APA Technical Topics
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Ceramic Tile Over Wood Structural Panel Floors

Wood structural panels have been used successfully under ceramic tile for decades. Due to the brittle nature of the tile, it is important to make certain that the floor system is as stiff as practically possible. Simply meeting code-minimum uniform load design deflection requirements (L/360), however, is unlikely to provide adequate support for a ceramic or natural stone tile floor.

Tile Council of North America (TCNA), in cooperation with APA, tested wood floor systems with joists spaced 24 inches o.c. One of the assemblies in Table A and one of the assemblies in Table B utilize oriented strand board (OSB). The systems in Table A have been tested by TCNA in accordance with ASTM C 627, *Standard Test Method for Evaluating Ceramic Floor Tile Installation Systems Using the Robinson-Type Floor Tester*, and received a service classification of Residential or Light Commercial even though they are not listed in the TCNA Handbook.

TCNA's *2007 Handbook for Ceramic Tile Installation* lists 23 floor systems that utilize plywood (Table B) or, in the case of assembly F155, OSB. Eight of these systems, F142, F143, F147, F149, F150, F152, F155 and RH130 have two-layer all-plywood substrates. Many systems call for joists at 16 inches o.c., but two permit joists spaced at 19.2 inches o.c. and six permit joists spaced at 24 inches o.c. Three systems are designed for floor-embedded electric heating systems and three systems are designed for floor-embedded hydronic heating systems.

All floor systems are for interior, dry-use only. Plywood and OSB panels must be dried to equilibrium prior to application of underlayment and prior to application of tiles. Panel underlayment edges should be offset by at least two inches from subfloor edges (many tile installers prefer an offset of at least 6 inches). Underlayment panel ends should be offset from subfloor panel ends by one or more joist spacings, plus 2 inches. All layers of panels should be installed with strength axis perpendicular to supports. APA Underlayment panels should be installed with corrosion-resistant fasteners. Underlayment fasteners should avoid joists to minimize the potential for nail pops that can lead to squeaks. For all TCNA-listed floor systems, consult TCNA's *Handbook for Ceramic Tile Installation and American National Standard Specifications for the Installation of Ceramic Tile*, ANSI A108, 118 and 136 for specific installation details.

TABLE A. ASTM C 627-TESTED ASSEMBLIES—NOT LISTED BY TCNA

TCNA No.	Service Classification[a][b]	Joist Spacing (in. o.c.)	Tile Adhesive	Underlayment Layer	Subfloor Layer	Other
Unlisted	Light Commercial	24	Multi-purpose thin-set mortar	Tested and passed with no underlayment layer: Minimum 1/4" plywood APA Underlayment layer recommended	1-1/8" APA Rated Sturd-I-Floor 48 oc T&G Exposure 1 Plywood	—
Unlisted	Residential	24	Multi-purpose thin-set mortar	19/32" APA Rated Sturd-I-Floor 20 oc T&G Exposure 1 OSB	23/32" APA Rated Sturd-I-Floor 24 oc T&G Exposure 1 OSB	Trowel-applied waterproof membrane over Underlayment

See Table B for footnotes

TABLE B. ASTM C 627-TESTED ASSEMBLIES LISTED IN TCNA'S *HANDBOOK FOR CERAMIC TILE INSTALLATION*

TCNA No.	Service Classification[a][b]	Max. Joist Spacing (in. o.c.)	Tile Adhesive	Underlayment Layer	Subfloor Layer	Comment
F141	Light Commercial	16	Portland cement paste, dry-set mortar or latex-portland cement mortar	Mortar bed (1-1/4" minimum)	19/32" Exposure 1 T&G plywood	Cleavage membrane
F142	Residential	16	Organic	19/32" Exposure 1 plywood	19/32" Exposure 1 T&G plywood	—
F143	Residential or Light Commercial or (with special tile), Heavy	16	Epoxy	19/32" Exposure 1 plywood	19/32" Exposure 1 T&G plywood	15/32" plywood underlayment layer gives "Residential" performance
F144	Residential or Light Commercial	16	Dry-set mortar or latex-portland cement mortar	Cementitious backer units or fiber cement underlayment	23/32" Exposure 1 T&G plywood	19/32" plywood subfloor gives "Residential" performance
F145	Residential or Light Commercial	16	Portland cement paste, dry-set mortar or latex-portland cement mortar	3/4" Minimum mortar bed	23/32" Exposure 1 plywood	Cleavage membrane + metal lath
F146	Light Commercial	16	Dry-set mortar or latex-portland cement mortar	Coated glass-mat backer board	19/32" Exposure 1 plywood	2" x 2" or larger tile only
F147	Residential	24[c]	Latex-portland cement mortar or dry-set mortar	3/8" Exposure 1 plywood plus uncoupling membrane	23/32" Exposure 1 T&G plywood	4" x 4" or larger tile only
F148	Residential	19.2	Latex-portland cement mortar or dry-set mortar	Uncoupling membrane	23/32" Exposure 1 T&G plywood	—
F149	Residential	24	Latex-portland cement mortar	19/32" Exposure 1 plywood	23/32" Exposure 1 T&G plywood	—
F150	Residential or Light Commercial	16	Latex-portland cement mortar	19/32" Exposure 1 plywood	19/32" Exposure 1 plywood	15/32" plywood underlayment layer gives "Residential" performance
F151	Residential	24	Dry-set mortar or latex-portland cement mortar	Coated glass mat backer board	7/8" Exposure 1 T&G plywood	8" x 8" or larger tile only
F152	Residential	24[c]	Latex-portland cement mortar	3/8" Exposure 1 plywood	23/32" Exposure 1 T&G plywood	4" x 4" or larger tile only
F155	Residential[d]	24	Latex-portland cement mortar	19/32" Exposure 1 plywood	23/32" Exposure 1 T&G OSB or plywood	OSB subfloor OK
F160	Light Commercial	24	Latex-portland cement mortar	3/8" plywood	23/32" Exposure 1 T&G plywood	8" x 8" or larger tile only

Table B Continued

TCNA No.	Service Classification[a][b]	Max. Joist Spacing (in. o.c.)	Tile Adhesive	Underlayment Layer	Subfloor Layer	Comment
F170	Residential or Light Commercial	16	Latex-portland cement mortar	Fiber-reinforced gypsum panel	19/32" Exposure 1 plywood	—
F175	Residential or Light Commercial	16	Dry-set mortar or latex-portland cement mortar	Cementitious-coated foam backerboard	19/32" Exposure 1 plywood	8" x 8" or larger tile only
F180	Residential or Light Commercial	16		Poured gypsum minimum 3/4"	23/32" Exposure 1 T&G plywood	Uncoupling Membrane
F185	Residential	19.2	Latex-portland cement mortar	Cementitious self-leveling	23/32" Exposure 1 T&G plywood	—
RH122	Residential	16	—	Mortar bed	23/32" Exposure 1 T&G plywood	Crack isolation, waterproof, or uncoupling membrane
RH123	Residential	16	—	Mortar bed	23/32" Exposure 1 T&G plywood	Crack isolation waterproof, or uncoupling membrane
RH130	Residential or Light Commercial	16	Latex-portland cement mortar	Light Commercial-19/32" Exposure 1 plywood	19/32" Exposure 1 T&G plywood	Use of 15/32" plywood Underlayment layer gives "Residential" performance
RH135	Residential or Light Commercial	16	Dry-set mortar or latex-portland cement mortar	Cementitious backer unit	23/32" Exposure 1 T&G plywood	Use of 19/32" plywood sub-floor gives "Residential" performance
RH140	Residential	19.2	Latex-portland cement mortar	Cementitious self-leveling	23/32" Exposure 1 T&G plywood	—

(a) Order of increasing serviceability: Residential, Light Commercial, Moderate and Heavy

(b) As typically performed, the ASTM C 627 Robinson-Type Floor Tester delivers three, simultaneous dynamic, 300-pound concentrated wheel loads moving in a 30-inch-diameter circle over the surface of test assembly. The number of cycles the system withstands without failure determines its Service Classification. One criterion used to determine failure is a maximum deflection of L/360 under the three concentrated loads.

(c) 1-1/2 inch net support width permitted with 8x8 inches or larger tile—otherwise 2-1/4 inches net support width is required.

(d) Passed ASTM C 627 tests with a "Light Commercial" rating using plywood as the subfloor and then again with OSB as the subfloor.

FLOOR DESIGN

The International Building Code (IBC) and International Residential Code (IRC) set the maximum deflection of floor joists and floor panels at L/360, where L is the center-to-center distance between supports. In the case of panels, L is the on-center distance between the floor joists. This requirement is related to how much a joist or panel will bend under load.

In the building codes, the floor joist and floor panel deflection are calculated assuming a uniform load. Code-minimum design live load for most residential floors is 40 psf. Design load for some code-minimum commercial floors is 100 psf or more. Other load requirements can be found in the IBC, Table 1607.1.

"Uniform load" is used in the building-code-required calculations for engineering convenience. This approach generally works well in designing floor joists because furniture and people are typically distributed over the surface of a floor in a manner that approximates a uniform load. Even though uniform load is routinely used for engineered design, it does not work as well for designing floor panel systems for use under ceramic and stone tile. This is because, in reality, floor panels are typically subjected to concentrated loads.

RECOMMENDED PANEL LOAD CAPACITIES

To use the convenience of uniform-load design and still accommodate heavy concentrated loads without breaking the tile, floor panels typically must be designed to be considerably stiffer than the codes require. An analysis of the two-layer wood structural panel floor systems in the TCNA Handbook suggests that Residential and Light Commercial performance may be achievable by combining wood structural panels with total capacities as shown in Table C.

Table C. Recommended L/360 Uniform Load Capacity of Floor Panel Systems[(a)(b)(c)]

Joist Spacing (in. o.c.)	TCNA Service Level[(d)]	
	Residential (psf)	Light Commercial (psf)
16	550	750
19.2	450	600
24	250	450

(a) Assumes two layers with the strength axis (grain) of both layers perpendicular to supports, top (Underlayment) layer is plywood with minimum fastening according to recommendations in APA *Engineered Wood Construction Guide*, Form E30, minimum of three or more spans, and ends of underlayment layer offset from subfloor panel ends by at least one joist spacing. The L/360 capacities of individual panels are available in APA Technical Note, *Load-Span Tables for APA Structural-Use Panels*, Form Q225 (www.apawood.org).

(b) It is recommended that the load capacities be doubled for stone tile.

(c) Loads in psf apply only to the floor panel system, NOT to the design of the floor joists.

(d) Capacity of floor panel systems is based on analysis of the L/360 uniform load capacity of similar systems in the 2007 TCNA's *Handbook for Ceramic Tile Installation*. Loads are guidelines only and performance level is not guaranteed.

DESIGN EXAMPLE

Assume a tile floor is desired to replace a carpet-and-pad floor in an entry foyer and the floor joists are spaced 24 inches o.c. The tiles being considered are 4x4-inches in size. The existing floor has single layer of 23/32-inch APA OSB T&G Sturd-I-Floor (SIF) with a Span Rating of 24 oc. It is anticipated that heavy objects, such as a grand piano, will be moved through the foyer after it is tiled. The owner prefers something that would qualify for "Light Commercial" (if the system could be tested). Adding more joists is not a practical option in this case. While thicker panels are better for floor stiffness, what thickness underlayment layer could be added on top of the existing floor panels to approximate a "Light Commercial" performance level and thereby minimize the risk of a tile failure?

A first impulse might be to add a layer of 23/32-inch plywood APA Sturd-I-Floor Rated 24 oc. From Table 2c of APA Technical Note, *Load-Span Tables for APA Structural-Use Panels*, Form Q225 (available free at www.apawood.org), the L/360 uniform load capacity of the existing single layer of 23/32-inch (24 oc) OSB Rated Sturd-I-Floor over joists spaced 24 inches o.c. is 130 psf. From Table C of this Technical Topic, the L/360 load capacity recommended for the Light Commercial performance is 450 psf. A second (underlayment) layer of plywood APA Sturd-I-Floor, Span Rated 24 oc will add another 143 psf for a total of 273 psf. This is greater than 250 psf, meeting the Table C recommended load capacity for "Residential" performance but not "Light Commercial."

To get to the 450 psf recommended L/360 uniform load capacity, we will need 450 – 130 = 320 psf of additional capacity. From Table 1c of Q225, this is achievable by adding a 48 oc plywood Sturd-I-Floor panel (1-1/8-inch thick) with a load capacity of 549 psf. The total L/360 uniform load capacity of these two floor panels would be 130 + 549 = 679 psf which is more than the 450 psf listed in Table C. This additional thickness, however, may cause too much elevation change in the transitions between adjoining rooms to be practical but that is a decision that the designer and owner will have to make.

For systems judged to provide marginal performance, it is suggested that an "uncoupling layer" be incorporated into the system between the panels and the tile (see TCNA's *Handbook for Ceramic Tile Installation*.) While an uncoupling layer provides little or no additional stiffness to the system, the tile performance will be enhanced by accommodating very slight movement between the tile and the underlayment layer.

APA forms E30 and Q225 can be downloaded for free from www.apawood.org. The TCNA Handbook may be purchased from Tile Council of North America, Inc., www.tileusa.com.

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