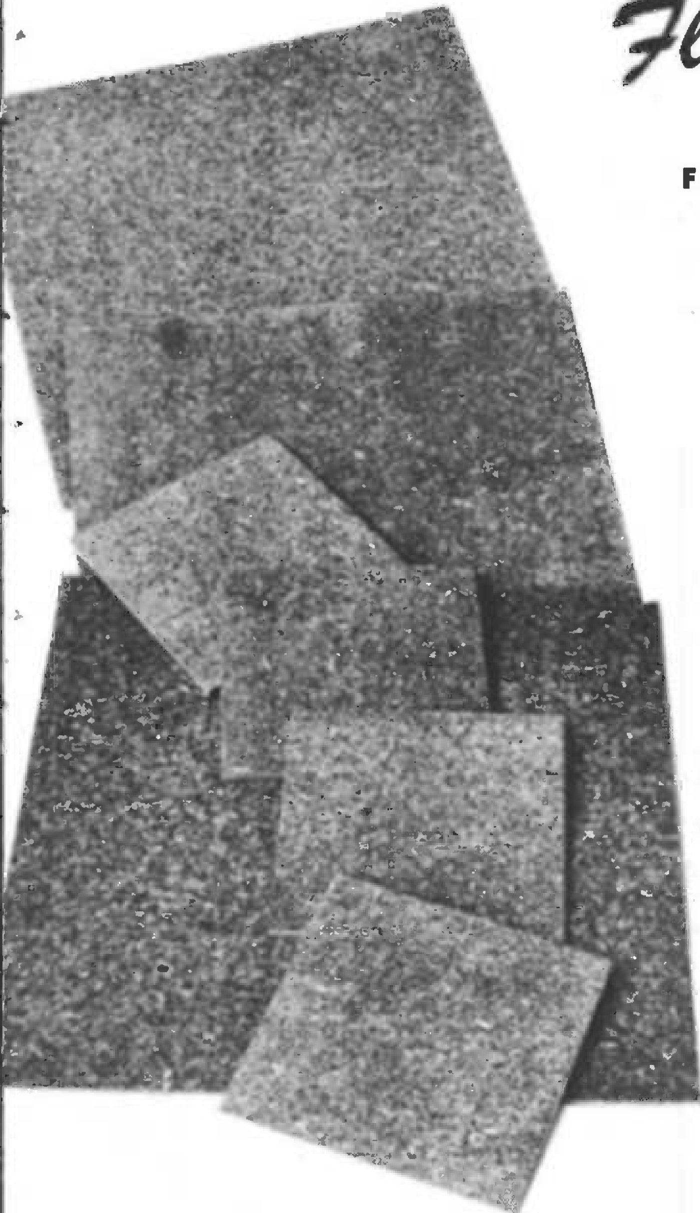
Floor Tile

FROM

DOUGLAS FIR CORK



By C.H. Burrows

STATE OF OREGON

Corvallis

Forest Products Research Center

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ACKNOWLEDGMENTS

The author is grateful for assistance from several individuals, especially R. A. Currier, H. M. Demaray, and W. W. Dostelik. An expression of thanks also is given to Weyerhaeuser Timber Company for furnishing Douglas fir cork, and to the several companies that furnished other materials and technical advice.

CUSHIONING EFFECT of Douglas fir floor tile was coupled with quick recovery from indentation.

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SUMMARY

Floor tile made from Douglas fir cork exhibited adequate wearing properties. Comparison with commercial flooring materials showed that Douglas fir cork tile was about equivalent to, or better than, tile from Mediterranean cork oak in properties tested. Estimated retail selling price of floor tile from Douglas fir cork was favorable when measured against prices of other commercial flooring materials.

Techniques used in making Douglas fir cork tile were similar to those followed in the production of wood particle board. It is, therefore, feasible that fir cork tile could be manufactured by present methods for manufacturing particle board, with minor modifications or additions to equipment. Other systems of manufacture could be developed to produce this product.

Floor Tile from Douglas Fir Cork

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INTRODUCTION

The market for hard-surface floor covering has continued to expand with home construction in this country. To illustrate the potential that exists, the following statistics are presented (4)*. In 1952, about four billion square feet of hard-surface flooring were consumed. In 1954, consumption increased to 4.4 billion square feet, and, in 1955, the figure had risen to 4.7 billion square feet. By 1960, an estimated 6 billion square feet of hard-surface flooring will need to be produced to meet consumer demand. These figures represent from 300 to 450 million dollars in sales value. Development of a floor tile made from Douglas fir bark cork would allow competition in this market. Such a product also would aid in utilization of bark residue.

To meet competition, Douglas fir cork tile should have physical properties comparable to, or better than, commercial cork tile. Manufacturing costs should be lower than, or at least equivalent to, costs of commercial cork tile. Exploratory work was undertaken to produce a tile with satisfactory properties at economical cost.

Silvacon 144, 383, and 388 (commercial bark products made by Weyerhaeuser Timber Company), as well as cork produced from laboratory-processed Douglas fir bark, were tried as raw materials. Silvacon 388 was selected as best raw material, mainly on basis of particle size and color. Numerous adhesives, sizing agents, and other additives were investigated in preliminary work. Pressing conditions were varied to arrive at best combinations. From extensive exploratory screening, a cork tile thought to be optimum was produced. This report will be con-

*Numbers in parentheses refer to references cited in the Bibliography.

cerned with evaluation of this final tile and not with exploratory research that led to its development.

Table 1. Conditions and Variables for Making Douglas Fir Bark Cork Tiles.

Raw material	Silvacon 388
Screen mesh	+ 10
Specific gravity	0.96
Thickness	0.1875 ± 0.015 inch
Size	none
Additives	5% butadiene-styrene, or 5% diethylene glycol
Batch moisture content	Average: 5.8% Range: 4.4% to 6.8%
Caul release agent	Silicone
Press conditions:	
a) temperature	230 F
b) pressure	60 and 100 psi
c) press time	8 min
d) cold flush	2 min (no pressure)

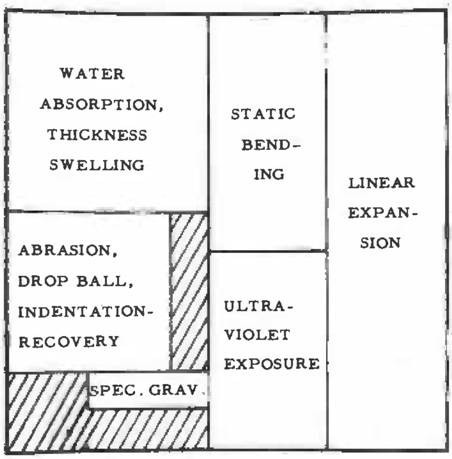

Figure 1. Scheme for cutting test specimens from 11 1/2-inch-square tile.

EXPERIMENTAL PROCEDURE

Experimental work described was done under laboratory conditions. Details of conditions and variables for making Douglas fir cork tiles are shown in Table 1.

Tile production

Douglas fir cork was screened to obtain a + 10 fraction. This particle size, in about 90 per cent yield from Silvacon 388 as received, produced a pleasing pattern in the finished tile.

After drying to a moisture content of 2 - 3 per cent, cork was weighed and placed in a rotary drum mixer. Half the tiles were made with 5 per cent butadiene styrene (Polyco 350N, Borden Company) and remaining tiles contained 5 per cent diethylene glycol, based on oven-dry weight of cork. These two materials were applied by spraying and were added to help in bonding the cork. Butadiene styrene, a thermoplastic elastomer, is considered a bonding agent. Diethylene glycol is not regarded as an adhesive, but acts more as a plasticizer or cork-softener. Douglas fir cork will bond by itself under proper heat and pressure, so both additives were considered as agents to supplement, or assist in, bonding. Urea-formaldehyde, phenol-formaldehyde, or other conventional resins were not added to bond the cork, because these resins caused the cork tile to become brittle and inflexible. No size was added in making tiles; properties of Douglas fir cork made it inherently water-resistant.

After mixing for five minutes, the cork coated with either butadiene styrene or diethylene glycol was removed from the mixer. Moisture content after mixing averaged 5.8 per cent. Cork particles were now ready for mat-forming, in which the desired amount of cork was sprinkled (enough to make the tile 3/16 inch thick and 0.96 specific gravity) on a 12-inch-square metal caul in a forming box. After forming the mat, another caul was laid on top and the entire unit was placed in a press. Pressing was done at 60 and 100 pounds a square inch for 8 minutes at 230 F; then tiles were cold-flushed with no pressure for 2 minutes*. The assembly was removed and the pressed tile withdrawn.

Following trimming, the tile was ready for finishing; this was done on one side in the following manner:

1. Sand with 3/0 paper.
2. Apply 1 coat of sealer.
3. Apply 2 coats of hard wax and burnish.

The above system was chosen because of simplicity, low cost, and adaptability to production. Resulting finish appeared adequate for the tiles. Other finishing techniques undoubtedly can be developed.

Tests made

Douglas fir cork tile was compared with a well-known brand of commercial cork tile by several tests and measurements. Although Douglas fir cork tiles were made with one of two different additives (butadiene styrene and diethylene glycol) and two different pressures (60 and 100 pounds a square inch), test results did not vary appreciably. Consequently, all test data and results for Douglas fir cork tile were lumped together.

Tests and measurements made on pieces as in Figure 1 were:

- Water absorption
- Thickness swelling
- Linear expansion
- Static bending (only for Douglas fir cork)
- Abrasion
- Drop-ball
- Indentation-recovery
- Ultraviolet-light exposure

Details on methods and procedures are presented in the Appendix.

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*Preliminary work indicated tiles could be pulled hot, but only if moisture content before pressing was held closely below 4 per cent to avert blisters from steam.

RESULTS OF TESTS AND MEASUREMENTS

Properties of Douglas fir cork tile were weighed against properties of commercial cork tile. All test values in graphs or otherwise mentioned are averages of ten specimens, except values for ultraviolet resistance and abrasion test, in which five specimens were averaged.

Water absorption

Any flooring material must be capable of withstanding frequent wetting associated with normal floor maintenance. Wax and other constituents found in Douglas fir bark cork help in making this material naturally water-resistant. Tests were performed on both commercial and Douglas fir cork tile, to obtain indexes for water resistance, water absorption, thickness swelling, and linear expansion.

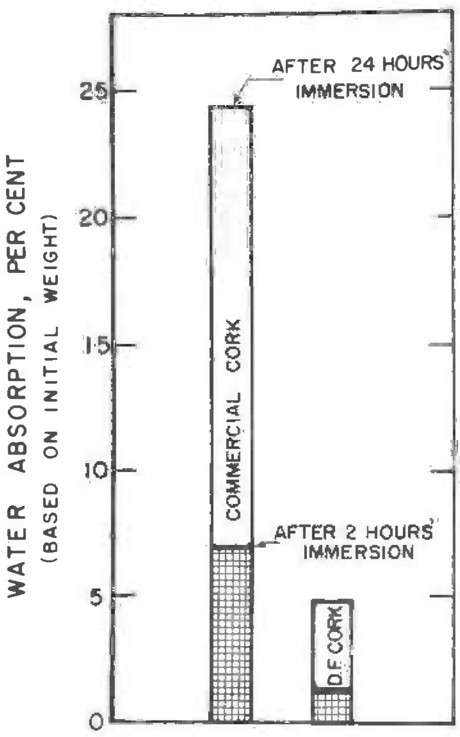


Figure 2. Absorption of water by oak cork and Douglas fir cork tile while immersed.

How the types of cork compared in water absorption is illustrated in Figure 2. Douglas fir cork specimens exhibited considerably less water absorption than did commercial cork. Douglas fir cork absorbed 1.4 per cent water after immersion for 2 hours and 4.8 per cent after 24 hours. Commercial cork specimens absorbed 7.1 per cent water after 2 hours and 24.4 per cent after 24 hours. Surfaces of the specimens following 24 hours of immersion showed differences, also. Douglas fir cork specimens had much smoother surfaces than did the commercial cork specimens.

Thickness swelling

Commercial cork specimens showed less thickness swelling than did Douglas fir cork, as shown in Figure 3. Following 2 hours of immersion, commercial cork had swelled 0.52 per cent, compared to 1.15 per cent for Douglas fir cork. After 24 hours, commercial cork had swelled 2.88 per cent, and Douglas fir cork tile swelled 3.06 per cent.

Linear expansion

In linear expansion, Douglas fir cork displayed lower values than

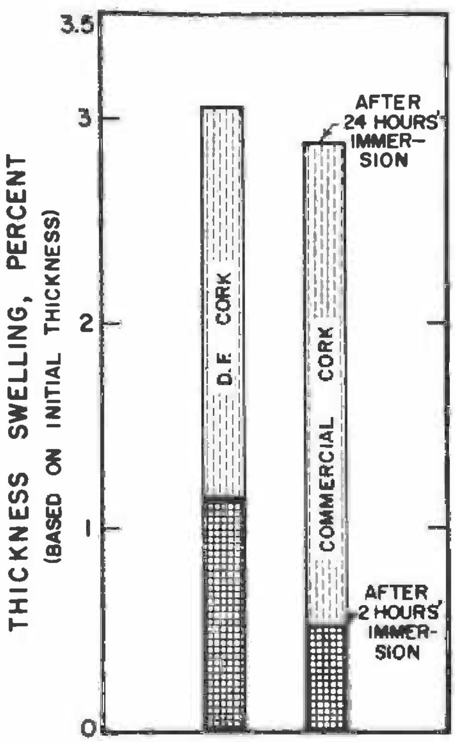


Figure 3. Swelling in thickness of oak cork and Douglas fir cork tile after soaking in water.

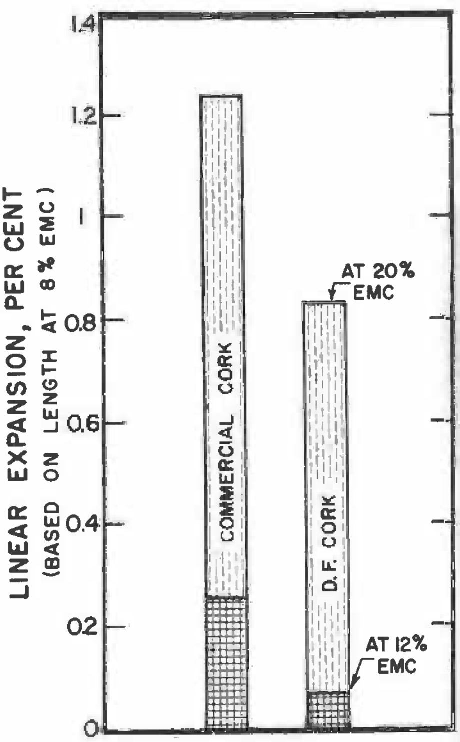


Figure 4. Linear expansion of cork floor tiles when moved from 8% to 20% EMC conditions.

did commercial cork (Figure 4). Douglas fir cork tile expanded linearly 0.071 per cent when changed from 8 to 12 per cent EMC (equilibrium moisture content) conditions; commercial oak cork tile showed 0.264 per cent linear expansion from the same change. From 12 to 20 per cent EMC, Douglas fir cork expanded linearly 0.839 per cent, and oak cork expanded 1.242 per cent.

Bending

Only Douglas fir cork tile was tested in bending; commercial cork specimens were too flexible to test. Bending strength was not considered critical in a floor tile laid on a rigid sub-floor. A floor tile, however, should be sufficiently flexible to permit satisfactory laying.

Modulus of rupture of Douglas fir cork tile was 771 pounds a square inch. Average deflection was 0.46 inches at an average maximum load of 9.2 pounds. These test values give an indication of flexibility and strength of Douglas fir cork tile.

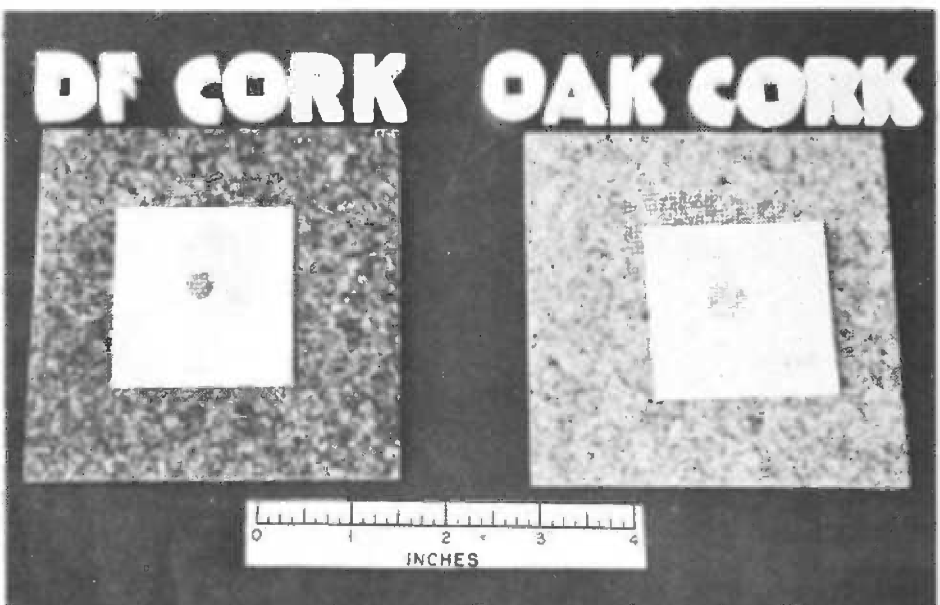


Figure 5. Diameter of mark left by carbon paper indicated extent of indentation in drop-ball test.

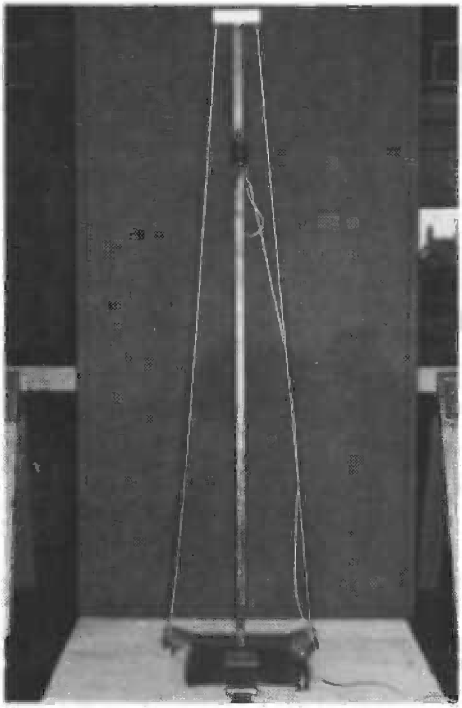


Figure 6. Apparatus for testing impact hardness of cork floor tiles.

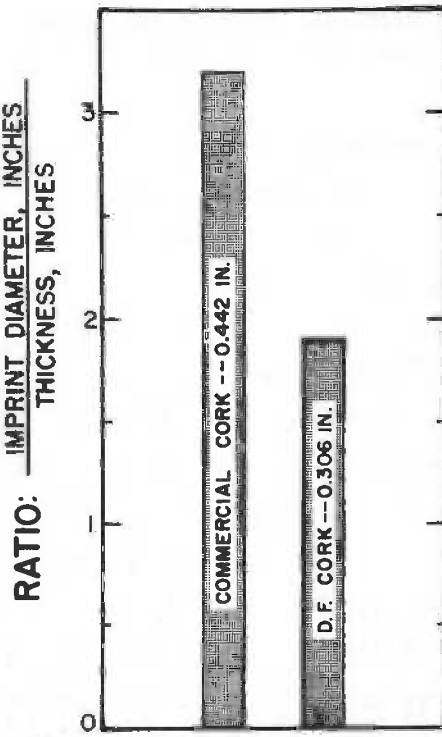
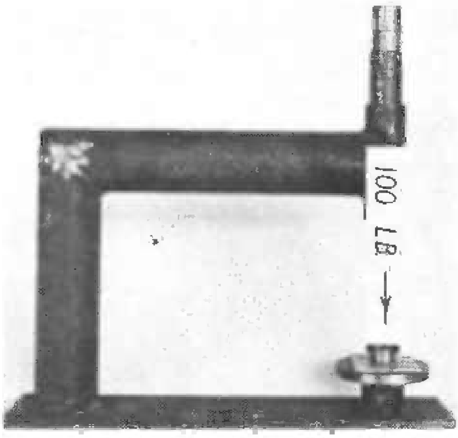


Figure 7. Ratios of impact hardness for cork floor tiles.

Impact hardness

To measure impact resistance of the two cork types, a falling-ball impact test (Figure 6) was made. This test provided a measure of resistance to damage that occurs when flooring is struck by a moving (dropped) object. A ratio of diameter of ball impression (see Figure 5) to specimen thickness at point of blow provided an index of resistance (Figure 7). Within the columns in Figure 7 are shown average ball-imprint diameters for the two cork types. The ratio for Douglas fir cork was lowest at 1.88. Commercial cork had a ratio of 3.20. Douglas fir cork showed more resistance to impact than did commercial cork, when measured by the index of resistance.

Figure 8. Apparatus for testing indentation recovery. ⟶



Indentation-recovery

The indentation characteristic of a flooring material is related to cushioning ability. Ease of indentation is desirable. Failure of a flooring material to recover once it has been indented is not desirable, as such lack of recovery causes floor surfaces to appear bumpy and unsightly. To evaluate resistance of cork tile to, or recovery from, indentation by foot traffic and other short-time loads, the indentation-recovery test was performed. Apparatus to perform this test is shown in Figure 8. Douglas fir cork specimens indented less and recovered more than did commercial cork (Figure 9). Douglas fir cork indented 0.45 per cent initially and after one hour had recovered to 99.75 per cent of the original thickness. Commercial cork had an initial indentation of 0.75 per cent and a residual indentation of 0.60 per cent after an hour. These test results indicate commercial cork will indent more easily than will Douglas fir cork and, thus, cushion more adequately. However, Douglas fir cork can be expected to show less surface denting, since it is more difficult to indent, and will recover somewhat better than does commercial cork.

Ultraviolet exposure

A weatherometer was used to determine how both kinds of cork and their finishes are affected by ultraviolet light and water spray. Ultraviolet light simulated sunlight; water spray provided surface wetting action that might occur on flooring. Relative performance of the cork specimens is shown in Figure 10. Reflectance changes were indicative

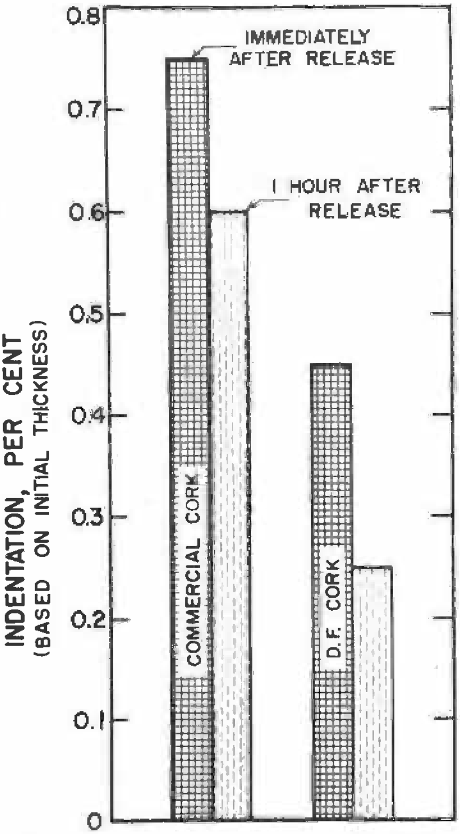


Figure 9. Recovery after indentation by 100-pound load over a circular area 1.125 inches in diameter.

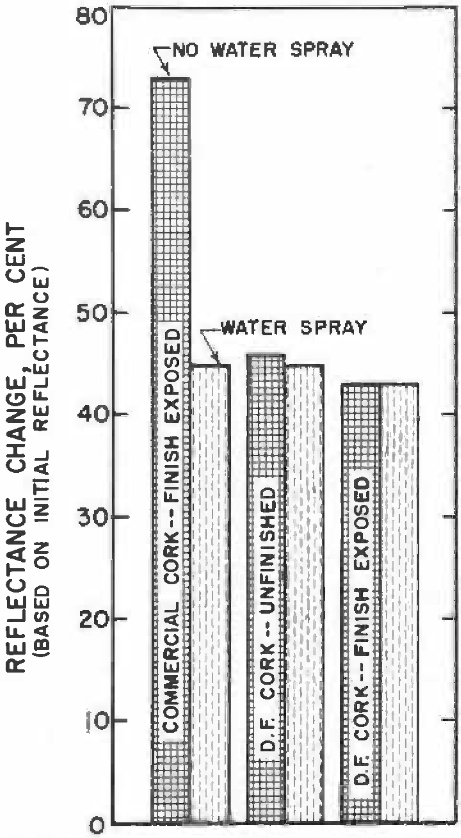
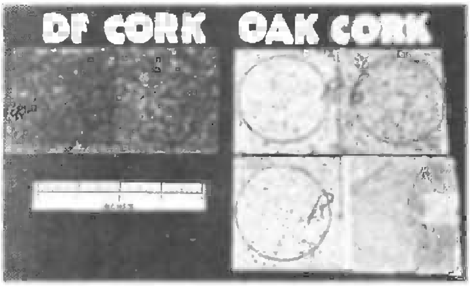


Figure 10. Reflectance change in 48 hours of exposure to ultraviolet light.

of color changes, and these two were interpreted analogously.

For Douglas fir cork specimens, test results showed that average reflectance values measured on exposed, finished surfaces were the same regardless of whether water had or had not been sprayed; for specimens with unfinished surfaces exposed, the difference in reflectance was slight. Douglas fir cork specimens with unfinished surfaces exposed darkened 46 per cent from initial color with no spray and with water spray darkened 45 per cent. Specimens with finished surfaces exposed darkened 43 per cent of initial color, regardless of whether their sur-

Figure 11. Left half of each specimen was exposed to ultraviolet light for 24 hours. Aluminum and asbestos shield is in place in lower right. ⟶



faces were wet or not. The wax finish on Douglas fir cork specimens helped reduce darkening to some extent. Absence or presence of water spray was critical with commercial cork. When water spray was introduced, commercial cork bleached from initial color 45 per cent; with no spray, however, the specimens showed excessive bleaching, to 73 per cent of initial color. Changes during test are illustrated in Figure 11.

Abrasion resistance

The abrasion test (Figure 12) was performed to obtain a measure of wear resistance for both kinds of cork tile. Although this test only

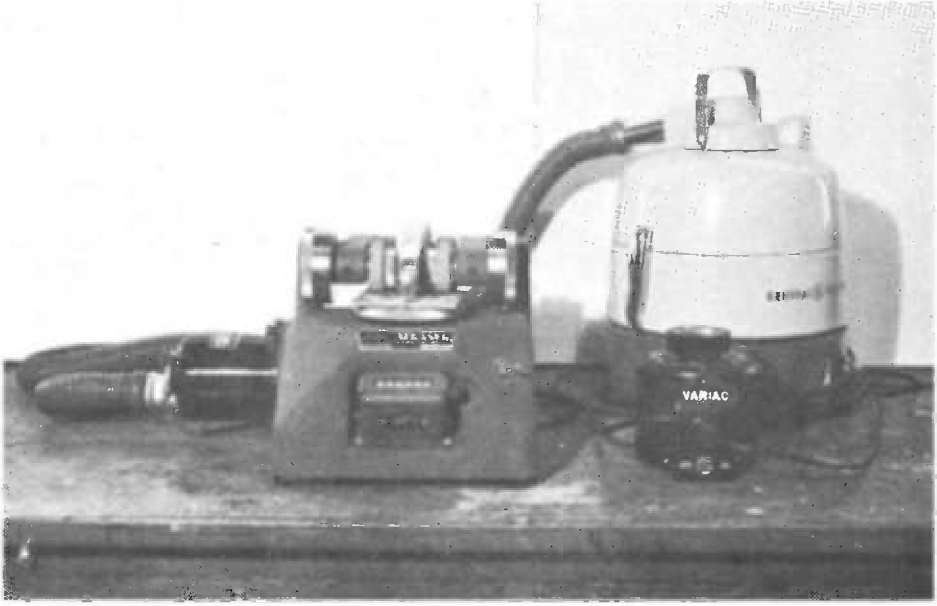


Figure 12. Taber Abraser model 140 PT.

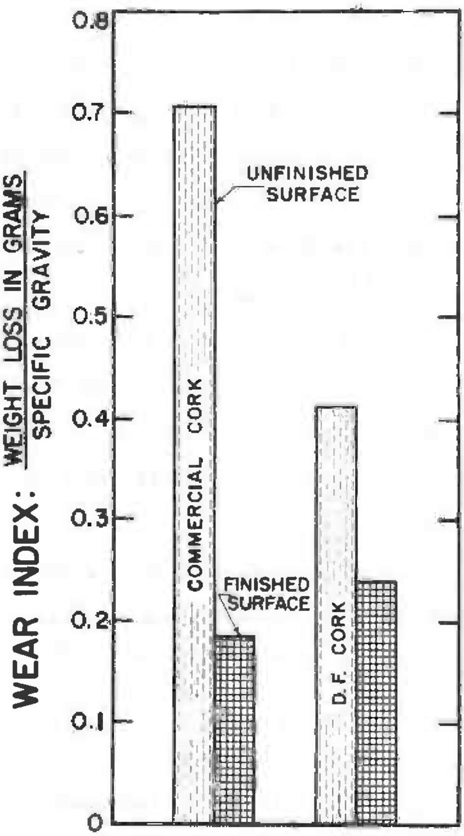


Figure 13. Wear resistance of oak cork and Douglas fir cork tile as measured by 1000 cycles on a Taber Abraser.

simulated actual traffic conditions, a valuable index was obtained indicating how both kinds of cork might wear under actual use (Figure 13). This index was computed as a ratio of weight loss to specific gravity. Results of abrasion tests on both finished and unfinished surfaces of both kinds of cork are shown in Figure 14.

Wear index values for both kinds of cork were lower when abrasion was performed on the finished surface, showing that the finishes were retarding abrasive wear. Finished surface of commercial cork exhibited lowest wear index, 0.185, but largest index on unfinished surface, 0.708. Douglas fir cork had a wear index of 0.238 on finished surface and 0.411 on unfinished surface. Finish on the commercial cork specimens was much more effective in retarding abrasive action than was the finish on Douglas fir cork specimens.

Specific gravity

Commercial cork was calculated at specific gravity of 0.51, and Douglas fir cork specific gravity was 0.96, both based on 12 per cent moisture content. Specific gravity of the test specimens was measured by water immersion (3).

In-service test

Two test sections were made, each containing 9- by 9-inch tiles of vinyl, asphalt, linoleum, commercial cork, ponderosa pine planer shavings*, and Douglas fir cork. These test strips were prepared to compare the wearability of these six floor materials under actual traffic conditions. One section was laid on a concrete floor; the other was laid on a plywood panel (Figure 15) that could be moved about.

Test sections were inspected after six months' wear and evaluated according to appearance. The portable section, which had been in an area of heavy traffic, showed more wear than did the section laid on concrete. To illustrate how the floor materials compared for the portable section, results of the inspection are presented:

Tile material	Condition
Douglas fir cork	Moderately scratched, dented, and worn; color fair to good.
Commercial cork	Pitted, worn badly; darkened from ground-in-dirt; color poor.
Linoleum	Moderately scratched, dented, and worn; color fair.
Vinyl	Slightly to moderately dented, scratched, and worn; color good.
Ponderosa pine planer shavings	Moderately scratched, dented, and worn; color good.
Asphalt	Moderately scratched, dented, and worn; slightly faded.

*Described in Information Circular 12, Forest Products Research Center, December 1958.

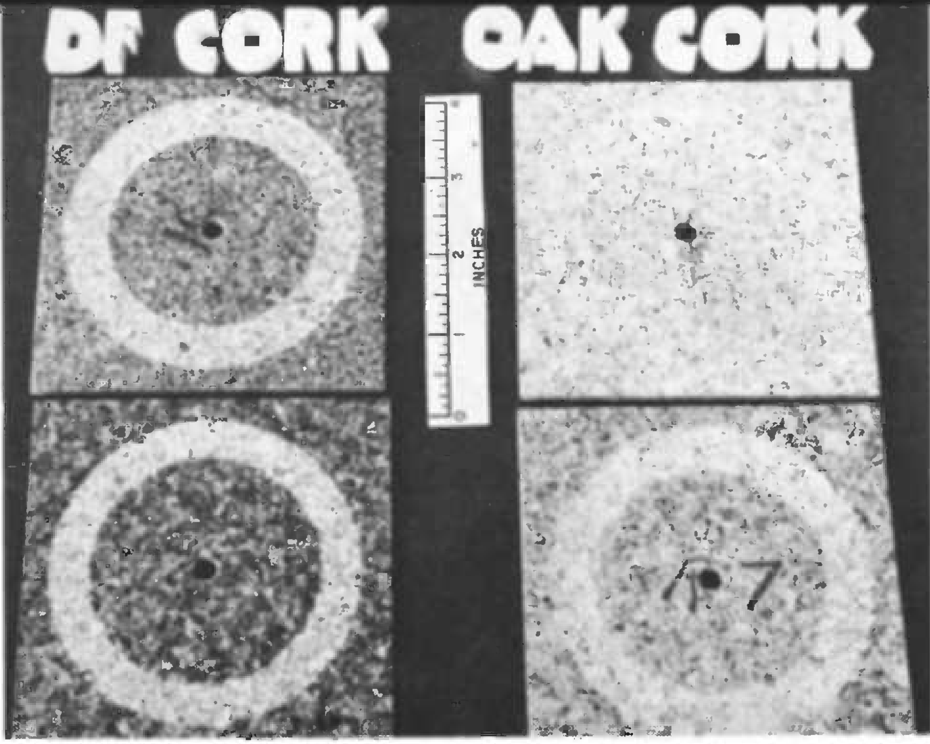


Figure 14. Wearing ability assessed by the Taber Abraser. Floor tiles have finished faces up in front, unfinished up in back.

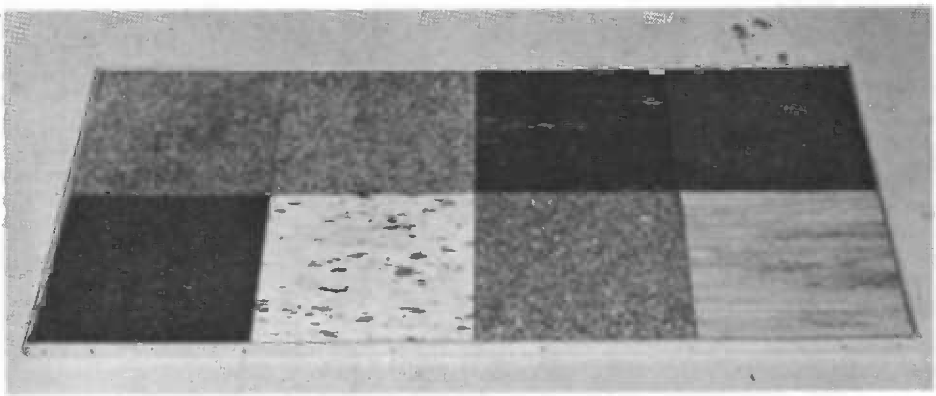


Figure 15. After six months at an entrance to the Forest Research Center, appearance of floor tile was as above. Back row, left to right; oak cork, wood shavings, asphalt, Douglas fir cork. Front row, left to right; Douglas fir cork, linoleum, wood shavings, vinyl.

COST ESTIMATE

An estimate of manufacturing costs for Douglas fir cork tile is given in Table 2. General operating, labor, overhead, and depreciation costs were estimated from manufacturing costs relating to manufacture of particle board (1, 6, 8). Material costs, which make up the largest percentage of manufacturing costs, were reasonably accurate. Cost of 5 per cent diethylene glycol was included. Diethylene glycol was more economical than butadiene styrene and performed as satisfactorily. Any of the cost figures are subject to change, as they are dependent on plant location, raw-material availability, degree of plant automation, utility rates, and other similar factors. Finishing costs were not included.

Comparisons of retail prices of commercial flooring materials and Douglas fir cork tile are illustrated in Table 3. Retail prices in 1958 for commercial materials were obtained from several sources (2, 5, 7). In calculating the retail price for Douglas fir cork tile, manufacturing costs were tripled.

Douglas fir cork tiles were made 3/16 inch thick. This thickness was thought to be optimum for several reasons. First, most particle board presses are capable of pressing to this thickness, and, second, this thickness allows flexibility and adequate wearing thickness. Tiles could be manufactured as thin as 1/8 inch, but probably at the expense of strength.

Table 2. Estimated Manufacturing Costs for 3/16-inch Douglas Fir Cork Tiles in a Plant Operating Three Shifts Daily.

Cost item		Cost/M Sq Ft
Material costs		$41.30
Silvacon 388, $70.00/ton (90% usable)		
Diethylene glycol, 5% at $0.16/lb solids		
General operating expense		4.00
Electricity		
Maintenance		
Miscellaneous		
Labor		15.00
Overhead and depreciation		15.00
100% of labor		
	Total	$75.30

Table 3. Retail Prices in 1958.

Floor material	Thickness	Price
	Inches	Cents per sq ft
Vinyl asbestos tile	1/16	22 to 42
Rubber tile	1/16	29
	2/25	29 to 30
	1/8	30 to 62
Asphalt	1/8	9 to 23
Oak cork tile	1/8	40 to 79
	3/16	45 to 64
Douglas fir bark cork	3/16	23 to 26
Vinyl tile	2/25	26 to 71
Linoleum tile	standard gauge	14
Linoleum, inlaid	----	11 to 33

CONCLUSIONS

As a result of information accumulated in this study several conclusions can be drawn:

- Physical tests indicate Douglas fir cork tile can be made with satisfactory wearing properties.
- Estimated costs for Douglas fir cork tile appeared reasonable and suggest this type floor tile can be competitive.
- Since technique of manufacturing Douglas fir cork tile differs little from methods used to manufacture wood particle board, an established production system likely could be modified to produce tiles. Other custom-built or miniaturized systems undoubtedly could be designed.

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APPENDIX

Details of tests and measurements are described here.

Surface of commercial cork tile was not waxed or otherwise changed from factory finish before testing. Thickness of commercial cork tile was 1/8 inch.

Conditioning

All specimens, with the exception of those to measure linear expansion, were placed in a conditioning room for two weeks to stabilize at 12 per cent EMC (equilibrium moisture content) conditions (65 per cent relative humidity and 70 F). Specimens to measure linear expansion were conditioned for two weeks at 8 per cent EMC conditions (44 per cent relative humidity and 90 F).

Water absorption and thickness swelling

Tests for water absorption and thickness swelling were run concurrently on the same specimens. Procedures in ASTM (American Society for Testing Materials) Standard D1037-55T for water-absorption tests were followed, with few exceptions. Weights and thicknesses were measured initially, after 2, and after 24 hours of immersion in water. Each 5-inch-square specimen was weighed to the nearest 0.1 gram and measured to the nearest 0.001 inch in thickness. Thickness was measured at five locations on each specimen, one in the center and the other four equidistantly around the perimeter, 1/2 inch from the edge. Thickness swelling for each specimen was expressed as an average of all five measurements. Water absorption and thickness swelling, expressed as per cent, were based on initial weights and initial thicknesses, respectively, of specimens.

Linear expansion

After two weeks conditioning at 8 per cent EMC conditions, specimen lengths were measured to the nearest 0.001 inch. The 3- by 11-inch specimens next were placed in a conditioning room at 65 per cent relative humidity and 70 F (12 per cent EMC conditions) for one week. Following this period, lengths were measured again and specimens were placed in a room maintained at 90 per cent relative humidity and 90 F (20 per cent EMC conditions). One week later, specimen lengths were measured for the final time. Changes in length occurring at 12 and 20 per cent EMC conditions were expressed as per cent, based on initial length measured at 8 per cent EMC conditions.

Static bending

Bending tests were performed according to ASTM Standard D1037-55T. Specimens were 3 by 6 inches, span was 4 inches, and headspeed 0.08 inch a minute. Finish side of specimen was up during test. Only Douglas fir cork tiles were tested in bending; commercial cork was too flexible to test.

Impact hardness

In the test for impact hardness, a 1-inch steel ball was dropped five feet into the center of a 4-inch-square specimen (Figure 5). A piece of carbon paper with inked side up was placed on the specimen and under a piece of white paper. When the ball was dropped, an imprint on the white paper indicated amount of deformation (Figure 6). Imprints were measured to the nearest 1/32 inch. Specimen thickness before test was obtained by averaging 10 measurements taken within 1-inch radius of the center. These measurements varied little and allowed for error when the ball did not hit exact center. The test is outlined in Impact Hardness Tests on Wood, by N. H. Kloot, Reprint No. 178, Commonwealth Scientific and Industrial Research Organization, Australia.

Indentation-recovery

Indentation-recovery was tested on 4-inch-square specimens. After measuring specimen thickness at center to the nearest 0.001 inch, a 100-pound load was applied to the specimen face through a flat-ended, cylindrical plunger 1.125 inches in diameter (Figure 8). Load was maintained for 10 minutes, then removed, and indentation was measured to the nearest 0.001 inch. One hour later the specimen was remeasured to determine recovered thickness. Details on this test can be found in Federal Specification LLL-T-431, Tile; Cork, paragraph F-2d. Initial indentation and residual indentation are expressed as per cent, based on original thickness.

Ultraviolet exposure

Test specimens were exposed to ultraviolet light in an Atlas weatherometer for 48 hours. Temperature in the chamber was 110 F. Half the specimens were tested with no water spray during the 48 hours. The remaining specimens were tested with water spray introduced the first 18 minutes of each 24-hour cycle, giving a total of 36 minutes of spray for the 48-hour period.

Water was sprayed directly on the specimens and was intended to provide some information on how specimen surfaces were affected by wetting. To obtain a measure of color change, reflectance readings of specimen surfaces were taken before and after test. A photovolt photometer was used to obtain reflectance readings with a black standard of zero per cent and white standard of 81 per cent. Half of each 2 3/4- by 5 1/4-inch specimen was covered with an aluminum foil jacket over a piece of asbestos (Figure 11). This jacket preserved the original color. Half the Douglas fir cork specimens were exposed on the finished side, and half on the unfinished side. Commercial cork was exposed on finished side only. Change in color occurring during test was expressed as per cent, based on initial reflectance.

Abrasion resistance

Relative abrasion resistance of cork specimens was determined with a Taber Abraser, model 140-PT, with CS-17 wheels and 1000-gram weight (Figure 12). A vacuum pickup removed loose dust from the surface of the specimen during test. Each 4-inch-square specimen was weighed to 0.0001 gram prior to test, then weighed after 250, 500, 750, and 1000 cycles. A wear index was computed based on weight loss after 1000 cycles and specific gravity of the specimen. This technique is described in detail in the Taber Instruction Manual, Section VI, page 39. Finished and unfinished surfaces of cork specimens were abraded. The abrading wheels were cleaned and resurfaced at intervals during the test to reduce experimental error.