CERAMIC TILE INSTITUTE OF AMERICA, INC.

12061 Jefferson Blvd., Culver City, CA 90230-6219

CTIOA REPORT 82-1-9(R-87)

SUBJECT: Ceramic Tile and Wood Frame Construction Plywood, Particle Board, and Other Wood Products

A. INTRODUCTION

1. The practice of bonding tile to wood, plywood and particle board has been a questioned installation by the Ceramic Tile Institute. CTI considers it to be a high risk for failure installation.

2. With the advent of the relatively new bonding mortars such as latex, epoxy and acrylic materials and their high bond values, a number of manufacturers have advocated bonding tile directly to plywood and particle board.

3. The problem in bonding tile to wood products lies not in bonding to wood, because a tenacious bond can be achieved, but rather the tremendous movement characteristics of the wood itself.

4. All wood products are dimensionally unstable and this report will discuss the movement pepeculiarities of various wood products.

B. DISCUSSION

1. The fact wood, including plywood and particle board, expands, contracts, swells and shrinks is not a new discovery. Most

people realize that wood products move, but perhaps do not understand how much movement can take place. The movement in wood products is dependent on many factors: moisture content in wood, amount of curing time, type of wood, relative humidity if it is installed on the exterior or interior of a structure and how well it is restrained (nailed or adhered).

2. Movement in wood is measured three ways: length, width and thickness. The movement varies according to the orientation of the wood cells (grain). If a piece of wood were saturated with water, the swelling and shrinkage would be greatest In the width or perpendicular to the grain. Shrinkage in length is O.l% or l/16"shrinkage in an eight foot green stud, dried free of moisture. The average potential for expansion and shrinkage of all woods is roughly 8% in width, 4% in thickness, and .I% in length.

3. Ply-wood: The several layers of wood that go to make up a sheet of plywood are placed so that the grain, of individual layers is opposite that of the preceding layer. However, the least amount of shrinkage will take place parallel with the face sheet grain. A typical sheet of Douglas Fir plywood unrestrained will expand and contract 7/32" over its length and over 3/32" on its width. The amount of expansion and contraction will also depend on how securely the sheet of plywood is restrained nailed or otherwise fastened.

4. Particle Board: The effective shrinkage percentage of particle board is generally the same as that of plywood, averaging about .5%. Particle board can also be prone to excessive deterioration due to moisture attack on the bonding resins of the board itself. For this reason it is felt to be even more dimensionally unstable than plywood.

5. Consider the expansion and contraction characteristics of plywood and particle board compared to concrete or a wire reinforced mortar bed. The plywood or particle board has the potential of moving almost 1/4" in six (6) feet. Concrete, on the other hand, moves roughly 1/4" in fifty (50) feet. One can easily see what a comparatively unstable surface plywood or particle board represents for the bonding of ceramic tile directly to them.

6. We have dealt thus far only with the problem of shrinkage and

expansion. Deflection of the wood must also be considered. The specification for installing ceramic tile calls for deflection no greater than 1/360 of the span and included both live and dead load. This allows 1/2 inch deflection in a 15 foot span.

7. Regardless of how the plywood or particle board is glued together and nailed to the joists, each individual sheet is subject to its own movement characteristics. That movement is substantial. When factors such as expansion and contraction, load stresses, susceptibility to moisture damage, individual movement characteristics and the general dimensional instability of plywood and particle board are taken into account, the benefits of bonding to wood are far out-weighed by the potentially disastrous consequences that could result from such an installation.

8. When inspecting installations where tile is bonded directly to plywood, the biggest problem is with the grout. As stated in the introduction, there are products on the market that will provide a tenacious bond of the tile to the wood. If the grout is a portland cement type it cracks, which is unsightly and causes grit and sand on the tile surfaces. Cleaning the grit up is often done with a vacuum which will then pull all of the grout out of the joints. If the grout is a resin grout, such as epoxy, hairline cracks will develop around the tile which again is unsightly and objectionable to the user. Such cracks are caused by the expansion and contraction of the plywood to which the tile is bonded.

9. <u>Other Construction Trades</u>

    a. The tile trade is not the only trade concerned about plywood backing. The following from the plastering trade:

PLYWOOD SHOULD BE PROTECTED FROM RAIN

Stacks of plywood at job sites - often are exposed to driving rains. In some instances, covers provided are blown loose allowing rain water to soak the plywood.

The same thing is true of plywood sheathing which has been applied during dry weather and is exposed to rain. Moisture causes plywood to expand from its original dimension.

Plywood can appear to be dry, but it's a good idea to use a moisture meter to make certain it is dry. When it is wet and is applied to a wall, for instance, it is covered with building paper and lath, and plaster is applied.

The surfaces may appear to be excellent, -with little or no cracking - for the first few weeks. Then cracks begin to appear. This reflects development of stresses that are greater in force than the ability of the plaster to resist. These stresses then cause cracking at weak planes in the stucco membrane.

The stresses may develop as the plywood dries and contracts. There have been instances where plywood has been checked during dry weather only to be found to be wet - the moisture having been present at the time of application of the plywood.

When it rains, plywood stocks should be kept dry. If sheathing has been applied, it should be covered to prevent problems from developing later.

C. CONCLUSION

1. Tile is a brittle material and for that reason it must have a sound, dimensionally stable surface upon which to be bonded.

2. The movement potential of plywood and particle board is too much for use with ceramic tile.

3. The required thickness for a double thick wood floor installation, (F 142-82 and F 143-82) in the 1982 handbook for the Installation of Ceramic Tile, is a sufficient thickness for a wire reinforced mortar bed or for the Wonder-Board system, F 144-82, to be installed. Each would provide a dimensionally stable substrate and would be infinitely more serviceable and compatible with ceramic tile.

4. A more comprehensive report is contained in appendix to Field Report CTI 82-1-9.

-EDITORIAL COMMENT-

The Ceramic Tile Institute expresses a big thank you to Mr. Manny Fleishman, CTC, for his research and the technical information contained in this report.

1. That wood shrinks and swells is not new, everyone agrees. The amount of movement varies according to the orientation of the wood cells and is measured three ways; length, width and thickness.

2. Saturate a piece of wood and the swelling and shrinkage is mainly in the width and thickness not in its length. Total shrinkage of wood in length is usually about . 1 %. Example, an 8' stud installed green (wet) and allowed to dry would shrink only about 1/16".

3. Shrinkage in width and thickness, on the other hand, is significant. It is reasonable to think of wood as having roughly.8%'shrinkage in width and.4% shrinkage in thickness. This is an average percentage shrinkage for all woods.

4. To understand the curing process of wood and the dramatic shrinkage wood is susceptible to, one must grasp how much moisture wood contains as free and bound water A living tree's liquid content is called sap. Sap is primarily water but contains minerals and other elements as well. To visualize the moisture content in a live tree, imagine a wet sponge When a tree is fully saturated with water or sap, it would be like the sponge. Squeezing the sponge will force most of the moisture out. You can do the same thing with a wet piece of wood. By hitting that piece of wood you can force some of the free water out.

5. On wood, the comparable situation of a partially squeezed sponge is called Fiber Saturation E2iLi.t FSP). In this state the cells of the wood are emptied of free water but the Walls of the cells are still saturated and weak. Only when the water cures out of the cell -walls does the wood begin to shrink and grow stronger. The water remaining in the cell wall is called bound water. How much of this bound water dissipates will depend on the relative humidity of the air.

6. Relative Humidity is the ratio of the amount of moisture in the air at a certain temperature to the amount it would be able to hold at that temperature. Example, at 70' (100% RH) a cubic foot of air could hold 8 grains. If it held only 4 grains the reading would be 5C)% relative humidity.

7. The moisture content of wood is measured as the ratio of the weight of water in a given piece of wood to the weight of the wood when it is completely dry. Example; a piece of wood weighs 30 pounds. After drying in an oven it weighs only 25 pounds, 5 pounds of water was evaporated. The moisture content would be 5/25 = .20 or 20% moisture content. If that same piece of wood weighed 50 pounds, the moisture content would be 25/25 or 100% moisture content.

8. Wood always responds to changes in atmospheric humidity and loses bound water as the relative humidity drops and regains bound water as the relative humidity increases. For a given relative humidity level, a balance is eventually reached at which time the wood is no longer gaining or losing moisture. When this balance is established the amount of bound water In a piece of wood is called equilibrium moisture content (F-MC). The relationship between bound water in wood and the relative humidity is the basis of expansion and contraction.

9. Shrinkage in wood can be calculated by a formula and anyone wanting to study this is referred to "Understanding Wood" by R. Bruce Hoadley. The Tauton Press, Inc. - 52 Church Hill Road - P.O. Box 355, Newton, Conn. 06470. The formula applied to a 12" wide piece of Douglas Fir which is kept outside a structure, and drying, changes from 90% moisture content to 50% moisture content and shrinks to 11 5/8" wide. If the same piece of wood is brought into the structure, with a lower relative humidity, it shrinks more.

10. Now we come to plywood. Plywood typically is composed of a number of thin layers of wood glued together with the grain direction of adjacent layers perpendicular to one another.

11. In the manufacture of plywood, the plies can be made very accurately in thickness and also dried to a low moisture content. Because of the cross ply construction, most properties are approximately equalized across the surface of the panel. However, the sheet is dominated by the greater strength of wood parallel to the grain of the face ply.

12. Douglas Fir has an average width shrinkage of about 7.7% and a shrinkage in length of about. 1%. When Douglas Fir is made into plywood, having an equal amount of wood in both directions, the panel has identical shrinkage levels of about .5%.

13. When the shrinkage formula is applied to Douglas Fir plywood, in a situation where the relative humidity is reduced from 90% to 40%, an 8 foot long sheet of plywood shrinks 7/32 inch. This is for an

unrestrained 4 foot by 8 foot sheet of plywood which will expand and shrink 7/32 inch in length and over 3/32 inch in width. The length and width at any given time will depend on the relative humidity at the place where tile plywood is located. The above amount of expansion and contraction will also depend on how securely the sheet is nailed (restrained) or otherwise fastened. (For those wanting the formula for estimating the shrinkage in relation to water loss, it is attached to this report).

14. The American Plywood Association has an ICBO research report number 1952 for application of plywood to receive tile on shower walls. Plywood is to be exterior type C (plugged) face grade or better painted with 2 coats of varnish on the face where the tile would be applied and treated with an exterior primer or aluminum paint to seal all edges. A solid coat of organic adhesive can be applied to the plywood instead of the two coats of varnish.

15. Prior to Installation of the plywood, all edges shall be caulked with non-hardening waterproof caulking compound compatible with the adhesives or caulked with tile adhesive. The caulking is applied by laying a bead on the blocking and pushing the panel into a butt joint allowing a 1/16 inch space between sheets. The plywood is attached to the supporting members with 6 penny nails spaced 6 inches on center. 2 X 4 blocking is required at ends of the panel of plywood.

16. We know that plywood has a tendency to shrink and expand. If left unrestrained, it would limit itself to about 7/32 inch in 8 feet. What we want to know is what happens to the plywood in a structural application. When it is nailed to the floor, the nails would have a restraining influence on the shrinkage and expansion. However, the moving weight of people or objects on the floor would loosen the nails and further expose the plywood edges.

17. Due to the lack of continuity in the plywood, movement will occur at those points. Also, relative humidity is very different in the various parts of the house and in different parts of the country. Example: a first level subfloor, which is exposed on the bottom to outside weather conditions, compared to second level subfloor which is completely closed. Another example would be the difference in relative humidity between a geographical area such as Los Angeles compared to Palm Springs.

18. Plywood is usually not treated and installed properly as required in the ICBO research report 1952 as listed earlier. The ICBO research report does not call for sealing the underside of the plywood. Besides,

there is no recommendation for its use on floors. The movement of the plywood would have a tendency to weaken the bond between the wood and the tile. If tile is installed over a series of plywood sheets and after a period of time has elapsed, one could read the sheets of plywood by the cracks in the tile.

19. Plywood is not a stable material and to directly install tile over it is an **invitation** for failure.

20. Particle board: The effective shrinkage percentage of particle board is in generally the same range as that of plywood, averaging about .5%. Particle board is not a stable substrate and is not suitable for bonding tile directly to it.

21. There is no question that cabinets fastened to the wall in back and to the floor in front will tend to drop in front because of the shrinkage of the floor. We always thought that when the cabinet man sets the cabinets he puts wedges in front on the floor to level front to back and the linoleum man removes the wedges and the cabinet drops. The above is true and also the wood in the floor shrinks and the wood in the cabinet shrinks.

22. The tile on the deck and the splash behind drop with the shrinkage. The front of the counter drops more than the back, so a separation between the deck and the splash takes place. Further, if the V-cap is not installed correctly, it will crack.

Submitted by Mr. Manny Fleishman, CTC,
Trustee of Ceramic Tile Institute and Executive Secretary of the
Associated Tile Contractors of Southern California

APPENDIX A

FORMULA FOR ESTIMATING SHRINKAGE OF PLYWOOD

Softwoods	**Tangential**	**Radial**	**T/R**
Baldcypress	6.2	3.8	1.6
Cedar, Alaska	6.0	2.8	2.1
Cedar, Eastern Red	4.7	3.1	1.5
Cedar, Incense	5.2	3.3	1.6
Cedar, Northern White	4.9	2.2	2.2

Cedar, Western Red	5.0	2.4	2.1
Douglas Fir (Coastal)	7.8	5.0	1.6
Douglas Fir (Inland)	7.6	4.1	1.9
Fir, Balsam	6.9	2.9	2.4
Fir, White	7.1	3.2	2.2
Hemlock, Eastern	6.8	3.0	2.3
Hemlock, Western	7.9	4.3	1.8
Larch, Western	9.1	4.5	2.0
Pine, Eastern White	6.1	2.1	2.9
Pine, Loblolly	7.4	4.8	1.5
Pine, Lodgepole	6.7	4.3	1.6