ROOF DECKS, A to Z

Part 3: Structural Clay Tile and Plywood

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This is the third in a series of articles briefly examining various deck types. Among the numerous considerations when selecting a roof system, the type of decking is among the most important. With the variety of decks to be encountered (both new and old), it is incumbent upon roofing experts to be the authorities on these matters. This article will explore features of 1) structural clay tile and 2) plywood.

STRUCTURAL CLAY TILE

Structural clay tile was used extensively throughout the United States when cities were rebuilt following disastrous fires that occurred in the late 1800s. During that era, concrete production was in its infancy and did not even exist in some areas; steel was the dominant type of construction, and structural clay tile was the primary material used for fireproofing buildings, including floor and roof decks.

Book tile is a form of structural clay tile that was popular during the late 1800s and early 1900s. The name is descriptive of the tile unit itself, which has the general appearance of a closed book, as shown in *Figure 1*. Book tile units were manufactured with concave and convex edges so that they would interlock when laid into position. This shape allowed units to abut one another. A common book tile unit dimension was 3 in thick by 12 in wide, supplied in lengths varying from 11 to 24 in. This thickness weighs approximately 18 pounds per sq ft.

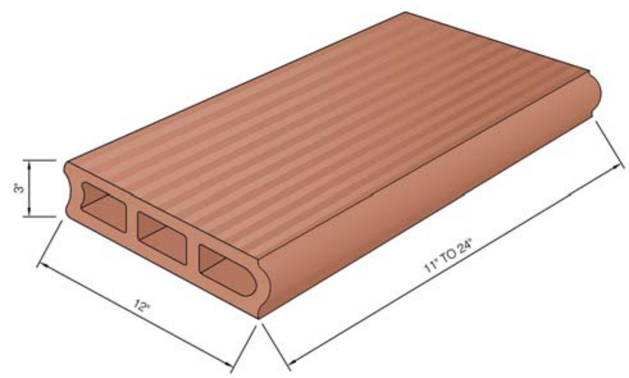

Figure 1 – With the general appearance of a closed book, these units were popular during the late 1800s and early 1900s.

The term "tile," as it relates to structural clay tile roof decks, is often paired with descriptors such as 1) hollow, 2) building, and 3) book, in generic reference to the material. These modular units first gained favor for use in both structural walls and non-load-bearing partitions due to their fairly low cost, ease of installation, and favorable performance during fire exposure. The units were laid in bedding mortar (similar to their next-of-kin, brick masonry units) with head and bed joints struck full of mortar. They could also be formed from the underside and integrated into cast-in-place concrete on concrete structures

Figure 2 – Structural clay tile units integrated into cast-in-place concrete on a concrete structure.

Figure 4 – The common arrangement of tiles nested onto sloped steel framing. Additional mortar would be struck into joints from the roof (top) side.

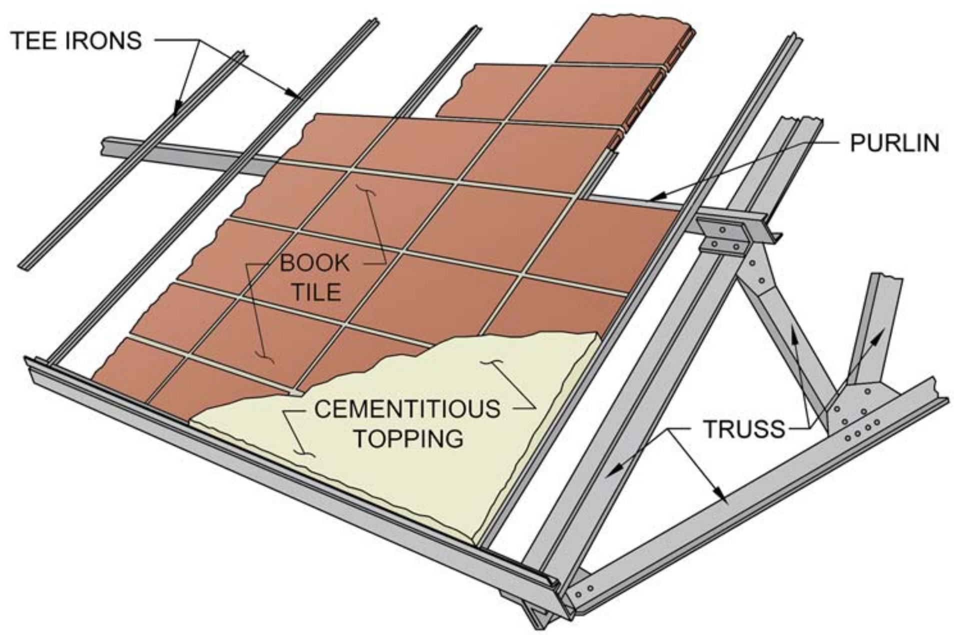

Figure 3 – Clay tile units mortared into place as fire-safing over structural steel in an old attic.

(*Figure 2*). Most multistory buildings of decades past having this type of roof deck might also have this arrangement as the floor-to-floor construction.

The manufacturing process for structural clay tile typically involved extrusion through a die with individual units cut off at prescribed lengths and then fired in a kiln. In the attics of buildings constructed in the early 1900s, these units were used widely on sloped planes as the roof deck and elsewhere on exposed structural steel as fire safing (*Figure 3*).

Book tile units were used for both steep and flat roof decks and were supported on inverted steel tees as shown in *Figure 4*. Space between the unit ends and the tee stems was filled with mortar. Tiles were situated over steel purlins spaced over rafters, joists, and trusses. The spaced purlin scheme allowed for quick and easy installation of a deck that was fireproof, and constructing it was not dependent on weather. Structural clay tile units were simply nested within the modules established by the tees, with fastening limited to bedding mortar as the pieces were set with additional mortar struck into the joints from the roof side in order to key the individual pieces together. The top and bottom surfaces of tiles usually had a rough texture so that a mortar-topping slab could be bonded on the top and a plaster finish adhered to the bottom side, if desired.

On some vintage buildings with pitched roofs, structural clay tile was considered an acceptable substrate for slate, copper, or roofing tile (*Figure 5*). Other variations could be structural tiles and a concrete slurry topping with integrated wood nailers or battens across the roof plane to which slates or tile would be anchored. These same vintage structures might also have tiles cast into the inboard face of parapets (*Figure 6*).

On some lower slope assemblies, the structural tile was used as substrate for a nailable concrete slurry. The "green" topping was satisfactory during the original construction in terms of direct nailing; however, that same slurry topping today, after 60 or more years of service, will most likely not be accepting of nailing attempts. Consequently, attachment of the roof components will need to be carefully reviewed. Possibilities may include a concealed batten arrangement to the steel framing or a

Figure 5 – Tile covering on clay tile deck on a vintage pitched roof.

Figure 6 – Tiles cast into the inboard face of a parapet.

Figure 7 – Attachment of new plywood cladding using toggle bolts.

Figure 8 – Delamination and spalling of mortar topping course.

through-bolted batten system to the tiles. Trial installation of anchors should be performed to determine feasibility of the proposed attachment method to minimize spalling.

Low-slope clay tile decks are best suited for adhered or ballasted membrane systems. Mechanical fastening is generally discouraged because drilling and attachment may generate spalls and cracking of the tile. On pitched framing, reroofing can be carried out by attaching wood sheathing over the existing deck using toggle bolts (*Figure 7*) fitted with stress plates. Low-rise foam adhesive can also be used to embellish this securement, but dust and any other parting agent would need to be removed for proper bonding.

Structural clay tile decks are susceptible to deterioration as well as corrosion of the embedded steel components. Failure of the tees can cause cracking in the tile units, which can allow leakage and further deterioration of the steel components. There is also potential for cracking of the top shell of the units if care is not exercised during removal and installation of the roof system. Less serious but equally important issues are delamination and spalling of the mortar topping from the top surface of tile units (*Figure 8*). Hammer-sounding the surface–or removing a test square before proceeding with full-scale tear-off–is a prudent step.

Figure 9 – Crickets/saddles can be crafted with plywood to effectively divert water.

Figure 10 – Permanent distortion from insufficient fastening along edges, likely aggravated by substandard attic ventilation.

PLYWOOD

Plywood apparently has several fathers. We are told that the modern version of plywood was invented circa 1850 by Emmanuel Nobel (father of Alfred Nobel, the famous inventor of dynamite and founder of the Nobel Prize). He apparently recognized that several thinner layers of wood bonded together would be stronger that one single, thick layer of wood; he is credited as well with inventing the lathe used in plywood production. Meanwhile, the APA (previously the American Plywood Association, but now the Engineered Wood Association) markets a publication entitled *The Plywood Age*, first published in 1955 to commemorate the "first 50 years of the industry." This would suggest a beginning date near the dawn of the 20th century.

Elsewhere, we find that plywood was

invented during World War II, where it was primarily used to build PT boats and landing craft for the military. Only after the war did residential construction begin to use this product. Yet a Google search reveals that it was the Egyptians, around 3500 BC, who first thought of sticking several thinner layers of wood together to make one thick layer.

In any event, plywood is perhaps the purest example of a "nailable" roof deck. It shares this attribute with oriented strand board (OSB), which has enjoyed great popularity over the past two decades as a substitute for plywood. But OSB is different enough to be considered in a separate article in this series. Meanwhile, although enjoying most of the residential roof deck market, plywood is certainly not limited to that domain. Indeed, western states widely use this substrate for low-slope assemblies, as it is compatible with virtually any type of roof covering. Even crickets/saddles can be crafted with plywood sheathing to effectively divert water (*Figure 9*).

Wood products respond to variations in temperature and moisture content by changes in dimension. If no gap is provided between sheets, heat buildup will expand the plywood. Edges cannot go down because of the framing members; they cannot expand laterally because of neighboring sheets; consequently, the only path for expansion is upward. This often results in permanent thermal distortion (*Figure 10*), manifested as deck buckling (*Figure 11*). Aside from attachment deviations, poor attic ventilation is the single greatest cause of surface undulations. With sufficient plenum/attic ventilation and correct span/thickness relationships, virtually all undulations can be avoided.

Formed metal "H-clips" (also called panel edge clips) should be used in most instances of plywood deck construction (*Figure 12*). Contrary to widely held beliefs, these clips are not intended to be the spacing element between panels, although they provide that incidental function. Instead, clips reduce the effective spacing of framing members; they make the panels stiffer by distributing loads to adjacent sheets, much in the same manner as tongue-and-groove edges do for wood planks.

As with many other deck types, plywood is intolerant of repeated wetting as well as prolonged exposure to singular wetting events. Procrastination in facilitating roof repairs can rapidly induce wood rot with attendant loss of load-carrying properties.

Figure 11 – Deck buckling from substandard ventilation, improper attachment along panel edges, or failure to provide space between sheets.

Figure 12 – H-clips (panel edge clips) reduce the effective spacing of framing members, better distributing loads to adjacent panels.

Load-span relationships (available in design tables and related literature) should be faithfully observed, as should fastening requirements.

Further, as to the notion of load capacity, there has been experimentation with plywood to make it less combustible. Years ago, fire-retardant treated (FRT) plywood found a market in construction of multifamily dwellings where sprinklers were considered cost-prohibitive and masonry firewalls emerging through the roof were undesirable. Where a flame spread rating of 75 or less is required by code, most lumber and plywood must be treated or coated with water-borne salts or fire-retardant chemicals. First-generation FRT products (apparently certain formulations only) experienced degradation from elevated attic temperature and humidity (*Figure 13*). A behavior termed “acid hydrolysis” could be generated at temperatures of about 130°F–a fairly common environment in the attics of pitched roofs. When hydrolysis was well under way, a sharp reduction in loading capacity could be experienced, sometimes with no outwardly visible distress signal. The remediation of FRT plywood decks behaving badly was a multibillion-dollar cleanup industry from years past.

Figure 13 – Some first-generation FRT products experienced degradation from elevated attic temperature and humidity.

SUMMARY REMARKS

As may be seen, when selecting a reroof system, there is far more to evaluate beyond the mere type of insulation and membrane covering. When there is any doubt regarding the type of deck being encountered or the loading capacity, a structural engineer should be contacted to assist. On vintage or obscure decks, span tables may not be available. In that event, in-situ load testing can be performed to evaluate actual loading capacity.

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