WOOD BITS

Ceramic Tile on Wood Floors

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Thanks to a wide range of factors including aesthetic versatility, easy maintenance, durability and the potential for improved indoor air quality, ceramic tile is an increasingly popular floor covering. A successful in-service tile installation requires a team effort by all parties involved: the owner or occupant, the project design professional, the floor system designer, the plan reviewer, the general contractor, the tile contractor, the framing contractor, and the framing inspector. The failure of any one of these parties to act in accordance with current industry standards, practices and installation requirements for the systems utilized can result in less than acceptable performance, up to and including a compromised safety factor. As such, the purpose of this *Wood Bits* is to review the specific roles and responsibilities of several key tile installation team members and highlight the need for coordination between them.

Roles and Responsibilities

For over a decade, the Tile Council of America *Handbook for Ceramic Tile Installation* (*TCA Handbook*) simply provided the following under "Requirements."

> *Design floor areas over which tile is to be applied to have a deflection not greater than 1/360 of the span when measured under 300 lb. concentrated load* (per ASTM International C 627, *Standard Test Method for Evaluating Ceramic Floor Tile Installation Systems Using the Robinson-Type Floor Tester*).

Similar language was provided in American National Standards Institute/Ceramic Tile Institute A108/A118/A136.1, *Specification for the Installation of Ceramic Tile* (ANSI A108).

This language could not be applied in a rational method by the floor system designer because it lacked reference to key inputs into the design process. Following a study by an ANSI committee, the deflection language in the 2005 edition of the standard—now located in A108.01 Paragraph 2.3—was modified to read as follows.

> *Floor systems, including the framing system and subfloor panels over which tile will be installed, shall be in conformance with the IRC* [International Residential Code] *for residential applications, the IBC* [International Building Code] *for commercial applications, or applicable building codes.*
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> *NOTE—The owner should communicate in writing to the project design professional and general contractor the intended use of the tile installation, in order to enable the project design professional and general contractor to make necessary allowances for the expected live load, concentrated loads, impact loads, and dead loads, including weight of the tile and setting bed. The tile installer shall not be responsible for any floor framing or subfloor installation not compliant with applicable building codes, unless the tile installer or tile contractor designs and installs the floor framing or subfloor.*

With the subsequent incorporation of this language into the 2007 *TCA Handbook*, the roles and responsibilities of the various parties involved have been significantly clarified. For the sake of simplicity, we will assume in the following explication that a professional architect or engineer has responsibility for the overall project design and focus on the owner or occupant, the project design professional, and the plan reviewer.

The Owner or Occupant

The property owner or occupant should commit to and communicate the future uses of tiled areas so the project design professional can make sure that the floor design meets the appropriate load provisions. For example, the residential uniform design live load given in Table R301.5 of the 2006 IRC is 30 pounds per square foot for "sleeping rooms" and 40 pounds per square foot for "rooms other than sleeping rooms." These values anticipate typical uses of areas including furniture and occupant traffic. However, tiled areas might be intended for uses beyond ordinary walking and resting, resulting in greater uniform loads (such as with an exercise room) or concentrated loads (such as with the installation of a grand piano) which—if communicated to the design professional—can be accounted for in the design and installation of the floor system.

Communicating the most structurally demanding uses of

building areas to the project design professional is also critical for nonresidential projects. For example, per Table 1607.1 of the 2006 IBC, floors in an office building are required to be designed for a minimum 50-pounds-per-square-foot uniform load and 2,000-pound concentrated load, whereas the first floor of a retail store is required to be designed for a minimum 100-pounds-per-square-foot uniform load and 1,000-pound concentrated load.

The Project Design Professional

The project design professional needs to account for both the live loads of tiled areas and the dead loads of the floor system, which include the weight of the specific tile method to be used. Thus, ideally, the project design professional should select the type and method of ceramic tile installation before the structural documents for the project are produced.

Based on laboratory tests and in-service performance, a variety of recommended tile installation methods are included in the *TCA Handbook*. However, because the standard test procedure given in ASTM C 627 does not include actual joists and the resulting floor deflections that occur in service, it is extremely important that floor joist systems be designed and constructed in conformance with the applicable building code.

Table 1 provides example calculations of the weight of eight common ceramic tile installation methods on wood-frame floors given in the 2007 *TCA Handbook*. Note that the component weights are for example only—the weight of actual components should be verified with the products' manufacturers. Table 2 provides example calculations of the total weight of these common installations on residential floors.

The data in Tables 1 and 2 are indicative of the fact that the commonly used 10-pounds-per-square-foot design dead load is not sufficient for many of the typical ceramic tile installation methods. Rather, based on the example calculations it appears that 20 pounds per square foot may be the

Table 1. Calculated weight of common ceramic tile installations on wood-frame floors.

TCA METHOD	TYPICAL MORTAR BED (psf)	BACKER BOARD (psf)	GYPSUM UNDER-LAYMENT (psf)	PLYWOOD UNDER-LAYMENT[2] (psf)	ASSUMED THIN-SET MORTAR BOND COAT (psf)	UNCOUPLING MEMBRANE (psf)	ASSUMED WEIGHT OF 3/8-INCH THICK CERAMIC TILE (psf)	TOTAL WEIGHT OF INSTALLATION MATERIALS (psf)
F-141 (2-inch mortar bed)	24.3[1]				1.0		4.0	29.3
F-144 (cement backer)		3[3]			2.0[4]		4.0	9
F-145 (3/4-inch mortar bed)	9.3[1]				1.0		4.0	14.3
F-147 (uncoupling membrane)				1.1 (3/8 inch)	1.5	0.2	4.0	6.8
F-148 (uncoupling membrane)					1.5	0.2	4.0	5.7
F-149 (double layer plywood)				1.8 (19/32 inch)	1.0		4.0	6.8
F-150 (double layer plywood)				1.4 (15/32 inch)[5]	1.0		4.0	6.4
RH-122[7] (1.5-inch poured gypsum)			14.4[6]		1.0		4.0	19.4

1. Wire reinforcing assumed to weigh 0.3 pounds per square foot.
2. Plywood sheathing approximate weight from 2004 *APA Panel Design Specification*.
3. Backer board assumed to be 1/2-inch thick.
4. Two layers required, top and bottom of backer board.
5. Residential application assumed.
6. Typical weight of gypsum underlayment assumed to be 1.5-inches thick.
7. Hydronic radiant heat system.

more appropriate minimum dead load value for many floor designs supporting tile installations and that some installation methods are likely to require the use of even higher design dead loads. For example, TCA method F-141, utilizing a 2-inch mortar bed, could require a design dead load of about 40 pounds per square foot depending upon the total weight of the specific framing system and tile installation method. In any case, once the proper design dead load has been determined the design professional can refer to the appropriate code for the required joist span.

Along with being required by the model building codes, the use of appropriate design dead loads can enhance the in-service success of tile installations. In general, when the proper dead loads are used for the floor system design, the resulting joist designs will have greater stiffness for the same on-center spacing and thus be more supportive to the tile and grout above. In some cases, a higher grade of lumber or deeper joists may be required to accommodate the higher dead load.

In addition, using the appropriate design dead loads for a specific construction can lower the relative stress level in the joists, thus lowering the tendency of the joists to "creep" under sustained loads. The extent of time-dependent, or creep, deflection is known to be related to the stress level in the material relative to the published values for the product. Section 3.5.2 of the 2006 American Forest & Paper Association *National Design Specification (NDS) for Wood Construction* gives specific design criteria for wooden members and wood structural panels subject to creep deflection due to the "long-term component of the design load." This could include the weight of materials (dead load) or a substantial live load that is stationary for a long period of time.

The Floor System Designer

If the floor system is to be designed by a truss manufacturer or a supplier of I-joists—as when I-joist and metal plate connected (MPC) floor trusses are utilized—the project design professional should further be certain that the designer is aware of the use of the framing area on which tile will be installed, the maximum permitted on-center joist

Table 2. Calculated total weight of residential floors with common ceramic tile installations.[1]

TCA METHOD (joist spacing, inches)	JOIST WEIGHT[2] (psf)	PLYWOOD SUBFLOOR[3] PER TCA METHOD (psf)	DRYWALL, 2.2[4], AND MISC. DEAD LOAD, 1.5[5]	TOTAL WEIGHT OF JOIST FRAMING, SUBFLOOR, DRYWALL AND MISC. DEAD LOADS	TOTAL WEIGHT OF INSTALLATION MATERIALS (psf)	TOTAL WEIGHT OF FLOOR AND CERAMIC TILE METHOD (psf)
F-141 (16)	4.5	1.8	3.7	10.0	29.3	39.3
F-144 (16)	4.5	1.8	3.7	10.0	9.0	19
F-145 (16)	4.5	2.2	3.7	10.4	14.3	24.7
F-147 (24)	3	2.2	3.7	8.9	6.8	15.7
F-148 (19.2)	3.8	2.2	3.7	9.7	5.7	15.4
F-149 (24)	3	2.2	3.7	8.9	6.8	15.7
F-150 (16)	4.5	1.8	3.7	10.0	6.4	16.4
RH-122 (16)	4.5	2.2	3.7	10.4	19.4	29.8

1. As a matter of good practice, design dead load selected by the design professional should be greater than the calculated weights of the materials to account for the range of weights possible for the same type construction and tile installation method.
2. Joists assumed to weigh 6 pounds per foot of length. Actual joist weight depends upon joist type (solid-sawn, I-joist or truss) and joist design.
3. Plywood sheathing approximate weights from 2004 *APA Panel Design Specification*.
4. Gypsum board (drywall), 1/2-inch thick, assumed to weigh 2.2 pounds per square foot.
5. Miscellaneous dead load accounts for plumbing and other small items found in the typical residential application. 1.5 pounds per square foot is used for example purposes—it does not account for water heaters and similar fixed objects.

spacing for the selected tile method, and the design dead load required for the selected ceramic tile installation and floor assembly, as well as any information from the owner or occupant as to the possibility of concentrated loads beyond those anticipated by the use category.

The floor system designer should also be aware of the current floor system deflection requirements given in ANSI A108.01 Paragraph 2.3, and all connections between joists (trusses) and floor girders should be detailed for use by the general contractor and framing contractor in order to prevent the potential for damaging differential movement between floor components.

The Plan Reviewer

For his or her part, the plan reviewer should confirm whether the floor design uses the appropriate dead load—especially, as we have seen, if a floor on which tile is to be installed is designed at a maximum allowable span (controlled by bending stress).

Consider for example a common residential tile installation using cement backer board on joists at 16 inches on center designed for 40-pounds-per-square-foot live load/10-pounds-per-square-foot dead load (50-pounds-per-square-foot total load) installed at maximum span. Referring to Table 1, the total weight of the installation materials using TCA method F-144 is 9 pounds per square foot. Referring to Table 2, the total dead load for the floor with a drywall ceiling is 19 pounds per square foot. How does the higher dead load fail to meet the requirements of the IRC and affect the safety of the floor system?

This question is easily answered by recognizing that the design dead load and live load are additive and that the sum of the two components determines the maximum span. Thus, any deficiency in the design dead load translates directly into a deficiency in the design live load. In our example, the total design load is 59 pounds per square foot—not the assumed 50 pounds per square foot used to determine maximum joist span. Because the joist span is at the previously calculated maximum, the actual design live load is 31 pounds per square foot rather than 40 pounds per square foot, as required by the code.

This is not an anomaly selected for the purpose of illustration. Based on the data presented in Table 2, the live load capacity of a common tile method installed on a 40/10-pounds-per-square-foot residential design can have up to a 22 percent deficiency. The potential deficiency is even more dramatic for a sleeping room with a 30-pounds-per-square-foot design live load: nearly 30 percent (9/30). As such, construction plans should contain a list of floor coverings for all areas along with the appropriate dead load (above the subfloor) for each floor covering system in order to prevent deficiencies in design live load due to incorrect calculation of design dead load.

The Framing Inspector

The framing inspector also plays a critical role in this team effort by being careful to note if specified framing members have been altered during construction or the installation requirements for engineered floor systems have not been followed. If so, the project design professional should review and approve a floor system repair design that restores the floor to code. For reference, the provisions for the alteration of joist products are located in the following sections of the 2006 IBC and IRC:

- solid-sawn joists—IBC Section 2308.8.2/IRC Section R502.8;
- I-joists—IBC Section 2308.8.2.1/IRC Section R502.8.2; and
- wood trusses—IBC Section 2308.8.2.1/IRC Section R502.11.3.

Conclusion

To summarize as briefly as possible: the foundation of a tile installation method is the floor framing system, the "use" of the tiled area dictates the required design live loads, and the installation method and framing dictate the required design dead loads. A failure to provide adequate framing support for the particular tile installation method employed can have detrimental effects on both the safety of the floor assembly and the in-service performance of the tile installation. As such, it is recommended that all construction plans include the floor covering and associated design dead loads for the covering in addition to the ordinary framing dead loads.

Of course the actual construction of the floor is no less important. Alterations to the framing by the various trades can result in a range of performance problems, so the framing inspector should ensure that damaged or cut members or improperly installed framing products are noted for subsequent repair. ◆

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