RESEARCH REPORT 139

Plywood Floors for Residential Garages

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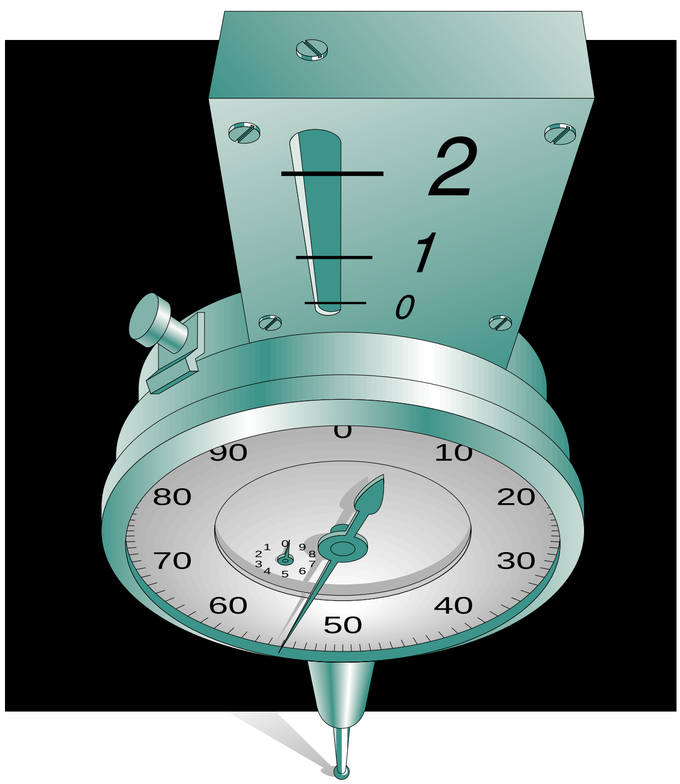
November 1980

Technical Services Division



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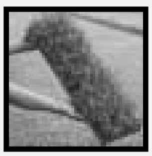
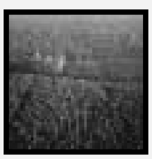


- *We're growing more wood every day.* American landowners plant more than two billion trees every year. In addition, millions of trees seed naturally. The forest products industry, which comprises about 15 percent of forestland ownership, is responsible for 41 percent of replanted forest acreage. That works out to more than one billion trees a year, or about three million trees planted every day. This high rate of replanting accounts for the fact that each year, 27 percent more timber is grown than is harvested. Canada's replanting record shows a fourfold increase in the number of trees planted between 1975 and 1990.

- *Manufacturing wood is energy efficient.* Wood products made up 47 percent of all industrial raw materials manufactured in the United States, yet consumed only 4 percent of the energy needed to manufacture all industrial raw materials, according to a 1987 study.

Material	Percent of Production	Percent of Energy Use
Wood	47	4
Steel	23	48
Aluminum	2	8



- *Constructive news for a healthy planet.* For every ton of wood grown, a young forest produces 1.07 tons of oxygen and absorbs 1.47 tons of carbon dioxide.

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SIZED FOR SPACING
EXPOSURE 1
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NOTICE:
The recommendations in this report apply only to panels that bear the APA trademark. Only panels bearing the APA trademark are subject to the Association's quality auditing program.

CONTENTS

ABSTRACT

Residential garage floor systems can be built with one or two layers of plywood. This test program forms the basis for garage floor recommendations that are suitable for long-term service. Floor systems include 12-, 16-, and 24-inch joist spacings, and perform under a 2000-lb tire load, as specified by the Uniform Building Code. Building codes may require an additional topping layer of noncombustible or asphaltic paving materials for garage floor surfaces.

Subsequent to the completion of this test program, both the Uniform Building Code (UBC) and International Building Code (IBC) have modified the 2,000-lb concentrated load requirement by applying it to a 20-in.^{2} area. New tests following the current UBC and IBC requirement for concentrated load were conducted. Test results are attached in Appendix B. Also, due to the environmental concerns on the use and handling of asbestos-containing materials, non-asbestos cement board was tested in the floor system as the top noncombustible surface to evaluate the suitability as an alternative material. Test results are attached in Appendix C.

RECOMMENDATIONS

The following plywood recommendations for residential garage floors are based on results of testing described in this report.

The user should be aware that garage floor framing design is critical and should be undertaken by an engineer familiar with wood design. It should also be noted that building codes specify pressure preservative treatment for all wood members within 8 inches of the ground. Building codes may also require an additional topping layer of noncombustible material for garage floor surfaces.

24" o.c. Floor Supports

1. 1-1/8" APA RATED STURD-I-FLOOR 48 oc (2-4-1) plywood with T&G edges, face grain perpendicular to joists, plus a covering layer of 1/2" APA Group 1 Underlayment EXT or 1/2" APA Group 1 A-C EXT. Joints of panels should be staggered, with face grain of the top layer parallel to the joists.
2. 1-1/8" APA RATED STURD-I-FLOOR 48 oc (2-4-1) plywood with T&G edges, face grain perpendicular to joists, plus a topping layer of 3" concrete reinforced with 6" x 6" 10/10 wire mesh.

16" o.c. Floor Supports

1. 23/32" APA RATED SHEATHING 48/24 Exposure 1 marked PS 1 (CDX), plus a covering layer of 23/32" APA RATED STURD-I-FLOOR 24 oc EXT. Joints should be staggered between layers, with both layers applied face grain perpendicular to joists.
2. 23/32" APA RATED SHEATHING 48/24 Exposure 1 marked PS 1 (CDX), face grain perpendicular to joists, plus a topping layer of 3" concrete reinforced with 6" x 6" 10/10 wire mesh.

12" o.c. Floor Supports

1. 1-1/8" APA Rated Sturd-I-Floor 48 oc (2-4-1) plywood with face grain perpendicular to joists, and T&G edges glued with AFG-01 (ASTM D 3498) construction adhesive.

Installation

Use 6d ring-shank nails for plywood up to 3/4" thick, 8d for thicker plywood, spaced 6" o.c. at edges and intermediate supports. Where required, fasten the top layer of 23/32" plywood with 6d ring-shank nails spaced 6" o.c. at all edges and on a 10" grid in the interior. Space end and edge joints 1/8".

When plywood is not topped with concrete or other noncombustible materials, it should be finished with a heavy-duty liquid floor coating to aid in cleaning and preventing moisture absorption.

INTRODUCTION

Objective

This research program was undertaken to develop recommendations for plywood floor systems capable of supporting a 2000-lb tire load as specified by the Uniform Building Code and International Building Code. It was necessary to establish a test method and associated performance criteria, since none existed.

Background

There are a number of construction situations for which above-ground residential garage floors are desirable. Site preparation for a concrete slab floor is often cost prohibitive on steeply sloping sites. During cold weather, the ability to continue construction with a wood system is an added advantage. A raised garage floor can also be insulated if desired. A garage floor supported on lumber joists is, therefore, frequently a desirable alternative to the slab.

Section 1607.33 of the 1997 Uniform Building Code requires that garage floors must be capable of supporting a 2000-lb concentrated load acting on an area of 20 square inches. Additionally, Section 312.5 of the 1997 UBC requires a noncombustible surface "or asphaltic paving." Similar provisions may be found in Section 1607.4 and Table 1607.1 of the International Building Code.

For panel products, a requirement for capability of sustaining a concentrated load is most easily proven through testing, rather than by engineering calculation. Furthermore, when the concentrated load is a moving wheel, good performance under long-term service conditions should be shown in order to assure appropriate construction recommendations. These considerations resulted in development of the test program described in this report.

TESTING

General

The test program was divided into two phases. The first phase was a screening process in which floor constructions were subjected to increasing wheel load increments to determine relative performance and potential capability to carry 2000 lb.

The second phase was a service simulation of longer duration. In this phase repetitive cycling of a tire load across the specimen represented long-term performance. Ten thousand test cycles were selected as approximately equivalent to going in and out of a garage once per day for 30 years.

A rolling wheel load has previously been established as a most severe test. Static loading with wheels fails to induce the range of shear stresses within the panel that occur in actual service. In addition, secondary stresses appear to be created by the rolling of the wheel and the deformation of the loaded tire on the surface of the floor. The rolling wheel evaluates the bending strength and rolling-shear capacity of the plywood panel and, at the same time, permits observation of the performance of joints and resistance of the surface to abrasion.

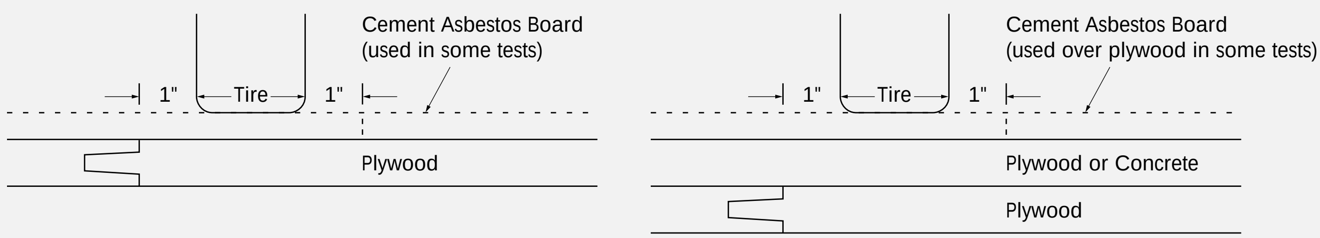
Materials and Specimens

All test specimens were 4-ft-wide plywood floor sections nailed with ring-shank nails 6" o.c. to 2-1/2"-wide wood sleepers bolted to 8-ft-long steel I beams. In most cases the specimen was 4 ft long, but specimens with concrete topping were extended to 5 ft to provide continuity of the topping at one end of the specimen and a landing pad at the opposite end.

Specimens were tested with the plywood panel joint across framing. The joint was parallel to and placed 1" away from the tire tread track, as shown in Figure 1. Joints in the double-layer plywood systems were staggered so that the joint of the lower layer was adjacent to the tread track, since this configuration was considered the most critical.

FIGURE 1

TYPICAL POSITION OF PANEL JOINTS



When a concrete topping was used it was not bonded to the plywood; in one case a 6-mil polyethylene film was placed between the concrete and the plywood. The concrete topping was produced from bagged concrete mix and yielded a compression test strength of approximately 3600 psi after curing for one month. All concrete topped specimens were cured for a month before testing.

Some specimens were tested with 1/4" cement asbestos board as a non-structural topping.* Joints were located parallel to and 1" away from the rolling wheel path (see Figure 1). Boards were fastened to underlying plywood with 4d galvanized box nails 6" o.c. at all edges and on a 10" grid in the interior.

The combinations of materials used in individual specimens are described in the Results section.

Test Setup

A heavy-duty floor test machine at the APA Research Center was used to move the specimen and support system under the loaded wheel (see Figure 2). The tire moved across the specimen in a direction perpendicular to the framing members in a path 52" long, at a speed of approximately one mile per hour. The load on the tire was applied hydraulically and maintained within 5 percent of the test load level.

Dial gages mounted below the panels and supported by the framework permitted observation of deflection as an indicator of the condition of the floor. Deflection itself was not a performance parameter.

*Note: Federal, state and local regulations govern the use, handling and disposal of asbestos-containing materials in many instances.

A 6.70 x 14 radial tire was used for loading which, according to a tire manufacturer's representative, is about as small as would ever be used on a pickup truck having a 2000-lb per wheel load capacity. The tread print of the tire carrying 45 psi of air pressure was 4-1/2" wide and 8-3/4" long, measured by applying dye to the tire surface and pressing it onto a panel at 2000 lb. The length of the tread print varied with load.

Test Procedures

Screening Test

In the screening test the wheel was initially loaded to 500 lb and then increased in 500-lb increments. A run of 50 cycles was made at each load level. (A cycle is the travel of the wheel forward and backward.) Deflection of the floor system under the tire track was recorded at the beginning and end of testing under each load increment. Relating increase in deflection to increase in load permitted determination of the condition of the floor. Both visual and audible observations were made continuously, with special attention to the panel joint area.

The load was increased in increments until the condition of the tire was considered unsafe and not representative of service loading conditions. At 4000 lb of load, with a tire pressure of 45 psi, the tire was severely deformed, with the sidewall of the tire nearly touching the surface of the specimen.

Test performance involved both objective and subjective evaluations of the floor system. While observations of the actual test included many features, determination of "distress" level was concentrated on the four parameters listed below. Distress level is defined here as the load at which *any* evidence of a problem in any of the four listed parameters was detectable.

1. Rolling shear failure within the panel, as indicated by non-linear relationship between the deflection increase and the increase in load.

2. Visible failure, such as broken wood fibers greater than 1/8" in width.

3. Audible failures, such as loud cracking noises. Problem areas were substantiated by close visual examination.

FIGURE 2

TIRE UNDER 2000-LB LOAD IN FLOOR TEST MACHINE

4. Excessive differential deflection at panel joints. Acceptable deformation was limited to the small clearance typical in a T&G joint (approx. 1/32"). Problem areas were substantiated visually after test completion.

Service Simulation Test

This procedure attempted to duplicate long-term loadings as might occur in severe service usage. A load of 2000 lb was placed on the tire and cycled across the specimen continuously for 10,000 cycles at a rate of 7-1/2 cycles per minute.

The criteria for evaluation of floor performance involved the four parameters outlined above, plus visible cracking of the topping layer (concrete or cement-asbestos board). Any detectable problem involving these parameters was cause for rejection of the floor system.

This test procedure is severe since the duration of loading is cumulative with succeeding cycles. It was noted that floors recovered some of their deflection overnight between days of loading, and thus it is apparent that an occasional heavy load on a floor is not as injurious as the continuously rolling heavy load used in this test procedure.

Results

Table 1 shows the load level at which any type of problem was first noted during the screening test. The tire with air pressure of 45 psi had a load limit of approximately 4000 lb before being deformed to where the sidewalls touched the floor. As indicated in the table, some constructions showed no distress at the load limit of the tire.

Constructions in which one or more specimens showed distress at load levels less than 3500 lb in the screening test were eliminated from further testing. The better performing all-plywood constructions, plus additional systems using concrete and cement asbestos board toppings, were then subjected to service simulation testing.

Table 2 shows floor systems that went the full 10,000 cycles without displaying any distress, as well as several floor systems that exhibited some type of problem during testing. Distress, if any, invariably occurred early in the testing.

TABLE 1

SCREENING TEST RESULTS

Floor System Description(a)	Joist Spacing (inches)	Tire Load at Distress(b)(c) (pounds): 1500	2000	2500	3000	3500	4000(d)
1-1/8" APA Sturd-I-Floor 48 oc (2-4-1), midpanel tire path	12						
	16						●→
	24				●	●	
1-1/8" APA Sturd-I-Floor 48 oc (2-4-1), blocked edge joint	12						
	16						
	24						●→ ●→
1-1/8" APA Sturd-I-Floor 48 oc (2-4-1), glued T&G edge	12						●→ ●→
	16			●			
	24		●	● ●		●	
1-1/8" APA Sturd-I-Floor 48 oc (2-4-1), unglued T&G edge	12					●	●
	16				●	●	
	24		●	●			
1-1/8" APA Sturd-I-Floor 48 oc (2-4-1), Plus 1/2" APA A-C Group 1 with face grain parallel to supports	12						
	16						
	24						●→ ●→
3/4" APA 48/24 CDX, plus 23/32" APA C-D P&TS Group 1; joints staggered	12						
	16					● ●	
	24				●		●

Very heavy automobile (1500)

Heavily loaded pickup truck (2000)

Minimum load considered for further testing (3500)

(a) Plywood face grain across supports unless noted.

(b) 6.70 x 14 tire, 45 psi air pressure.

(c) Each point represents one specimen.

(d) ●→ indicates no distress; stopped due to tire load limit.

TABLE 2

SERVICE SIMULATION TEST RESULTS (2000-LB TIRE LOAD, 45 PSI TIRE AIR PRESSURE, 10,000 CYCLES)

Joist Spacing (inches)	Floor System Description(a)	Number of Specimens: Total	Number of Specimens: Passing (no failure)
12	1-1/8" APA Sturd-I-Floor 48 oc (2-4-1), unglued T&G edges	2	2(b)
16	1-1/8" APA Sturd-I-Floor 48 oc (2-4-1), midpanel tire path	2	0
	1-1/8" APA Sturd-I-Floor 48 oc (2-4-1), unglued T&G edge joint, plus 1-1/2" concrete with 6" x 6" 10/10 wire mesh	1	0
	3/4" APA 48/24 C-D with exterior glue, plus 23/32" APA Sturd-I-Floor 24 oc	2	2
	3/4" APA 48/24 C-D with exterior glue, plus 23/32" APA Sturd-I-Floor 24 oc, plus 1/4" cement asbestos board wear surface; all joints staggered	1	1
	3/4" APA 48/24 C-D with exterior glue, plus 3" concrete reinforced with 6" x 6" 10/10 wire mesh	1	1
24	1-1/8" APA Sturd-I-Floor 48 oc (2-4-1); blocked T&G edges	2	2
	1-1/8" APA Sturd-I-Floor 48 oc (2-4-1), unglued T&G edges, plus 1/2" APA A-C Group 1 with face grain parallel to supports	2	2
	1-1/8" APA Sturd-I-Floor 48 oc (2-4-1), unglued T&G edges, plus 1/2" APA UNDERLAYMENT Group 1 with face grain parallel to supports, plus 1/4" cement asbestos board wear surface; all joints staggered	1	1
	1-1/8" APA Sturd-I-Floor 48 oc (2-4-1), unglued T&G edges, plus 1-1/2" concrete with no wire mesh	1	0
	1-1/8" APA Sturd-I-Floor 48 oc (2-4-1), unglued T&G edges, plus 1-1/2" concrete reinforced with 6" x 6" 10/10 wire mesh	1	0
	1-1/8" APA Sturd-I-Floor 48 oc (2-4-1), unglued T&G edges, plus 3" concrete reinforced with 6" x 6" 10/10 wire mesh	1	1

(a) Plywood face grain across supports unless noted.

(b) Close inspection after 10,000 cycles revealed incipient crack at T&G joint.

Floor systems performing with no distress for 10,000 cycles are included in resulting recommendations, with two exceptions. Upon completion of 10,000 cycles, the system tested at 12" joist spacing showed an incipient crack at the unglued T&G joint. A T&G joint glued with adhesive meeting APA Performance Specification AFG-01 (ASTM D 3498) is therefore recommended. Also, whereas the 1-1/8" plywood with blocked edges performed satisfactorily with joists 24" o.c., midpanel loading with joists 16" o.c. showed distress. The system therefore was not included in final recommendations for joists 24" o.c.

Deflections were recorded, but used only to ascertain possible shear failure, as would be indicated by an abrupt increase. Values varied quite widely, but maximum readings near the end of 10,000 cycles under 2000-lb load were generally about 1/100 of the span. Systems which included 3" of reinforced concrete generally deflected no more than 0.02".

Observations and Discussion

Stresses

Bending strength, especially at edges or T&G joints, was the most frequently observed limitation in floors carrying pneumatic tires. This is in contrast to forklift truck wheel loading with hard rubber tires, where rolling shear is frequently the mode of failure.

Tire tread print size is of major importance to the ability of the floor to carry the tire load. As a tire with a small tread print reaches a position close to the support members, the load travels through a diminishing effective area of the panel toward the support, and the rolling shear stress within the panel at that location increases greatly. The effect of tread print size on localized bending stress is also important. Minor local deviations of grain direction on the bottom side of the panel can become distress points when they occur directly under smaller tread prints, especially at longer spans.

The tire air pressure has a significant influence on panel stresses, because it affects tread print size under load. If a vehicle is heavily loaded, the tire with lower pressure will deform more and come in contact with a larger amount of the floor surface. This reduces the unit bending stress and shear within the panel for a given load.

In some of the screening tests, it was questionable whether increasing load on the tire actually caused any greater stress within the panel, since the tread print got substantially larger. With 12" spacing of the framing members, the tread print for some of the higher loads extended almost from one support member to the other.

For longer spans between framing members, load capability was reduced in a nearly direct relationship. This was because load capability was governed by bending stress, which is directly proportional to span in accordance with beam theory for concentrated loading.

The two-layered floor system has very desirable features related to bending strength, as well as providing bridging of the joint between panels. It appears that the top layer tends to distribute the concentrated load of the tire so that the lower layer is less subject to high localized bending stress.

Joints

Joints between panels are critical in the floor systems. The tongue-and-groove joint at edges of 1-1/8" APA Sturd-I-Floor 48 oc (2-4-1) plywood panels is inadequate to transfer the large loads occurring on garage floor systems. Gluing the joint with a construction adhesive increases the strength only slightly, although enough to permit the system when joists are spaced 12" o.c.

Concrete topping is beneficial in bridging the joints. Testing clearly pointed out, however, that wire mesh must be used in the concrete to hold it together since, when flexed with a plywood deck, it tends to crack. Efforts to use a 1-1/2"-thick concrete topping (rather than 3") failed, showing cracks and minor spalling. Since this was to be an impervious topping, the cracks would represent failure to meet that requirement.

In a two-layer plywood system, staggering of joints seems to provide the bridging effect needed. A layer of 1/2"-thick plywood was installed with its face grain perpendicular to the T&G joint of a first layer of 1-1/8" APA Sturd-I-Floor 48 oc (2-4-1) plywood. This was an effort to gain the greatest bridging effect possible, since the 2-4-1 panel alone had the structural strength to span between the joists but needed reinforcement at the joint. Both layers of the two-layer system of 3/4" plywood were installed with face grain perpendicular to the joists in order to maximize the strength between joists.

The cement asbestos board topping layer added little strength to the floor system but, when joints were adequately closed, provided an impervious noncombustible layer. See Note page 4. For this reason it was tested as a topping over floor systems that had previously shown sufficient strength. The laboratory tests indicate that, with the plywood backing for the cement asbestos board, cyclic wheel loads and impacts from dropped tools or other items did not appear to be a problem.

CONCLUSIONS

1. The most critical stress is bending for a plywood floor carrying tires inflated to 45 psi. Bending stress is most frequently a problem where a strength-reducing characteristic coincides with the edge of the panel.

2. Glued tongue-and-groove joints of 1-1/8" 2-4-1 plywood panels are adequate to transmit loads as produced in garage floors when joists are spaced 12" o.c. For joists spaced 16" or 24" o.c., double-layer plywood floor systems with staggered edge joints are necessary to overcome joint problems.

3. A topping layer of concrete over a plywood garage floor must be 3" thick and have wire mesh reinforcement to function without cracking under cyclic wheel loads.

4. A test loading of 10,000 cycles adequately simulates long-term service conditions.

APPENDIX A. SCREENING TESTS AT HIGH TIRE PRESSURE

To provide further information on the effect of tire pressure, a series of screening tests was run with the tire inflated to 95 psi to simulate commercial vehicles. Loads were applied in increments identical to the procedure described for the screening process in this report.

With the higher tire pressure the tread print was smaller, 4-1/2" wide x 6-5/8" long at 2000 lb of load. A 6000-lb load level was considered maximum for the tire during tests, since this was significantly beyond the normal service load for this size of tire. At 6000 lb the sidewalls of the tire nearly touched the surface of the floor.

Results of the tests are given in Table A-1. Unlike tests with tires inflated to 45 psi, rolling shear was a fairly frequent mode of failure for the plywood floor systems, especially on the shorter spans. No attempt was made to develop recommendations.

TABLE A1

SCREENING TEST RESULTS

Floor System Description[a]	Joist Spacing (inches)	Tire Load at Distress[b][c] (pounds) 1500	2000	2500	3000	3500	4000	4500	5000[d]	5500	6000
1-1/8" APA Sturd-I-Floor 48 oc (2-4-1), midpanel tire path	12					●	●●	●			
	16				●●●●	●					
	24			●●							
1-1/8" APA Sturd-I-Floor 48 oc (2-4-1), blocked edge joint	12										
	16				●	●					
	24		●	●							
1-1/8" APA Sturd-I-Floor 48 oc (2-4-1), glued T&G edge	12										
	16				●	●●					
	24		●	●							
1-1/8" APA Sturd-I-Floor 48 oc (2-4-1), unglued T&G edge	12		●								
	16	●		●							
	24	●	●								
1-1/8" APA Sturd-I-Floor 48 oc (2-4-1), Plus 1/2" APA A-C Group 1 with face grain parallel to supports	12					●●					
	16			●		●					
	24					●●					
3/4" APA 48/24 CDX, plus 3/4" APA C-D P&TS Group 1; joints staggered	12								●		●
	16					●		●			
	24		●	●							
1-1/8" APA Sturd-I-Floor 48 oc (2-4-1), two layers, unglued T&G, joints staggered	12										
	16							●			●
	24							●	●→		

(a) Plywood face grain across supports unless noted.
(b) 6.70 x 14 tire, 95 psi air pressure.
(c) Each point represents one specimen.
(d) ●→ indicates no distress; stopped due to tire load limit.

APPENDIX B. CONCENTRATED STATIC LOAD ACTING ON A 20-IN^2 AREA

Overview

The APA recommendations for residential garage floors given in this report were based on the results of cyclic tire load tests with different joist spacings and plywood thicknesses and lay-up arrangements. In the past, no loading area was specified – only the 2,000-lb wheel load. However, UBC and IBC provisions now require that the 2,000-lb concentrated load acts on an area of 20 in.^{2} (to simulate the loading condition of a car jack), for residential garage floors. Therefore, in order to verify that the current code requirement on residential garage floors is met, new concentrated static load tests were conducted.

Concentrated Static Load Test

APA Test Method S-1 with a 24 in. o.c. test span was followed. A single-layer floor of 1-1/8" Sturd-I-Floor T&G plywood (2-4-1) was used in the tests. This floor assembly represents the most conservative case among the three APA recommendations. Load was applied through a 4 in. x 5 in. (20 in.^{2}) load plate at two critical locations: 1 in. from the T&G joint at midspan and 1 in. from the support (Figure B1 and Figure B2). Load was applied using a hand-driven hydraulic pump gradually up to 2,000 lbs. The load and corresponding deflection of the plywood under a load plate were automatically measured and recorded, although the deflection measurement is not required by either UBC or IBC.

FIGURE B1

CONCENTRATED STATIC LOAD TEST SETUP

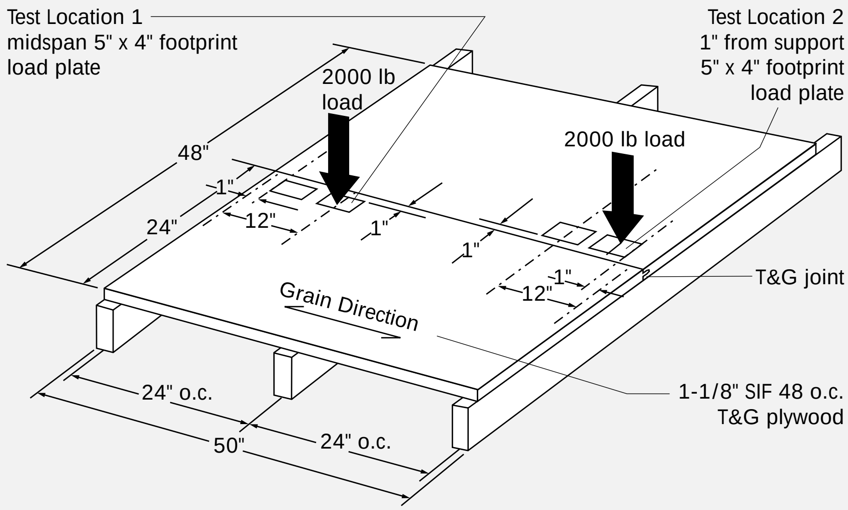


FIGURE B2

CONCENTRATED STATIC LOAD TEST

TABLE B1

CONCENTRATED STATIC LOAD TEST RESULTS

Location	Mid-span		1" from Support	
Specimen	Load[a] (lb)	Deflection[a] (in.)	Load[a] (lb)	Deflection[a] (in.)
1	2,003	0.149	2,008	0.118
2	2,002	0.132	2,002	0.105
3	2,004	0.155	2,002	0.109
4	2,003	0.142	2,003	0.110
Mean	2,003	0.144	2,004	0.110
COV %	0.05	6.98	0.13	4.89

a Average of two tests at one location

Test Results and Remarks

The average values of the concentrated static load tests are tabulated in Table B1. The center (midspan) deflection of the floor over supports 24 in. on center was averaged 0.14 in. whereas the deflection under the load 1 in. from support averaged 0.11 in. There was no kind of damage observed during the tests: No sign of rolling shear failure (delamination) was seen in the areas where load plate was 1 in. from the support (a rolling shear failure is likely to occur at this location). The single-layer 1-1/8" plywood 2-4-1 floor test assembly appeared to be capable of withstanding the 2,000-pound concentrated load acting on a 20 in.^{2} area.

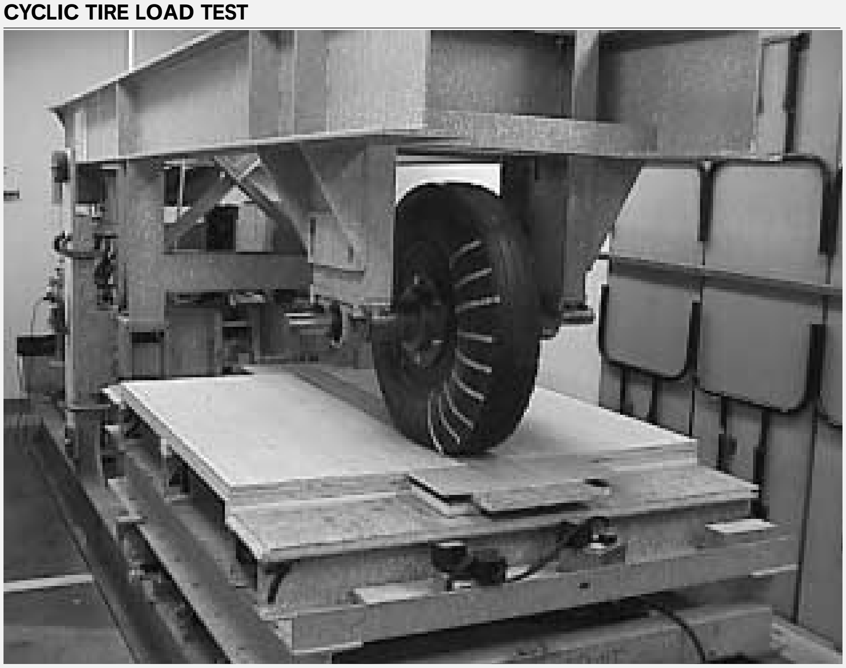
APPENDIX C. CYCLIC TIRE LOAD TESTS ON PLYWOOD WITH NON-ASBESTOS BOARD

Overview

In the code provisions, a noncombustible surface of the residential garage floor is required. Asbestos cement board was used in earlier tests and included in APA recommendations for garage floors. Due to the environmental concerns on the use and handling of the asbestos-containing materials, non-asbestos cement topping boards should be used. Cyclic tire load tests were conducted to verify if the new cement board has satisfactory resistance to surface abrasion when subjected to 10,000 cycles under a 2,000-lb tire load testing condition.

FIGURE C1

CYCLIC TIRE LOAD TEST



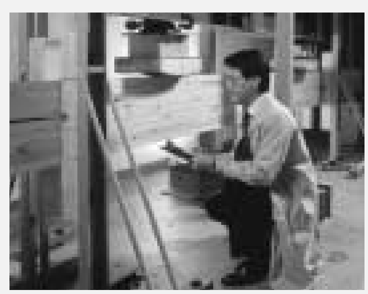
Cyclic Tire Loading Test

The test setup and test method followed that used in this report. The test specimen was constructed using 1-1/8" Sturd-I-Floor T&G plywood (2-4-1), covered by a 15/32" thick Group 1 Underlayment panel, plus a top layer of 1/4" noncombustible fiber cement board. Both materials were purchased locally. A 24-in. o.c. floor support configuration was used. A 6.70 x 14 radial tire inflated with 45 psi air pressure traveled in the center across the supporting frame (see Figure C1). The load on the traveling tire was 2,000 lb and the tire traveled continuously for 10,000 cycles (the machine was stopped after work hours and resumed the following day) at a rate of approximately 7.5 cycles per minute. Deflection at the middle of the 24-in. span was measured.

Test Results and Remarks

The floor assembly did not show any signs of visible failures such as cracking or splitting upon completion of 10,000 cycles with the tire load of 2,000 pounds. No audible failures such as loud cracking noise were evidenced during the whole process of cyclic testing. The top noncombustible fiber cement board did not show any damage except the inevitable track marks under the 2,000-lb tire rolling path. Finger touching across tire tracks did not reveal any ridges or grooves. This indicates good surface abrasion resistance of the cement board. The floor assembly was carefully taken apart to observe any evidence of damage. The underlayment was cut to two pieces to see if any rolling shear damage occurred underneath the tire tracks. There was no visually observable sign of rolling shear damage. No structural damage was seen on the bottom 1-1/8" plywood 2-4-1 in the T&G or elsewhere.

Test results show that the top covering noncombustible non-asbestos fiber cement board possesses satisfactory properties for use in garage floors.



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