the concrete. Dusting, efflorescence, or blooming may occur if these rules are violated.

Dusting occurs when a thin layer of soft, chalk material appears on the surface. The abrasion encountered in ordinary wear may file away the high spots on the concrete floor. These filings form a fine dust which rises from the

floor and settles on everything in the room. This dusting can usually be prevented by sealing. Dusting, crazing and cracking may be caused by inadequate curing, over-troweling the finish, by dusting on sand or cement, or by using cement and sand mortar for the top coat without coarse aggregate (6).

Efflorescence is a dried deposit of water soluble salts. All concrete contains a small amount of water soluble salts which are mainly sodium sulphate, magnesium sulphate and calcium sulphate. When the floor has contact with a source outside the masonry material such as damp masonry walls this moisture may dissolve the soluble salts. These salts are slowly carried to the surface and when dried by the air the deposit is called efflorescence or alkali ice. This deposit must be removed with acid before sealing the floor since it makes an unstable base for any sealer. If there is not too much water pressure, the sealer may prevent evaporation and moisture to the surface.

Blooming is a type of stain which appears on concrete floors and may occur when there are too many impure salts in the water or simply too much magnesium chloride in the magnesite (6). Sealing will help to prevent blooming.

After a concrete floor has cured and thoroughly dried the surface may be improved by applying some material to assist in hardening and binding (33). Magnesium fluosilicate, zinc fluosilicate, sodium silicate, aluminum sulphate, zinc sulphate, chinawood and linseed oil and various gums, resins,

and paraffins are used for this purpose, but will not correct poor materials or careless workmanship. Many manufacturers of maintenance materials produce a special application for sealing concrete floors; some maintenance men recommend painting.

The sodium silicate treatment for concrete floors has proved satisfactory in residence halls at Michigan State University. Commercial sodium silicate in a 40 percent solution known as water glass is viscous and requires thinning before it will penetrate concrete. A good mixture combines 3 gallons of water with 1 gallon of sodium silicate. Two or three coats are recommended and each coat should be thoroughly dry before another is applied. Scrubbing machines will assist the penetration (33). The amount of solution required to treat a floor will vary with the porosity of the concrete. Generally, 1 gallon will provide one coat for 150 to 200 square feet of floor surface.

Concrete floors may be painted in areas not subject to heavy trucking or dragging. Oil paints, rubber-base paints and synthetic resin paints are available. Three coats of paint are advisable. The first coat should be very thin, about equal parts of thinner and paint. Some thinner may be used in the second coat and the third coat should be applied as it comes from the can.

Concrete should be thoroughly cleaned and dried before it is painted. The Portland Cement Association has recommended that one of the two following procedures be used (33).

- (1) After the concrete has cured for several months, neutralize the surface with a solution of 2 to 3 pounds of zinc sulphate per gallon of water. Allow 48 hours for this solution to react with the concrete and to dry. Clean the surface with water and let dry thoroughly before applying the paint.
- (2) Recent laboratory tests indicated that a good procedure was to apply a solution of 3 ounces of zinc chloride and 5 ounces of ortho-phosphoric acid (85 per cent phosphoric acid) per gallon of water to a cured floor. After this solution has dried for 24 to 48 hours any dust on the surface should be brushed off but the surface should not be rewetted before applying the paint. While laboratory tests gave excellent results with this treatment, actual field applications at present have been limited.

After a concrete floor has been properly sealed or sealed and painted the regular cleaning should be considered. Since concrete is alkaline, harsh alkalis and soaps with a high pH should not be used. Highly alkaline salts such as trisodium phosphate or soda ash may precipitate to form crystals which may eventually crack the concrete (21). Synthetic detergents may be preferred to soaps since they are generally more free rinsing and some soaps may start a chemical reaction with the lime in the concrete.

Maintenance people disagree on the advisability of waxing concrete. The main complaint is slipperiness which can be overcome with a slip-resistant wax or synthetic. Waxing improves the appearance of concrete and makes cleaning faster and easier by helping to hold the soil on the surface.

The Joint Committee on Standard Specifications for

Concrete and Reinforced Concrete has prepared a table on the resistance of concrete to chemical attack. See Table 2.

TABLE 2
EFFECT OF CERTAIN CHEMICALS ON CONCRETE

Substance	Effect on Concrete
Petroleum Oils	None
Coal tar distillates	None or very slightly
Inorganic acids	Disintegration
Organic materials:	
Acetic acid	Slow disintegration
Oxalic and dry carbonic acids	None
Carbonic acid in water	Slow attack
Lactic and tannic acids	Slow attack
Vegetable oils	Slight attack
Inorganic salts:	
Sulphates of calcium, sodium, magnesium, potassium, aluminum, iron, Chloride of sodium, potassium, calcium Chloride of magnesium	Active attack
	None
	Slight attack
Miscellaneous:	
Milk	Slow attack
Silage juices	Slow attack
Sugar solution	Active attack

Source of data: Encyclopedia Americana. 7:473. 1957.

Concrete is impervious to certain organic salts and inorganic materials, slowly attacked by other substances in these classifications and disintegrated by inorganic acids.

Hard Tile

Hard tile includes a group of clay tiles baked to a

stone hardness. Tile floors first became popular in European churches during the 12th century. In the 18th century the use of plain, undecorated, square, red tiles, known as quarry tiles, became common in Western Europe and later in America. By 1929 modern potteries all over the western world were producing many varieties of elaborate, decorative, floor tiles for homes and public buildings.

Manufacture and cost. Tile is manufactured from a mixture of clays, shales, feldspar, and flint which may be obtained locally or from various areas of the world. New Jersey, Pennsylvania, Ohio and California produce much of the vitrified floor tile in the United States (16). Differing compositions of the ingredients, methods of mixing and ways of firing account for the various types, colors and surfaces of tile. In 1927 the Department of Commerce in Washington in conjunction with manufacturers, architects and dealers established definite standards which cover the manufacture, sizes and grades of white glazed tile and unglazed ceramic mosaic.

Tile is made in many different colors with both glazed and unglazed surfaces. The decorative possibilities of color effects and compositions are almost unlimited. In manufacture, the ingredients pass through grinding, mixing and refining processes and are then formed into the desired shapes by either the plastic or the dust pressed method. In the plastic method wet materials are shaped on the moulds by hand.

For the dust pressed method excess water is removed and the materials in an almost dry state are pressed by machinery to a solid mass.

Unglazed tile, either vitreous or semi-vitreous, is produced in one firing. The color depends upon the kind of clay or the addition of oxides. Unglazed tile is manufactured in the following shapes and sizes:

Square	1 1/16 inches to 9 inches
Oblong	1 1/16 by 7/32 inches to 9 by 4 1/2 inches
Octagonal	3 by 3 inches to 6 by 5 3/8 inches
Hexagonal	4 1/2 by 2 1/8 inches to 6 by 5 3/8 inches
Triangular	1 5/32 inches to 3 inches

Glazed tile is made of the same materials and by the same methods as unglazed tile but in two firings. The body, called the bisque, is first formed and burned, then the glaze is applied and the tile is fired a second time. The glaze is a paste composed of feldspar, silica, and coloring metallic oxides which is spread upon the somewhat porous bisque. The second firing at a higher temperature melts the feldspar which fills the pores of the bisque and a continuous, semi-transparent glaze results. By trade custom the term glazed tile often refers to white tile and the term enamels to the tile with a colored glaze. Glazed tile and enamels are produced in the following shapes and sizes:

Square	1/2 inch to 6 inches
Oblong	2 1/8 by 1 1/16 inches to 9 by 6 inches
Hexagonal	2 5/16 by 2 21/32 inches to 3 by 2 15/32 inches
Octagonal	3 inches

The most prominent floor tile is ceramic mosaic (6). This is the familiar small tile, an inch or two on the side, fully vitrified and usually unglazed. Ceramic is derived from the Greek word keramas, meaning a vessel of baked clay, and the term mosaic refers to the design in the tile. Quarry tile is made from natural clay, is usually unglazed and is frequently sized in 4 or 6 inch squares. Quarry tile is commonly seen in shades of red in vestibules, hallways and institutional kitchens where the traffic is heavy. Pavers are unglazed tile resembling ceramic mosaic but larger in size. Faence tiles have highly colored glazes, a rugged artistic appearance and are often used to emphasize special decor in a building.

Although the effort may be to produce tile of only the best quality certain uncontrollable variations may occur. White glazed tile is graded as to degree of perfection into Selected, Standard, and Commercial grades. Other tile is divided into two grades, Selected and Commercial. The Standard grade is used for general classes of work, the Selected grade for the finest class and the Commercial grade where sanitation and service are more important than appearance (17).

The initial cost of hard tile depends upon several factors:

- (1) Grade, color, and size of tile.
- (2) Decorative effect and the amount of labor required for installation.
- (3) Local labor rates.

In most areas of this country, hard tile floors are high in initial cost. Marble is the most expensive non-resilient floor; tile and terrazzo of the various grades and designs frequently overlap in a cost comparison.

Installation. Regardless of the subfloor upon which hard tiles are to be installed, a concrete fill is necessary. This fill may also serve as the grout between tiles and become an integral part of the floor. The grout, which consists of Portland Cement, hydrated lime and sand, serves both a utilitarian and artistic purpose. It holds the tile in place, prevents the penetration of dirt and moisture between the tiles and helps control expansion and contraction (43). From an artistic standpoint the grout emphasizes the beauty of the tile, breaking the monotony of a one color expanse and distinguishing the separation of different colors.

After installation the tile is cleaned with a diluted acid to remove grouting from the surface.

Utility. Hard tile is particularly adapted to the exacting demands of an institutional floor:

- (1) Economical to maintain.
- (2) Attractive and long wearing when properly maintained.
- (3) Availability of large variety of colors, shapes, sizes and decorative effects.
- (4) Easy replacement of damaged areas.
- (5) Not easily damaged by acids, alkalis or hot water.
- (6) Not susceptible to indentation.

Certain disadvantages may preclude the use of tile:

- (1) High initial cost.
- (2) Susceptibility of grout to acid and alkaline damage.
- (3) Glazed tile in kitchen areas may become greasy and very slippery.
- (4) Tile in dishwashing rooms may crack and break from dropped silverware and dishes.
- (5) Tile floors have little resiliency and may be noisy from traffic.

Maintenance. Little information is available on the maintenance of hard tile floors. Tile and grouting require proper care to look attractive and provide long service life.

There is a slight difference in the maintenance of glazed and unglazed tile.

- (1) Unglazed tile. Some authorities (43) recommend sealing and waxing unglazed tile. Any soap, detergent or powder used in cleaning must be one which will not disintegrate the grouting. In general, anything which is not recommended for concrete, should not be used on hard tile. Although many acids and alkalis will not harm the tile they may deteriorate the grout.
- (2) Glazed tile. Synthetic detergents may prove superior to soaps since they tend to rinse better and leave less residue (44). Glazed tile does not take a seal or wax readily. Authorities differ on whether or not to wax or seal glazed tile; many recommend waxing but not sealing. Coarse steel wool and harsh abrasive cleaners should never be used on glazed tile since they may scratch the surface finish.

Marble

Ancient peoples made their finest buildings of either

granite or marble; the Egyptians used granite while the Greeks and Romans found marble more suited to their needs. The temples and arcades at Athens and Corinth and the Forum Romanum stand as monuments to marble and to the genius of the Greek and Roman Empires.

Marble is any limestone hard enough to take polish and is principally calcium carbonate in crystalline form. Most marble contains crystals of calcite or dolomite which are white when pure; the finest white stone is called statuary marble.

Black, gray, pink, red, green and many kinds of mottled and banded marbles are available. The beautiful colors are due to impurities or staining matter mixed with the calcite or dolomite crystals; serpentine marbles are green and yellowish-green silicates; fossiliferous are limestones full of fossil shells and on polished surfaces of such marbles the cross sections of the shells may be seen through the rock.

Manufacture and Cost. The fabricator of marble is mother nature, who has changed or metamorphosed limestone through the action of heat and pressure far below the earth's surface over a period of centuries.

Shells or irregular grains of calcium carbonate in crystalline form constitute ordinary limestone. In marble the crystals have been ground firmly together and metamorphosis has made the stone more uniform in hardness and grain, freed it from small cavities and pores and produced a texture

sufficiently close to permit polishing, Marble may vary in porosity from $\frac{1}{2}$ to over 13 percent and some types are ten times stronger than others (6).

The most famous quarries are in the Apuan Alps, an off shoot of the Apennines, and the stone is largely worked in the neighborhood of Carrara. Stone from these quarries was employed in Rome for architectural purposes in the time of Ausustine (63 B.C. - A.D. 14). The finest varieties, adapted to the needs of the sculptor, were discovered later and made famous by Michelangelo and Leonardo da Vinci in the fifteenth century.

Marble is generally the most expensive floor which can be installed. Certain grades and varieties of mosaic tile and terrazzo may be more expensive than some of the cheaper grades of marble. Marble is often installed when the initial cost is not the determining factor in the selection of a floor, but rather long life and beauty. Fancy, imported marbles are the most expensive. Other factors which determine the cost are color, size, grade, and depth of the tile or slab.

Installation. Unlike some other floors, marble requires special processes in installation. The cement bed which receives the marble should consist of one part Portland Cement to not more than three to five parts of sand, mixed quite dry for tamping and should be spread over the rough fill (27). Grout, commonly used to separate other hard tiles,

providing for expansion and contraction as well as decorative effect, is not normally used in laying marble floors since marble has less tendency to expand or contract from changing temperatures. The tiles are set closely together and the edges between the tiles may be coated with a litharge and glycerine mixture.

Marble is not adaptable for installation over wood floors but only over a concrete or cinder fill. The Marble Institute (27) has recommended that marble steps be laid on metal frames imbedded in cement mortar. Plaster of Paris, Portland Cement and non-staining white Portland Cement are standard setting materials for all marble floors.

Marble is adapted to a high polish which is called a "honed" finish. This highly polished finish is not slip resistant and is also subject to abrasion. The coarser finished marbles are known as "sand and grit" finish and "saddles". To decrease the slip hazard, non-slip inserts and nosings are sometimes used on stair treads and ramps.

Marble tiles are about 7/8 inch and are supplied in standard sizes of 8 by 16 inches, 12 by 12 inches, and 10 by 20 inches. Larger sizes are considered slabs rather than tiles.

Utility. The long wearing qualities and attractiveness of marble can be substantiated by many of the buildings of the Roman Empire in existence today. The utilization of marble in a building ranges from the exterior facade to the interior walls, columns, staircases and floors. Floors present the greatest

maintenance problem. For the institutional floor marble has many distinct advantages:

- (1) Availability in many attractive colors and designs.
- (2) Easy to keep clean and attractive when properly sealed.
- (3) Low maintenance cost.
- (4) Excellent wear resistant qualities.
- (5) Good resistance to indentation.
- (6) Seldom damaged by hot water.
- (7) High load limit per square inch.

Marble floors have certain disadvantages:

- (1) High initial cost.
- (2) Solvent action exerted by acids.
- (3) Difficult removal of oil, iron and acid stains if they have penetrated the marble.
- (4) Difficult replacement of damaged areas.

Maintenance. Marble has too often been considered indestructible and the maintenance has consequently been neglected. The closely integrated surface offer little refuge for dirt and soil and if the design is variegated it also serves to camouflage small litter and minor stains. However, negligence will eventually become obvious in stains, abrasion marks and even cracks.

To keep marble in good condition a regular maintenance procedure is necessary. Strong alkaline solutions have a tendency to penetrate the marble and, upon drying, expand

and break the minute cell walls, causing a surface disintegration. Daily maintenance with a good neutral soap or detergent is usually sufficient. To prevent stains, acids, rust and oils from penetrating marble is much easier than to remove them. If a floor has been neglected, it may have to be scrubbed with a mild abrasive powder. While the Marble Institute does not recommend or caution against seals and waxes, many maintenance people are using them successfully. The maintenance man who seals and waxes a marble floor should check that the floor does not become too slippery; seals and waxes are available which have anti-slip properties. A well sealed, properly waxed floor is easier to clean because the soil is kept on the surface.

The Marble Institute (27) has published a pamphlet, How to Keep Your Marble Lovely which contains a list of cleaning materials recommended. Brenn (6) has suggested that anyone who has marble to maintain should become familiar with A Study of Problems Relating to the Maintenance of Interior Marble by D. W. Kessler, Technologic Papers of the Bureau of Standards, No. 350.

Oxychloride

Oxychloride, one of the least publicized types of flooring, is also known as magnesite, but that term is seldom used by industry today. About 50 million square feet of oxychloride flooring are installed each year; a high percentage of the total production is purchased by the Federal Government.

Manufacture and cost. Oxychloride flooring is composed principally of magnesium chloride and magnesium oxide which react chemically to form a product having unusual cementing properties.

The materials for an oxychloride floor are supplied on the job in two parts. One part consists of flake magnesium chloride; the other part is a dry mix of magnesia and the required fillers, aggregates, plasticizers and color pigments. All of these ingredients are properly proportioned and thoroughly machine mixed by the manufacturer. The installer dissolves the magnesium chloride in the required volume of water to yield a solution of the proper density. The dry mix is placed in the mortar box or machine mixer and gauged with sufficient volume of the chloride solution to yield a workable plastic mix. Almost any color may be obtained since the color pigments are simply combined with the mix.

Oxychloride flooring is available in a variety of

mixtures from a dense, strong, hard floor of mineral aggregates to a more resilient type through the incorporation of such fibrous aggregates as wood flour and sawdust. Terrazzo-like floors can be produced by the addition of marble chips to the oxychloride cement which replaces the Portland Cement matrix used in the construction of conventional terrazzo floors. The surface of these floors must be ground down.

A finished oxychloride floor resembles very smooth concrete, though the color pigments may give it the appearance of battleship linoleum; or it may have the appearance of terrazzo if marble chips have been incorporated in the matrix.

The cost of installed oxychloride will depend upon the aggregates used in the mix. In general, oxychloride floors are more expensive than concrete but less expensive than terrazzo. They may be cheaper or more expensive than some hardwood floors depending upon the aggregate used in the oxychloride and the wood floor with which they are compared.

Installation. Until the Oxychloride Cement Association was organized in 1943, no generally accepted set of specifications was available for the laying of these floors (8). A wide variety in quality of oxychloride floors resulted from poorly standardized methods of installation. Today, reputable flooring contractors follow the specifications approved by the Association.

The subfloor should be smooth and level to prevent

humps and irregularities on the finished floor, since rough or uneven places are susceptible to damage through wear. The coatings of oxychloride floors run from 1/2-inch to 5/8-inch in thickness.

The subfloor base for the plastic oxychloride mix may be any type: concrete, stone, brick, ceramic tile, steel and even wood. If oxychloride is applied over a wood subfloor, best results are obtained by first covering the wood with asphalt saturated felt. A metal anchoring medium should be nailed over the felt at 6-inch intervals (8). This metal anchor may be a heavy wire mesh over which the plastic mix is poured and thoroughly worked into all openings and recesses. When the installation mix is brought to the proper level it is then soft-troweled and from four to six hours later given a final hard trowelling to produce a hard, dense, smooth and polished surface.

If the oxychloride coat is applied over an old concrete floor, the entire surface of the floor must be roughened by sandblasting, tooth-chiseling or picking. The roughening will provide the necessary mechanical and chemical bond between the concrete subfloor and the oxychloride coating.

When the oxychloride floor is installed over a new concrete floor the surface of the new concrete should not be troweled in finishing. Just before the final set the concrete should be "broomed" in one direction to produce a

finish resembling tapestry brick. The new concrete subfloor should be allowed to age for about 30 days before the oxy-chloride mix is applied.

Hard subfloors such as stone or ceramic tile require sandblasting or tooth-chiseling to roughen the surface. Since satisfactory roughness for good bondage may be difficult to secure, a latex or plastic base bonding medium is sometimes used for this purpose.

Utility. Oxychloride floors are frequently installed in hallways and lobbies. The advantages follow:

- (1) Lighter and more resilient than concrete floors.
- (2) High-strength to low-weight ratio.
- (3) Wearing hardness comparable to granite.
- (4) Monolithic form of installation (one complete slab) possible.
- (5) Medium to low initial cost.

Oxychloride floors have certain disadvantages:

- (1) Sealing is necessary.
- (2) Maintenance is difficult.
- (3) Water, alkalis and acids may cause damage.
- (4) Damaged areas are not easy to repair.

Maintenance. A newly installed oxychloride floor should be thoroughly cleaned after the final set but should not be scrubbed or flooded with water for two weeks after completion (8).

A good penetrating sealer should be applied after the floor is thoroughly dry. Since an oxychloride floor is fairly absorbent, the sealing is essential and enough sealer must be applied to adequately fill the floor without leaving an excess on the surface.

In cleaning an oxychloride floor a good neutral soap or synthetic detergent is advisable; strong alkaline and acid cleaners must be avoided. The Oxychloride Cement Association recommends that water be left on the floor only long enough to loosen the soil and should not be allowed to dry on the floor. Oxychloride floors may be scrubbed with a scrubbing machine.

The waxing of oxychloride floors is recommended by the Association. Either solvent or water emulsion waxes may be applied depending upon the aggregate used in the cement. An oil-type dressing of equal parts of turpentine and china-wood (tung) oil is sometimes used in place of wax.

In summary, these precautions should be observed in the maintenance of oxychloride floors:

- (1) Avoid acids and alkalis. Lye, sal soda, trisodium phosphate or soda ash may damage the floor.

In most cases the filler of these floors is readily attacked by strong acids and alkalis. The floor must be cleaned with a soap or detergent which will not harm any vulnerable filler such as cork or wood.

- (2) Seal to prevent blooming. Oxychloride may bloom if incorrectly formulated or installed.

- (3) Use water with care. Oxychloride floors are undesirable for high moisture installations. If water is permitted to remain on the surface the filler may rot. Moisture also attacks and deteriorates magnesium oxychloride binder.

Terrazzo

The origin of terrazzo dates to the enterprising Venetians of the sixteenth century who mixed odd chunks of marble in cement to floor their terraces; hence the name "terrazzo" (30).

After much experimenting the Italians discovered that if they crushed marble, mixed the small chips and poured the marble-cement mixture into place, the surface was more uniform. Eventually they learned that if this mixture was rubbed down with a wet cement grout to ease the friction, the color in the marble chips could be intensified. After pushing a rubbing stone, known as a "gallera", back and forth across the floor for a good many hours a beautifully colored surface was produced.

Many improvements were made in the finish of terrazzo subsequent to its introduction in America. One of the first was the use of metal divider strips which allowed such intricate work as monograms, pictures and maps to be incorporated into the floor. These brass and zinc alloy strips contributed to strength and endurance by taking care of expansion and contraction and by helping to prevent cracks. Rubber

and plastic materials have also provided effective divider strips for terrazzo installations. A second development, the electric grinding machine, made it easier to polish the terrazzo finish, shortened the time of installation and enhanced color qualities. Treatment of the top surface of terrazzo with white cement and the advent of mineral color pigments introduced an almost limitless color selection and provided a further refinement for terrazzo floors.

These technical improvements in the installation of terrazzo have been instrumental in the development of one of the truly beautiful floors of the twentieth century.

Manufacture and Cost. Terrazzo floors consist of a mixture of 70 per cent marble chip aggregate imbedded in 30 per cent Portland cement.

The coarse aggregate is waste marble or granite chips which have been run through a crusher and over screens for a minimum 2-inch size grading. Although ornate patterns may be worked into the terrazzo, many floors carry no definite design but display an expanse of irregular, vari-colored marble chips in close proximity to each other in the cement.

The cost of terrazzo flooring is considered medium-high and may vary considerably in cost per square foot installed according to the grade and amount of the marble, coloring pigments added, intricacy of design and amount of finishing.

Installation. Terrazzo floors may be installed over concrete construction by one of two methods: bond the terrazzo to the structural slab or separate the two components.

For the first method a concrete fill of cement, sand and crushed stone or gravel in the proportion of 1:2:4 provide the underbed which should be at least $1\frac{3}{4}$ inches below the finished floor. Before the terrazzo is installed the surface of the concrete should be thoroughly cleaned of all debris and slushed with neat cement grout to ensure a good bond.

The second procedure is advisable in buildings where cracking is anticipated either from settlement, expansion and contraction, or vibration, and this method requires a total thickness of at least 3 inches above the structural slab. The concrete slabs are covered with a thin bed of dry sand over which a sheet of Kraft or tar paper is laid before the underbed is installed. Consequently, the cracks originating in the structural slab terminate at the sand bed and are less likely to appear on the finished surface.

The installation of terrazzo over wood floors requires the following procedure:

- (1) Cover the wood floor with tar paper.
- (2) Place a reinforcing wire fabric lapped four inches over this paper.
- (3) Lay the concrete underbed as in method two.
- (4) Pour the terrazzo topping to a minimum 2-inch thickness.

The National Terrazzo and Mosaic Association (30) has compiled detailed specifications and has stated certain precautions for the installation of terrazzo:

- (1) The terrazzo topping must be at least 5/8-inch thick.
- (2) Composition for the terrazzo should be two parts of marble granite to one part of Gray or White Portland cement, mixed dry.
- (3) The finished surface should show a minimum of 70 per cent marble granite.
- (4) The metal dividing strips should be at least 1 1/4-inch deep and be anchored.
- (5) The floor should be kept moist for at least six days by sand, paper, or curing mats.
- (6) When the floors have set sufficiently they should be machine rubbed with a #24 abrasive followed by a #80 abrasive.
- (7) After 72 hours the grouting should be ground off with a #80 grit. Subsequently, the terrazzo must be cleaned, thoroughly treated and sealed.

Utility. Terrazzo has the strength and economy of concrete and the durability of marble. For areas which receive heavy traffic such as corridors, terrazzo is one of the best floors which can be installed. Considering service life and maintenance, the cost is low. Terrazzo is not recommended for floors under soup kettles in kitchens or for areas which are subjected to acids or strong alkaline concentrations.

Terrazzo floors have a number of advantages:

- (1) Innumerable colors and designs.

- (2) Long life in any area not subjected to strong alkaline or acid.
- (3) Economical in terms of maintenance cost and service life.
- (4) Smooth, easily cleaned surface.
- (5) Fairly non-absorbent to soil when properly sealed.
- (6) Resistant to indentation.

The disadvantages are:

- (1) Medium high to high initial cost.
- (2) Sealing is necessary.
- (3) Damaged areas cannot be easily replaced.
- (4) Strong acids or alkalis may damage terrazzo.
- (5) Oil and grease spots are difficult to remove.

Maintenance. For the maintenance of terrazzo, the National Terrazzo and Mosaic Association (30) has made a series of recommendations:

- (1) The physical characteristics of the floor must be kept in mind in selecting the methods and materials to maintain it. Since terrazzo is usually 70 per cent or more marble and 30 per cent or less neat Portland Cement, the materials and methods must be suited to marble and concrete.
- (2) Suitable materials for treating and cleaning terrazzo floors will fill the original pores or have little effect on them. Harmful materials (such as trisodium phosphate or soda ash) will increase the number and enlarge the size of the pores.
- (3) Terrazzo is benefited by a penetrating sealer which prolongs hydration of the cement to provide color density and longer life on new terrazzo. On old terrazzo it will reduce the penetration of water, stains and grime.

- (4) New terrazzo, when not given a special treatment, often has a dull, gray appearance. This is caused by a deposit of efflorescent mineral salts which are a by-product of the setting and curing of the Portland Cement. This chemical action continues at a decelerating rate over a period of months, unless the terrazzo floors are sealed.
- (5) The cleansing agents used on terrazzo should not contain strong alkalis, acids or metallic salts. The floor must be rinsed thoroughly after each scrubbing to remove any harmful residue.
- (6) Natural terrazzo has frictional resistance in excess of the slip resistance minimum coefficient of .50 established by the Underwriters Laboratories. Slipperiness of terrazzo is due to wax, soap and oil. A residual of cleaning materials is also a common cause of slipperiness.
- (7) Low cost maintenance is an outstanding feature of terrazzo. The Association warns against using cheap, unsuitable cleaning materials and especially against soaps and scrubbing powders which contain water soluble inorganic salts or crystallizing salts. These salts can crystallize out and cause cracking and pitting of the terrazzo.

Wood

Wood floor installations in commercial establishments and institutions are primarily hardwood. The common hard wood floorings are oak, maple, beech, birch and pecan. Oak, the most plentiful, constitutes the highest percentage of wood flooring in the United States.

Oak. Twenty varieties of oak are processed into flooring. Except for grouping nine of them as white oak and eleven as red oak, no attempt has been made to classify them in commercial practice (29). In

quality and utility there is little difference between the two groups. To the untrained eye the difference between white and red oak lumber is not readily apparent. The experienced lumber man will note, however, that although both groups are light in color, white oak has a brownish tinge. Red oak is characterized by a pink cast which usually turns reddish brown after application of finish.

The beauty of oak is due to two important characteristics of its cellular construction. First, it is one of the few heavy hardwoods that are ring-porous. The springwood of growth each year is comprised of larger and more prominent pores than the summerwood and this contrast produces the attractive figure conspicuous in plain-sawed oak. Secondly, oak is marked by strips of cells extending radially in the tree. Known as wood rays, these cells appear as flaky figures when the wood is quarter-sawed. Singular in its possession of these more or less prominent wood rays, oak is the only popular flooring hardwood that is quarter-sawed.

Maple. Next in order of popularity among the flooring hardwoods is hard maple (29). The two species in this classification, sugar maple and black maple, are exceptionally hard and strong and have great resistance to abrasion. Although lacking the striking

beauty of oak, maple takes an excellent finish and is used rather extensively where extremely heavy wear is encountered.

Since it has no prominent springwood pores, maple is designated as a diffuse-porous wood. The pores are very small and evenly distributed; the wood is close-grained, the heartwood is light reddish brown; and sapwood is white with a slight brownish tinge. However, the contrast in color between the hardwood and sapwood is not as pronounced as is oak. Varying natural colors of the wood are permitted even in the higher grades although a special grade provides for clean white stock.

Beech. Only one species of beech is produced in this country (29). In texture, strength, hardness, abrasive resistance and color beech closely resembles birch. The prominent wood rays are not sufficiently attractive in figure to warrant production of quarter-sawn stock.

Birch. Of the dozen or more species of birch grown in the United States two are utilized for flooring (29). These are yellow birch which is abundant and widely used and sweet birch. Like maple and beech, birch is a diffuse-porous wood of fine, uniform texture. Hard, heavy and strong, birch possesses considerable abrasive resistance. The two species vary

only slightly; both have heartwood of reddish brown and sapwood of much lighter color. Certain color variations occur frequently, but these are not considered in grading. Special grades, however, are manufactured from all red-faced stock.

Pecan. The hardest of all hardwoods is pecan, which belongs to the hickory family. It is close-grained, extremely durable, and has fine or invisible wood rays. The heartwood is darker than that of most woods ordinarily used for flooring (29).

Other Species. Because of scarcity and consequent high cost, the other species occasionally used for flooring, walnut, cherry, ash, hickory, and East Indian teak, are relatively unimportant. Extremely hard and durable, most of these species have grain patterns which result in strikingly beautiful floors and they are usually processed into parquetry.

Manufacture and Cost. Lumber processing areas in the United States are located near the source of the raw material. The Pacific Northwest is a leading lumber producing area; Tennessee is another large producer of hardwood (13).

All large mills are integrated in that they perform both the sawing and planing operations. The sawmills are usually built near a river or some other body of water so that adequate storage space is available for large log inventories.

The logs are hauled from storage to the sawing floor by means of specialized handling equipment, sawed to proper length, thrown onto the log deck, and from there to an adjustable log carriage. The sawing process is a progressive operation and the original log may go through as many as a dozen sawing, cutting, and trimming operations, before it finally emerges in specified size and shape. After sawing, the lumber is conveyed to the sorting and grading table and from there transported to drying piles or the kiln.

Regardless of the processes used in cutting and finishing, the timber must have proper seasoning and drying. This important procedure tends to decrease shrinkage after installation, increase resistance to decay, reduce weight and improve strength and mechanical properties (18). The two common methods of wood drying are air and kiln. Air drying is cheaper but takes a great deal of time and storage space and may result in a loss due to checking and warping of the woods. Kiln drying, a controlled procedure which assumes more uniform results, may employ warm moist air or superheated steam. The length of time varies from a few days to several months; the longer drying period produces better wood for floors.

Certain classes of building lumber go to lumber products manufacturers for further conversion to flooring. Most hardwood flooring in the United States is manufactured

by specialized mills which are equipped to produce flooring of different styles or types, with the result that a type of hardwood flooring can be obtained to harmonize with any style of architecture or furnishings. Broadly, these types are classified as strip, plank, and pattern or parquet flooring. A fourth type known as block flooring is sometimes given a separate classification, although strictly speaking it is a form of parquetry.

Strip flooring. As the name implies, this type consists of flooring pieces cut in narrow strips of varying thicknesses. Most floors of this type are composed of strips of uniform widths. Interesting patterns are formed from stock selected for variations in color or other natural irregularities; attractive designs also may be achieved by using strips of random widths. Most hardwood strip flooring is tongued and grooved at the factory, so that each piece joins its neighbor snugly when laid; square-edge strips are also available.

Strip flooring of oak, maple, beech, birch and pecan is manufactured in a variety of sizes, ranging in width from 1 inch to $3\frac{1}{2}$ inches and in thickness from $\frac{5}{16}$ inch to $3\frac{3}{32}$ inches. Length of strips in a bundle of flooring varies, but average lengths are specified in each grade. Some strips may be as long as 16 feet.

Plank flooring. One of the oldest types of hardwood floors, plank flooring dates to the handcraft era and was widely used in medieval Europe. This flooring was also popular in American colonial homes and recently the demand for it has been increasing for homes, clubs and other buildings where an atmosphere of rugged informality is desired. Colonial plank flooring derived much of its charm from rough effects and interesting irregularities which were unintentional. This charm is retained in modern plank flooring even though the product is now precision made.

Plank floors are random width pieces tongued and grooved, with square or matched ends. Frequently, the edges of planks are beveled to reproduce the effect of the large cracks which characterized early hand-hewn plank floors. The wood pegs by which the old plank floors were fastened are simulated by means of wood plugs glued to holes on top of the countersunk screws which actually fasten the planks to the sub-floor.

Solid planks generally are processed in 25/32-inch thickness for tongue and groove flooring and 5/16-inch thickness for square edge flooring. Widths range from 3 to 9 inches in multiples of 1. Minimum length for certain types is 2 feet, for others 3 feet.

Pattern or Parquet Flooring. Pattern floors, known as parquet and design floors, appeared as early as the 14th century in Europe and represent the most elaborate and expensive type of hardwood flooring. Early pattern floors presented bizarre effects which would be incompatible with present architectural styles. Today parquetry assumes geometric patterns such as squares, rectangles and herringbone in almost infinite variety. Literally hundreds of designs are available which may feature variations of species or of shades of the same species. Most parquet flooring is oak, although it also is produced in maple, beech, walnut mahogany, East Indian teak and ebonized wood. The latter consists of dyed white maple or holly.

Parquetry is manufactured in short lengths of individual pieces. Each piece must be cut to exact dimensions to match perfectly the dimensions of another piece, or multiples thereof. Customarily tongued and grooved and end-matched, the pieces are laid separately, either by nailing or setting in mastic.

Parquetry is manufactured principally in 25/32-inch thickness. Most common face width for each piece is 2 1/4 inches, but widths of 1 1/2, 2 and 3 inches can be obtained by special order. Standard lengths are in multiples of face width.

Block flooring. Block flooring, a form of parquetry, differs from conventional parquetry in that the pieces are assembled into square or rectangular blocks at the factory. They are held together by various means on the back, sides or ends. These prefabricated blocks are laid as units, either in mastic or by nailing.

Prefabricated blocks are made in thicknesses of $1/2$ inch, $25/32$ inch and $33/32$ inches. Customary strip widths are $1\ 1/2$, $2\ 1/4$, $3\ 1/4$ and 4 inches. All thicknesses are not produced in every width. Dimensions for the completed blocks, of course, are in multiples of the strip widths.

Many complex and inter-related factors affect the installed cost of a wood floor.

- (1) The grade, pattern, size, and type of wood.
- (2) The area of the country in which the floor is installed.
- (3) Local labor rates.
- (4) Subfloor on which the wood is laid.

In general, hardwood floors rank relatively low in initial cost of non-resilient floors. Oak is the cheapest followed by birch, beech, and maple. There is, however, overlapping in price between various grades of the different varieties of wood.

Installation. Building experts are unanimous in

agreeing that in conventional joist construction sound subflooring beneath the finish flooring is essential. Ordinarily nailed directly to floor joists, subfloors are so necessary to good construction that most modern building codes specify them. Their omission usually is poor economy, even though the finish floor is of strong, durable wood.

Subflooring serves several important purposes. It lends bracing strength to the building and provides a solid base for the finish floor, practically eliminating the possibility of floor sag and squeaks. By acting as a barrier to cold and dampness, subflooring helps keep the building warmer and drier in winter and provides a safe surface during erection of the building.

If strip flooring is to be used, flooring should consist of good quality wood boards about 1 inch thick and not more than 6 inches wide. Wider boards are subject to excessive expansion and contraction. The boards should be spaced about one-fourth inch apart, and face-nailed solidly at every bearing point with two 10-penny nails. Inadequate nailing may result in squeaky floors. In order to provide maximum support, all butt joints of the boards should rest on joists.

Square edge boards are preferred to tongued and grooved boards because the snug joining effected by the latter is undesirable in subflooring. Boards should be kiln dried or thoroughly air dried. The use of green subfloor boards frequently causes squeaks.

The subflooring should be laid diagonally. This arrangement not only adds bracing strength to the building, but permits the finish strip flooring to be laid in any direction. Should the building be of two or more stories, the subfloor boards should run in opposite diagonal directions on alternate floors.

Before installation of the finish flooring is to begin, the subfloors should be examined carefully and any defects corrected. Raised nails, for instance, should be driven down and loose or warped boards replaced. The subfloors should be swept thoroughly or scraped if necessary to remove all plaster, mortar, or other foreign materials. These precautions must be observed if the finish flooring is to be laid properly.

The last operation before actual installation of the wood finish flooring should be the application of a good quality asphalt coated building paper over the subflooring. This will protect the finish floor and the interior of the building from dust, cold and moisture which might seep through the floor seams. Strip flooring presents the most attractive appearance when laid lengthwise of the longest dimension.

Adequate nailing is absolutely essential in the finish floor as well as the subfloor. The baseboard is installed with the lower edge slightly above the finish floor. Shoe moulding should be nailed to the baseboard after the entire floor has been laid.

The National Oak Flooring Manufacturers' Association (29) and the Maple Flooring Manufacturers' Association (26) list directives for the installation of a wood floor.

- (1) The building in which wood flooring is to be laid should be heated for 10 days to at least 70°F. The flooring should be loosely piled in the building for several days to acclimate it to the moisture conditions in the building.
- (2) Provision for an expansion joint (the width depending on size of floor area) is a safeguard against buckling. Dry flooring laid in a damp building will swell and may cause cupping or buckling.
- (3) Do not lay flooring until plastering and cement work are thoroughly dried and woodwork and trim are installed. All plumbing, electrical wiring, plastering and painting should be completed before the finish floor is begun. The laying and finishing of hardwood floors should be the last operation in building construction.
- (4) Do not close the windows; opening a window at the top aids in driving out moisture through air circulation.
- (5) Do not under any circumstances lay the flooring tight against studding or walls.

More detailed information on the installation of wood floors can be obtained from these Associations.

Utility. A properly installed and maintained hardwood floor has well known advantages:

- (1) Structural strength. Certain species have been known to support weights of 5,000 pounds per square inch.
- (2) Durability. Properly installed and maintained hardwood should last many years in certain areas of a building.

- (3) Comfort. All of the hardwoods possess considerable insulating value. They are easier to walk or work on than other non-resilient floors.
- (4) Attractiveness. The natural variations in the wood form an attractive flooring design.
- (5) Capacity for being restored. Good hardwood floors can usually be sanded and refinished to obtain a new surface.
- (6) Availability. Most of the hardwoods are available in a variety of sizes and shapes. Oak grows in greater abundance than any other hardwood, consequently, it is produced in greatest volume, and normally is readily available.

Certain disadvantages of wood for institutional floors are also known:

- (1) Installation requires an expert.
- (2) Wood floors require sanding and sealing.
- (3) Highly alkaline cleaners can damage the wood.
- (4) Excessive use of water on wood floors can cause swelling, warping and buckling.
- (5) Open grain woods such as oak require a filler in addition to sanding, sealing and waxing.
- (6) The maintenance of wood floors in areas such as dining rooms and kitchens may be expensive.
- (7) Well sealed wood floors are not entirely resistant to solvents, greases and acids.

Maintenance. The ideal hardwood floor finish should be attractive, durable, easy to maintain and should have the capacity for being retouched without revealing a patched appearance. The finish applied to the flooring should be transparent to accentuate the natural beauty of the wood.

The three principal types of finishes are: floor seal, varnish and shellac. Lacquer is applied occasionally but the most popular finish for institutions is the floor seal. Two types of floor sealers are adaptable for hardwood floors: the penetrating and the surface coatings.

Requirements of a good floor finish:

- (1) The finish must have penetrating qualities that become an integral part of the wood itself, so that after application it will only wear away as the wood wears away.
- (2) The finish must seal the pores in order to keep out dirt and resist soil stains.
- (3) The finish with its penetrating qualities must not darken the wood, but must give the floor an attractive, satin-like sheen, showing the varying natural color of the wood.
- (4) The finish must reflect light to improve illumination.
- (5) The finish should be non-slippery.
- (6) The finish must not mar, scratch or flake.
- (7) The finish must be of such quality that even retouching of worn spots can be accomplished without complete refinishing, and, with the resulting treatment, show a uniform appearance.
- (8) The finish (sealer) after application, must insure economy in maintenance in order to eliminate constant resanding and complete refinishing.

Directions for applying floor seal, vary with specific recommendations of manufacturers. In general, the seal is first applied across the grain, then smoothed in the direction of the grain by a wide brush, squeegee or wool applicator. After a period of 15 minutes to 2 hours, depending

on the directive of the manufacturer, the excess seal should be wiped off with clean cloths or a rubber squeegee. For best results the floor is then buffed with #2 steel wool. Two coats of seal are recommended with buffing after each coat.

Both the Maple and Oak Manufacturers Associations recommend waxing after the sealer has dried thoroughly with either paste or liquid wax.

Any good soap which is not too highly alkaline can be used to clean wood floors. However, continuous scrubbing or even wet mopping may cause the boards to warp or cup. In general, highly alkaline cleaners and excess amounts of water should be avoided in the maintenance of wood floors. Vacuuming, dust mopping and sweeping will help to prolong floor life.

Comparison of Resilient Floor Coverings and Non-Resilient Floors

The preceding discussion has pointed out the important characteristics of the various floors and floor coverings. Tables 3, 4, 5, 6, 7 and 8 summarize certain advantages and disadvantages of particular significance to management.

Tables 3 and 4 illustrate the point that each floor has both favorable and unfavorable service qualities. As an example, resilient floor coverings which are low in cost are generally most difficult to maintain. The high cost non-resilient floors such as marble and hard tile rate excellent for wearability and ease of maintenance.

TABLE 3
COMPARISON OF RESILIENT FLOOR COVERINGS

Floor Covering	Initial Cost	Wear-ability	Resistance to Indentation	Color Stability	Ease of Maintenance	Comfort
Asphalt tile	Low	Poor	Poor	Fair	Poor	Fair
Cork	High	Fair	Poor	Fair	Poor	Excellent
Linoleum	Medium	Good	Fair to good	Good	Fair to good	Good
Rubber	High	Good	Good	Good	Good	Excellent
Vinyl	High to very high	Excellent	Excellent	Excellent	Excellent	Good to excellent
Vinyl Asbestos	Medium	Fair	Fair	Fair	Fair	Fair

Source of data: Compiled by the author.

TABLE 4

COMPARISON OF NON-RESILIENT FLOORS

Floor Covering	Initial Cost	Wear-ability	Resistance to Indentation	Color Stability	Ease of Maintenance	Comfort
Concrete	Low	Good	Excellent	Fair	Good	Poor
Oxychloride	Medium	Fair	Excellent	Good	Fair	Poor
Marble	Very high	Excellent	Excellent	Excellent	Excellent	Poor
Terrazzo	High	Excellent	Excellent	Excellent	Excellent	Poor
Hard Tile	High to very high	Excellent	Excellent	Excellent	Excellent	Poor
Wood	Low to Medium	Fair to good	Good	Good	Fair to Poor	Fair

Source of data: Compiled by the author.

Table 5 indicates the maximum safe load limit for the resilient floor coverings. Asphalt tile, which is low in price, also has a low load limit. Rubber and vinyl which are high in cost have a high load limit.

TABLE 5

MAXIMUM SAFE LIMIT FOR RESILIENT FLOOR COVERINGS

Floor Covering	Load Limit In Pounds Per Square Inch
Asphalt tile	25
Vinyl-asbestos	25
Cork tile	40
Linoleum	75
Rubber	200
Vinyl	200

Source of data: Earl Brenn's Floor Maintenance Manual, page XV-2.

Table 6 shows the resistance to indentation of various floors and floor coverings. The hard floors such as hard tile or marble are virtually immune to indentation. Softer floors, cork or asphalt tile, are more susceptible to damage.

TABLE 6
RESISTANCE TO INDENTATION OF SELECTED RESILIENT FLOOR
COVERINGS AND NON-RESILIENT FLOORS

Material	Indentation
Vitreous tile	0.0
Neat Portland Cement	0.0
Marble	0.0
Maple Wood	0.0
Oxychloride	0.0
Rubber	4.0
Linoleum	13.6
Cork tile	26.7
Asphalt tile	61.9

Source of data: Earl Brenn's Floor Maintenance Manual,
page XV-3.

Tables 7 and 8 show the relative costs of floor coverings and floors in the Lansing, Michigan area as of March, 1959. Actual dollar cost may fluctuate but the relative ratings remain fairly constant.

TABLE 7
COMPARATIVE COSTS OF RESILIENT FLOOR COVERINGS

Floor Covering	Relative Cost
Asphalt tile	1
Vinyl-asbestos	1.5 - 2
Linoleum	1.5 - 2
Rubber	3.1 - 4
Cork	3.1 - 6
Vinyl	2.5 - 10

TABLE 8
COMPARATIVE COSTS OF NON-RESILIENT FLOORS

Floor Covering	Relative Cost
Concrete	1
Wood	1.1 - 1.5
Oxychloride	1.2 - 4.5
Terrazzo	3 - 10
Hard tile	5 - 15
Marble	15 - 25

Source of data: Compiled by the author.

This manual has attempted to show that there is no simple answer to the overall flooring problem. The discussion and tables in this report should be helpful in the selection of flooring for an institution.

It has been pointed out that the purchase of a floor or floor covering on initial price only is not economically sound. Floors that are low in cost may be uncomfortable to work on or may require expensive maintenance to prolong their life. Even the high priced floors such as marble or quarry tile have their disadvantages. All of the pros and cons of each type of floor and floor covering should be considered before the final selection is made.

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APPENDIX

TRADE ASSOCIATIONS FOR THE FLOORING INDUSTRY

American Concrete Institute
18263 W. McNichols Road
Detroit 19, Michigan

Asphalt Tile Institute
101 Park Avenue
New York 17, New York

Assoc. of American Soap and
Glycerine Producers
295 Madison Avenue
New York 17, New York

Chemical Specialties
Mfgs. Association
50 East 41st Street
New York 17, New York

Maple Flooring Manufacturing
Association
35 East Wacker Drive
Chicago 1, Illinois

National Assoc. of Marble
Dealers
219 E. Island Avenue
Minneapolis, Minnesota

National Oak Flooring Assoc.
814 Sterick Bldg.
Memphis 3, Tennessee

National Terrazzo and Mosaic Assoc.
711-14th Street, N. W.
Washington, D. C.

Oxychloride Cement Association, Inc.
1832 "M" Street, N. W.
Washington, D. C.

Portland Cement Association
33 West Grand Avenue
Chicago 10, Illinois

The Marble Institute of America
32 South 5th Avenue
Mt. Vernon, New York

The Rubber Manufacturers
Association
444 Madison Avenue
New York, New York

Tile Council of America
10 E. 40th Street
New York 16, New York

Tile Manufacturers Association
50 East 42nd Street
New York 17, New York

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