SIMULATED SERVICE TESTING OF WOOD AND WOOD-BASE FINISH FLOORING
Abstract

When a new kind of flooring is developed, either as a demonstration of its suitability or the screening of good points from bad, it becomes necessary or desirable to evaluate its performance by simulated service test procedures. One can hardly wait for several years for a flooring to prove satisfactory before marketing it.

Over the years, the Forest Products Laboratory has developed a group of accelerated test procedures specifically designed to measure the potential performance of new wood or wood-base finish floorings. Results obtained are both quantitative and qualitative and, based on comparisons with data from wood floorings giving satisfactory service, a set of performance criteria values can be established for specification purposes. After several years of experience with these procedures, they were offered to and accepted by ASTM through its Committee D–7 on Wood. They are now included in “Standard Methods for Simulated Service Testing of Wood and Wood-Base Finish Flooring,” D 2394-68.

Included in the Standard are procedures for measuring resistance to concentrated loading, floor surface indentation from small-area loads or falling objects, and damage from rolling loads. Methods are presented for measuring abrasion resistance, coefficient of friction, and the effects of surface wetting. Because in many situations the overall performance of a finish flooring depends on the support of underlaying material, some of these testing procedures have been used successfully to appraise complete flooring systems.
SIMULATED SERVICE TESTING OF WOOD AND
WOOD–BASE FINISH FLOORING

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Introduction

Traditionally, wood finish floors have been accepted and preferred because they satisfied consumer acceptance criteria for wearing resistance, stability, resilience, beauty, renewability, and cost, without any actual performance requirements ever being set for the use.

Early experience showed that end grain was more resistant than side grain to heavy wear; hence, various forms of end-grain block flooring were developed for industrial use. Fifty years ago end-grain wood blocks were used for pavements because they were quieter under steel rims and horses hooves than brick or stone.

For houses and other buildings, woods of local origin were used for floors. Experience showed that the denser hardwoods wore better than the softwoods, and they also were more beautiful when finished. Thus, in home building it became the practice to use hardwoods like maple and oak in living areas and halls and, because of lower costs, to use softwoods like southern pine and Douglas-fir for bedrooms. Edge-grain (quartersawn) softwood boards were preferred since they did not splinter and wore more uniformly than flat-grain boards. It was determined also that wide boards developed cracks that were wider under winter heating conditions (lower moisture content in the wood) than desirable.

2 Maintained at Madison, Wis., in cooperation with the University of Wisconsin.
Out of all of this experience there evolved standard patterns for wood flooring. It was usually installed in strips, although short pieces were fabricated and laid in parquet blocks about 9 inches square or in diagonal herringbone effect. Strip flooring for housing was 25/32 inch thick, about 2-1/4 inches wide with tongued-and-grooved sides and ends, and was furnished in random lengths. Standards were developed for various grades for the different species used. The predominant ones were oak for general building uses and hard maple for housing and especially for gymnasium floors where it has been preferred for its performance and uniform light color.

Special grades and cross sections of flooring were developed for such uses as bowling alley beds and truck body and railway car floors, but these are beyond the current consideration. The traditional building flooring was the aforementioned 25/32- by 2-1/4-inch strip flooring. The tongues and grooves were located low in the profile so the flooring could be resurfaced, if necessary, at least two times during its life without exposing the nailheads from the blind nailing along the tongue side.

Wood flooring practice as we know it today developed from experience and its performance was well understood by architect, homeowner, code authority, and mortgagee. Only rarely did it not perform satisfactorily in service, and when it did not it was usually due to unusual exposures or use. The flooring was repairable and could be refinished in place.

Floors of this kind became relatively more costly as unit labor rates increased and as the flooring itself became more expensive because of the costs of manufacture and reduced availability of material of the quality required for top grades of hardwood flooring. Other flooring materials, mainly resilient floor tile, were developed that offered lower in-place cost. The use of conventional wood flooring declined. Personal preferences for wood floors did not really diminish, but changes in construction practice (mainly elimination of basements with concrete slab on ground and reduced two-story construction for homes) further increased comparative costs for conventionally laid wood strip flooring.

The need for new kinds of wood and wood-base flooring that were lower in initial cost, more adaptable to modern construction methods, and lower in cost to install became apparent and new floorings were developed to satisfy that need. Each new wood-base material or combination of wood with something else was suspect so far as performance in service was concerned, until sufficient experience had been gained with the new flooring to determine its adequacy.
The Forest Products Laboratory was frequently requested both to investigate the performance of these new floorings and to advise government organizations like the Federal Housing Administration or Army Engineers on the prospects for adequate service performance. As a result, a series of test procedures were developed to simulate exposures and loadings possible in service for finish flooring elements. This drew heavily on research experience gained during World War II in evaluating various combinations of materials for floor surfacing and floor systems for cargo aircraft.

This presentation summarizes the various procedures developed for simulating service loadings and exposures to wood and wood-base finish flooring. After nearly 20 years of experience with these procedures, both for comparing different wood and wood-base finish flooring and for establishing specification limits for a specific kind of flooring, the procedures were detailed in ASTM format and accepted through Subcommittee IX, Methods of Test, of Committee D-7 on Wood as tentative in 1965. In 1968 they were advanced to Standard.

Purpose and Scope of Procedures

The purpose of the test procedures is to provide factual information, both qualitative and quantitative, that will permit the assessment of the probability of a specific kind of wood or wood-base finish flooring performing satisfactorily in service. Since the procedures simulate a loading, or condition possible or probable in service, they are used in some instances to appraise the behavior of underlay materials when these have a direct effect on the performance of the finish flooring.

They may be used also to set limitation values in specifications when it has been determined that service performance of a given material is acceptable. This was done in 1959 by FHA in setting "Minimum Physical Property Requirements of Particle Board Block Flooring." It was determined from field installation studies that particleboard block flooring of one manufacturer was performing satisfactorily in service and was adequate for FHA-insured construction. That specific product was then evaluated using in part the simulated service tests now detailed in D 2394. Values obtained were used in establishing minimum properties for FHA-insured construction. This was done because other manufacturers had the capability of producing "particleboard block flooring" and it was recognized that anything of equivalent properties should be permitted for use.

The simulated service tests in that instance were supplemented by basic property tests of the material itself for such properties as bending strength, modulus of elasticity, internal bond strength, hardness, moisture content, and dimensional change with change in relative humidity exposure.4

The simulated service tests in D 2394 can be classified as follows into Loading, Mechanical, and Moisture Tests:

Loading Tests
Concentrated loading
Floor surface indentation from small-area loads
Falling ball indentation
Rolling load

Mechanical Tests
Abrasion resistance
Coefficient of friction

Moisture Tests
Surface, restrained and unrestrained

Details on how the tests are performed and interpreted are presented in the following sections.

Concentrated Loading

The concentrated loading procedure obtains a quantitative value of the resistance to loads introduced by such items of furniture as heavy chests or pianos without undue deflection, indentation, or fracture of the finish flooring itself. The procedure is a direct adaption of a testing procedure that has always been included in E 72,5 Sections 19.1 to 19.4. It is used in a different way to measure resistance of flooring to loading. Figures 1 and 2 show the places loaded and the method of loading. Points of loading are located in such a way that the first point will produce maximum deformation of one segment of flooring with respect to other segments adjacent to it. Failure may be by excessive deformation of the

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5ASTM E 72, Standard Methods of Conducting Strength Tests of Panels for Building Construction, Part 14 of ASTM Standards.
Figure 1.—Layout of specimens for concentrated load test: A, finish flooring in parquet or tile form; B, finish flooring in strip form.

(M 136 611)

Figure 2.—Assembly for concentrated loading test for finish flooring showing 1-inch-diameter loading tool with micrometer bridge for measuring indentation.

(M 81099 F)
supporting material if the finish flooring is thin and flexible, by breaking off the corner if finish flooring is brittle, or by failure of tongue and groove from load transfer to adjacent sections. The second loading point is selected to obtain a measure of the near maximum resistance to concentrated loading. In the instance of finish flooring in tile form, the point of loading is at the center of the tile; failure in a wood or wood-base material is in flexure, punching shear, or excessive compression under the load. When the test is performed on wood and wood-base materials in strip form, the failure may be in flexure, from excessive compression under the load, or by shearing tongue or groove between the piece of flooring under loading and adjacent ones.

In the concentrated loading test, the 1-inch-diameter loading tool is “pushed” into the flooring material and a record of load deformation (measured by the micrometer bridge as shown in fig. 2) is obtained. The bridge spans the area compressed and thus measures total deformation under the concentrated load. The slope of the load-deformation curve, the endpoint in tests as indicated by excessive compression, or fracture are the quantitative values obtained. When failure does not occur before a loading of 1,000 pounds is attained, the test is stopped, the load is removed, and after 1 hour the depth of the remaining indentation is measured.

While the concentrated load test procedure is used on finish flooring, values obtained are dependent upon the system and support provided by the underlaying material. If the wood or wood-base flooring is not sufficiently stiff to resist and spread the load, the underlaying material must resist the concentrated force. For the usual test of a finish flooring, it is supported on plywood, which is typical of general construction other than installation direct to concrete, Values over concrete can be considered higher because of the additional support. Now that increased attention is being paid to sound transmission through floor systems, an added factor must often be considered--that of a low-density sound-deadening board under the finish flooring. In instances of that sort, the properties of the underlayment have a major influence on the satisfactory performance of the finish flooring and evaluations of the combined construction should be performed.

Floor Surface Indentation from Small-Area Loads

Not so long ago, most of us who had an interest in building materials or constructions were silently or vocally concerned with the damage to finish flooring materials from the “stiletto” heels on women’s shoes. Materials and finishes with satisfactory service experience were being pockmarked by them, carpets
Figure 3.—Assembly for tests of floor-surface indentation from small-area loads; loaded maple roller studded with boot calks and specimens firmly supported on heavy beam.

(M 136 578)
were being punctured, and they were even punching holes in the metal skins of airplane floors. With style changes the stiletto-heel problem has diminished. This does not make the "boot calk" test any less important, for there are several other sources of small-area dynamic loadings that may produce similar damage to the surface of a finish flooring. They include granules of small gravel or similar hard substances which are tracked in and then stepped on, protruding nails in shoes, and impacts from sharp dropped objects.

The test for resistance to indentation from small-area loads was developed to simulate the kind of dynamic point loading that can occur enough times in the life of a flooring so that extensive deep refinishing or replacement of the finish floor might be required. In heavy traffic areas, a finish flooring that resists this kind of loading may be warranted even at higher cost than another flooring comparable in other respects.

In the evaluation procedure, a roller studded with standard boot calks is rolled over a firmly supported finish floor as shown in figure 3. The superimposed load on the roller is 200 pounds. One hundred trips (50 each way) complete the test. The results from this test are qualitative and the amount of damage among different kinds of flooring is compared or the flooring under consideration is compared to oak flooring after the same number of trips. If the damage to the material under test is no worse than for the accepted flooring material, it is generally considered to be acceptable.

Figure 4 shows four common wood and wood-base materials that were evaluated for possible use as finish flooring. If in this instance the oak flooring (L) was considered adequate in resistance, then one could decide that Douglas-fir plywood (E) was not, and the two other materials were superior to the oak.

Considerable judgment must be used by the operator in making this test. Any tendency for the finish flooring to split or sliver should be noted as the test progresses. The depth of the damage has a bearing on the comparison as well as the ease with which the damage can be removed or the material refinished.

**Falling Ball Indentation Test**

The falling ball indentation test is a procedure that obtains a measure of the resistance of a finish flooring material (or system) to impacts of a more general nature than the procedure for "resistance to indentation from small-area loads." Because the amount of indentation is related to energy absorption from a free-falling object, it is important in this test, as in the concentrated loading test,
Figure 4.--Comparative damage to four wood and wood-base materials from small-area load tests. Materials: E, Douglas-fir plywood; F, high-density wood flour overlay on plywood; L, regular oak strip flooring; K, high-density fine particleboard.

(M 86139 F)
Figure 5.—Apparatus for falling-ball indentation test for wood or wood-base finish flooring.

(M 86364 F)

Figure 6.—Plot of height of drop versus indentation for falling-ball indentation test.

(M 136 612)
that the underlaying material be considered. With thin, yielding finish floorings, the indentation produced by the falling ball may actually be in the underlaying material itself.

In the usual evaluation of a wood or wood-base finish flooring to falling ball indentation, the material itself is required to absorb the impacts with a firm nonyielding support under it. This would correspond in service to the flooring being laid on a concrete or other rigid base. In some instances, as with thin parquet flooring composed of narrow loose slats, it is necessary to cement the flooring to something else to make the test. Usually, 5/8-inch-thick Douglas-fir plywood is used because it is a common underlayment material. When this is done it must be recognized in interpretation of values obtained from test. Indentation values will be less than if the material was evaluated without the underlayment.

The falling ball indentation test is made as shown in figure 5 by dropping a 2-inch-diameter steel ball (weighing 1.18 lb.) from different heights and measuring the depth of indentation produced for each drop. Each indentation is produced at a different location on the specimen so the value as measured by the micrometer tool shown in figure 5 is for a single drop. Values obtained for different heights of drop are plotted as shown in figure 6, and the curve for the flooring material under test is compared to similar ones for other materials.

In the instance shown in figure 6, the best test material was a 1/4-inch-thick, high density, particleboard block flooring; the next material in terms of amount of indentation was regular oak flooring, and the two materials with maximum indentation were 1/4-inch-thick ponderosa pine and Douglas-fir plywood, materials not usually recommended for use as finish flooring.

This test is useful also in appraising finishes and brittleness of some finish floorings. Any unusual fracture of coatings or tile itself that would require extensive refinishing or replacement should be noted.

**Rolling Load**

The resistance to rolling load simulates the loading condition that exists when castered furniture or other units may be rolled repeatedly across the same area of a floor. A bed that is rolled out from the wall daily to make a bed is an example. The assembly and apparatus used are shown in figure 7. The "caster" is a standard ball bearing assembly 1.18 inches in diameter, 9/16 inch wide.
Figure 7.--Apparatus for simulated rolling caster load.

(M 114 832)

Figure 8.--Wood-base finish floor after 50 trips of the rolling caster, showing also method of attaching finish flooring to plywood underlayment for test.

(M 114 833)
In the actual test, the dolly with the caster attached is loaded so that the force on the caster is 200 pounds. The material under test is oriented so the caster rolls across corners of tiles or ends of strip flooring in the diagonal direction. This creates the maximum amount of wear at the corners as the caster rolls from one segment of flooring to another, and may show a tendency for damage not apparent from the measurement of indentation near the center of a piece of flooring.

During the test the path of the caster is controlled by the guides on either side of the specimen so that each pass is nearly exactly on the same path. With most flooring materials, the test is terminated after 25 trips (forward and back is two trips). The amount of indentation is measured and is the quantitative index from the test. With superior flooring materials or where the contemplated use will require considerable resistance to wear of this kind, the test may be continued for 50 trips. Qualitative information should also be included on any breakdown of the surface or at the corners as previously mentioned.

Figure 8 shows the amount of caster wear produced in a wood-base flooring that is superior from the standpoint of resistance to the rolling caster load. The test was continued for 50 trips and the indentation at the center of the tiles averaged about 0.003 inch. Twenty-five trips produce about 0.007-inch indentation in white oak flooring. Since this is a dynamic test and energy is involved, it is important to duplicate the conditions of support as nearly as practicable during test. If the finish flooring is likely to be applied directly to concrete, this should be done. For wood to be employed above grade, a 5/8-inch-thick plywood underlayment is frequently used to simulate the support under such conditions.

**Abrasion Resistance**

Tests for determining abrasion resistance of various materials and simulating different use conditions have been many. Different results are obtained using different abrasion equipment. Even on the same equipment, reproducibility of results may be difficult unless there is a continuous supply of new abrading medium, since the abrading material itself is worn by the abrading action.

In considering suitable wear resistance of wood and wood-base flooring, consideration must also be given to the effect of maintenance of the finish film, be it a liquid film finish like floor sealer, wax, or a combination. Presumably, if this film is maintained and renewed often enough, there will be no abrasion of the flooring itself. From the conservative point of view, one must assume the films cannot or will not be maintained to the point, at least in high traffic areas,
that there is no wear of the flooring itself. Because of this factor, wear resistance of the flooring material after finish has been abraded away should be a consideration for suitability of a flooring material.

The Navy-type wear tester was developed especially to simulate the action of the human foot in walking, and experience by the Navy has shown that wear values obtained from it correlate well with actual wear performance of wood decks of various kinds. Test results have good reproducibility because the abrading medium is a continuous supply of new No. 80 aluminum oxide powder.

In the test the 2– by 3-inch surface of the specimen is abraded by a double revolution action of the abrading disk and the specimen as shown in figure 9. Wear is expressed as loss in thickness (inportions of an inch) per 1,000 revolutions of the abrading disk. This is frequently obtained from the slope of a line obtained by plotting accumulative wear against revolutions.

A few representative wear values for wood and wood-base materials are tabulated below:

<table>
<thead>
<tr>
<th>Material</th>
<th>Wear (loss in thickness for 1,000 revolutions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hard maple</td>
<td>0.009</td>
</tr>
<tr>
<td>White oak, tangential face</td>
<td>0.017</td>
</tr>
<tr>
<td>Yellow birch, tangential face</td>
<td>0.025</td>
</tr>
<tr>
<td>Teak</td>
<td>0.067</td>
</tr>
<tr>
<td>Douglas-fir</td>
<td>0.049</td>
</tr>
<tr>
<td>Tempered hardboard</td>
<td>0.099</td>
</tr>
<tr>
<td>Untreated hardboard</td>
<td>0.251</td>
</tr>
<tr>
<td>High-density particleboard</td>
<td>0.057</td>
</tr>
</tbody>
</table>
Figure 9.—Navy-type wear machine for abrasion resistance tests of wood and wood-base finish flooring.

(M72251 F)
Note that hard maple and white oak, which have proven to be preferred materials for wood finish flooring, have excellent resistance to uniform wear as determined by the Navy-type wear tester. Some of the newer materials do not. Experience with an installation of tempered hardboard flooring at the Forest Products Laboratory bears out the fact that materials with low resistance to abrasion (high wear) may require replacement in service. Thirty years ago hardboard was suggested for use as finish flooring so it was installed in FPL corridors and some rooms on one floor. It has performed well in those areas where traffic is not too heavy and maintenance is adequate. However, at elevator entrances and at stairways, wear has required replacement of individual tiles.

Coefficient of Friction

Coefficient of friction of finish flooring should be a property for which limit values are available for different kinds of occupancies and exposures. In an experimental installation of high-density particleboard with different finishes, the same material was satisfactory or unsatisfactory depending on the kind and quality of the finish applied to it.

The installation was in a corridor and those floorings with the hardest, most glassy finish proved unsuitable because of excessive slipperiness, which was aggravated by any sandy material tracked in. At the opposite extreme, those finishes that were excessively soft and not slippery attracted and held dirt until they were difficult to clean.

The coefficient of friction, both static and dynamic, of finished wood and wood-base flooring is determined by the method shown in figure 10. In this test a piece of prime grade shoe leather (4 by 4-1/2 in.) is cemented to a 25-pound mass and is pulled along the surface of the flooring as shown. For determining static friction, the rate of movement of the testing machine is 0.05 inch per minute, and the maximum load required in starting the movement is divided by mass of the sliding unit (weight plus leather) to determine the coefficient.

Moving friction is determined by the force required to slide the unit over the flooring at a rate of 2 inches per minute. This force is not steady but pulsating at a rate of about 2 times per second. When autographic equipment is used, maximum and minimum values of force per pulse are averaged from the chart. The mean sliding coefficient of friction is calculated in the same way as for static coefficient. When autographic equipment is not available, the mean force must be estimated from the limits of fluctuation of the hand on the load-indicating dial.
Figure 10.--Test assembly for determining static and dynamic coefficients of friction for finish flooring surfaces.

(M 114 828)

Figure 11.--Restrained surface wetting specimen after 48 hours of wetting, showing doming produced and method of estimating amount.

(M 114 835)
The surface of the sole leather is renewed between each evaluation by sanding lightly with 1/2-grit (No. 60) garnet paper.

Following is an indication of the values obtained from this evaluation for a few wood and wood-base materials. Values for plate and window glass are included for reference purposes.

<table>
<thead>
<tr>
<th>Material</th>
<th>Coefficient of friction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Static</td>
<td>Mean</td>
</tr>
<tr>
<td>------------------------------------------------</td>
<td>-------------------------</td>
</tr>
<tr>
<td>Prefinished high-density particle-board tile</td>
<td>0.48</td>
</tr>
<tr>
<td>Unfinished tempered hardboard</td>
<td>0.73</td>
</tr>
<tr>
<td>Unfinished oak, parallel to grain</td>
<td>0.76</td>
</tr>
<tr>
<td>Window glass</td>
<td>- -</td>
</tr>
<tr>
<td>Plate glass</td>
<td>0.42</td>
</tr>
</tbody>
</table>

The prefinished particleboard flooring was acceptable for use in houses even though there were small differences between it and plate glass.

**Surface Wetting**

The surface wetting test is performed on wood and wood-base finish floorings because the probability exists that the surface of flooring will occasionally become wet. This wetting may come from tracked-in water from outside, rain from an opened window, overflow from plumbing, or spillage. Wood materials are hygroscopic and rate of moisture absorption depends on surface finishes and absorbency of the material itself. Any increase in moisture content will result in some swelling. The purpose of the surface wetting test is to obtain a measure of the difficulty that may occur if the surface of the flooring is accidentally wetted. It is performed usually on finished flooring. Two conditions are simulated, restrained as it conceivably could be in the center of a floor area, and unrestrained.
For the restrained test, the floor, in about a 10-inch-square piece, depending on size of component parts, is enclosed in a restraining frame as shown in figure 11. Steel strapping around the periphery of the frame restrains the specimen from swelling in the plane of the frame during the wetting process. This corresponds to flooring laid tightly together. The wetting exposure consists of placing saturated blotters on top of the specimen and keeping them wet for a period of 48 hours. For the restrained test, 1/4-inch clearance of the blotter is maintained along all four edges so the frame itself is not wet. At the end of the 48-hour wetting period, the blotters are removed and any doming or bowing is estimated as shown in figure 11. The specimen is then dried at room temperature and after stabilization any residual distortion is measured. The specimen is examined with reference to any refinishing that would be necessary to restore the surface to its original condition. In segmental flooring such as parquet, observations are made to determine whether or not there is any splitting of individual slats or if spaces between slats are irregular.

The unrestrained tests are made on the same size specimens, but they are free to expand without restraint. Similar observations are made at the end of the 48-hour wetting period and after drying.

In an evaluation of a high-density prefinished particleboard floor tile, restrained specimens developed doming of about 1/4 inch, but were essentially flat after drying. The unrestrained specimens only domed about one-third as much, and were flat also after drying. The surface became irregular from swelling of individual particles, but light sanding and sealing restored the original surface, showing damage could be repaired. This also showed that the flooring should be used in areas away from entrances (where water could be tracked in) or where water spillage was frequent.

Possible Uses of the Tests for Other Flooring Materials

Because these procedures have been developed around exposures and loadings of probable and possible use, they offer possibilities for appraising the suitability of materials other than wood for finish flooring. While they have not been tried for such materials as resilient tile, terrazo, or some of the poured-in-place plastics, they might be considered among methods of evaluating specific finish flooring materials.

6A common size in parquet-type flooring with small slats is 5–1/2 in. Two widths and two lengths are commonly fabricated into an 11-in. square, so this is the size of specimen used.
In many instances, we must in the future consider more the floor system rather than the components individually. The satisfactory performance of a small slat wood parquet floor or a resilient tile may depend on the performance of the underlayment and the adhesive bonding the two. The satisfactory performance of carpeting may depend on the cushioning or the substrate. Not all of the procedures discussed in this paper need to be used in any evaluation. Certainly, coefficient of friction or the wear test would have little relevance in the instance of evaluating a carpet, but the concentrated rolling load or boot calk test might if the lack of support by an underlay material could result in breakage of the fiber in the base of the carpet. The surface wetting test would have little use with any material that was not hygroscopic, but again some underlaying material could result in failure from water getting to it.