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THE LOSS OF BOND BETWEEN ROOF TILES AND MORTAR ON PITCHED ROOFS

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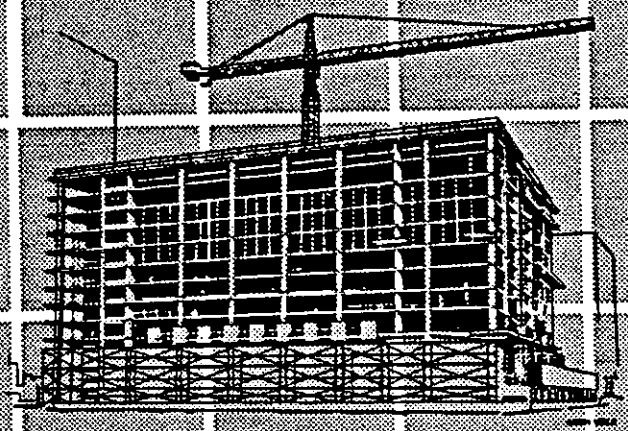

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1994

THE LOSS of BOND BETWEEN ROOF TILES and MORTAR

on PITCHED ROOFS - PHASE I

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I. EXECUTIVE SUMMARY

This study is the first phase of a much wider proposed study. The present work represents an effort to identify and record such documentation and other learned opinion of fact as exists on the issue of bond/loss of bond between roof tiles and bedding mortar.

This study, classified contractually as a literature search, includes extensive correspondence with industry and associations representing both manufacturers and contractors. Appropriate research activities have been identified and such information as is released has been reported herein. Contact with cognizant regulatory offices also has been made.

A brief analysis of the literature has been included in this report in the interest of reflecting the general content of the search findings. It is manifestly clear that the bulk of the references identified originated in the "post-Andrew" period. By no means does this infer that the "pre-Andrew" references are inferior or lesser in importance, just earlier. On the other hand, the post-Andrew research and development and regulatory stiffening is of great import in that it reflects new knowledge as well as re-emphasis of important related matters.

II. FINDINGS, CONCLUSIONS, and RECOMMENDATIONS

FINDINGS - There is a limited amount of definitive material on the subject. This is likely due to the fact that routine large scale use of the mortar set installation method is confined to the South Florida area. Available documentation dealing with the subject per se has been generated by the user oriented bodies: namely, local regulatory agencies; manufacturer and contractor associations; and, individual product manufacturers.

During the course of this study, considerable work was done within regulatory agency committees and code re-writing bodies; individual product manufacturing organizations; and, manufacturer and contractor associations. Although none readily acknowledged blame for construction weaknesses revealed by Andrew, all have

worked diligently to improve roofing performance.

There is a small amount of definitive material addressing closely related issues. This is in the form of governmental standards, well structured objective research, and information on products of interest.

CONCLUSIONS - Effective performance of tile roofing systems depends on a combination of appropriate materials and proper installation. Even given suitable materials, opportunities abound for installation to go awry. There is room to improve products for such installations, but there is much to be done to improve installation. Defective installation procedures applied to the best procedures will result in eventual breakdown of any roofing system. Installation procedures will only be improved through a combination of improved contractor knowledge, effective work force supervision, and vigilant inspection of systems during installation. Failure to effect better workforce performance at the point of installation in the near future may be justification to deny mortar set as an approved method of installation.

RECOMMENDATIONS - Further work should be undertaken to:

A. Follow up on current and recent research to add new information to that provided herein;

B. Develop written educational material for designers and roofing contractors to be distributed on a statewide basis;

C. Define minimal regulatory provisions for inclusion in all controlling building codes in the state.

D. Develop improved testing procedures for clay and concrete roof tiles installed with the mortar set method;

III. PROJECTION

Proper follow-up on the work authorized under this study has the potential to catalyze significant improvement in job site conduct of installation procedures. This could be accomplished with cooperation of licensing agencies and contractor associations.

IV. MAIN DISCUSSION

IV. A. Background and Objectives

Clay and concrete tile is widely used as a roofing material in South Florida residential and light commercial construction. A common installation technique for such tiles in this region is known variously as the mud-on or mortar-set system. Tile roofing is regulated as to where and how these installations can be made, but the damage from Hurricane Andrew underscored problems with this technique that had been brewing for some years.

Since the 1920's, many tile roofs have been installed with success using the mortar set system. Loose tile does not seem to have been a problem in earlier times and most tile roofs would last as long as the organic underlayments, generally 25 to 30 years. In recent years it was evident that problems existed with clay and concrete tile bonding to mortar in newer installations. Many tile roofs appearing tight at the time of installation were discovered later to have suffered a loss of bond between the tile and setting mortar. Often, this was occurring shortly after installation.

The problem had been identified prior to Hurricane Andrew and many segments of the construction industry were experiencing woes arising from this phenomenon. These ranged from the simple issuance of code violations to lawsuits for large sums of money.

The Dade County Board of Rules and Appeals began addressing loose roof tile in 1987, and its Roofing Committee has been working with industry since then on the problem. Respected and licensed roofers had noted the loss of bond problem as being prevalent even in tight quality control situations. In the fall of 1991, the Board agreed on certain material and procedural changes that would provide more satisfactory installations in the short term while industry research and product improvement could be carried out.[1]

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[1] Pistorino, John *"Roof Tile Recommendations,"* letter to Dade County Board of Rules and Appeals Roofing Committee, Pistorino & Alam, Miami, January 1993.

Hurricane Andrew arrived as a small sized, rapidly moving, and dry hurricane. Although not the strongest hurricane ever to hit mainland U.S., Andrew is to date the most destructive and costliest hurricane to have impacted the continental coastline.

The effect of Andrew on construction of all types was analyzed extensively after the storm. Roofing in general, was treated quite thoroughly by various authors. Some aspects were rigorously evaluated, especially the supporting structure and the attachment of sheathing thereto as a function of old and new wind loading standards.

Less tractable due to the paucity of standards for manufacturing and performance were the various roof coverings and methods of attachment. Among published writings on these subjects, discussions of traditional mortar set installation methods for attaching roof tiles exhibited minimal definitive information.

Visual assessments of the Andrew damage led to numerous reports of the high level of economic loss attributable to roof covering failure, and notice of roof tile separation from the mortar bedding which in most cases clung to underlayments.[2] [3] The loss of bonding and indications of ineffective installation were also noted by Dave Siple in an article summarizing roof failure modes during Andrew.[4]

It was clear that while many observers recognized the failure phenomenon and apparent causes, few had spoken definitively about the physical specifics of the problem. The objective of this study then, was to identify literature relevant to the described loss of tile bond to mortar and to set the stage for knowledge growth.

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[2] Huff, Sam *"Hurricane Andrew, Personal and Professional Impressions,"* Interface Newsletters - EXTRA, the Roof Consultants Institute, Raleigh, October 1992, 2-4.

[3] Smith, Thomas L. "Hurricane Andrew: A Preliminary Assessment," Professional Roofing, October 1992, 58.

[4] Siple, Dave *"Residential Roof Failures,"* Interface Newsletters, The Roof Consultants Institute, Raleigh, January 1993, 3-4.

IV. B. Approach, Technique and Scope

The State of Florida Building Construction Industry Advisory Committee commissioned the Department of Construction Management at Florida International University to undertake a study intended to increase understanding and assist in correction of the loss of bond between roof tile and mortar.

The study was intended to establish a base line of information sources from which further and more analytical work could progress. The study as represented by this report attempted to identify documentation bearing on the issue of roof tile installation with a mortar set system and the several products involved. This identification and compilation of documents represents the literature search called for by initially funded work.

The search advanced on three fronts simultaneously. They included: the conventional approach of screening library files and data banks, identification and contact of relevant product manufacturers, and solicitation of help from individuals and organizations thought to have knowledge of the issue.

i. The conventional approach of screening library files and data banks for potential sources yielded the following:

a. 33 periodicals whose scope incude roofing:

Architects' Journal Builder/Architect
Building Research and Information
Building and Environment Buildings
Construction Bouletin Construction
Construction Methods and Equipment
Constructin Contracting · Constructor
Florida Contractor Florida Constructor
Florida Builder Industrialization Forum
Building, Design and Construction
Professional Builder and Apartment Business
Florida Architect Custom Builder ENR
Science Civil Engineering
Journal of Research of the NIST

Plant Engineering Custom Builder
Journal of Testing and Evaluation
Progressive Architecture Architectural Record
Business Week Consumer's Magazine
Professional Roofing Roofing Materials Guide
Construction Specifier Roofing Siding Insulation
--Screened and reviewed per Appendix entries--

b. A = National Institute of Standards and Technology,
Author Index - Florida International
109 entries, 11 reviewed

c. American National Standards Institute,
Author Index - Florida International
52 entries, 2 reviewed
Keyword Index - Keyword Index
56 entries, 1 reviewed

d. American Institute of Architects,
Author Index - Florida International
48 entries, 8 reviewed
Keyword Index - Florida International
48 entries, 5 reviewed

e. A=American Society of Heating, Refrigeration, and Air Conditioning Engineers
Author Index - Florida International
17 entries, 5 reviewed

f. K=Roofing
Keyword Index - Applied Science/Technology
54 entries, 12 reviewed

g. K=Roofing
Keyword Index - Florida International
47 entries, 14 reviewed

h. K=Roofing
Keyword Index - Academic (1988-date)
44 entries, 4 reviewed

i. K=Hurricane
Keyword Index - Applied Science/Technology
118 entries, 12 reviewed

k. K=Hurricane and Construction
Keyword Index - Academic (1988-date)
27 entries, 5 reviewed

l. K=Mortar
Keyword Index - Applied Science/Technology
55 entries, 19 reviewed

m. K=Mortar
Keyword Index - Florida International
12 entries, 6 reviewed

n. K=Masonry Mortar
Keyword Index - Florida International
1 entry, 1 reviewed

o. K=Cement
Keyword Index - Florida International
130 entries, 0 reviewed

p. K=Masonry Cement
Keyword Index - University of Florida
14 entries, 0 reviewed

q. K=Roofing
Keyword Index - University of Florida
152 entries, 33 reviewed

r. K=Hurricane
Keyword Index - University of Florida
334 entries, 8 reviewed

s. K=Hurricane
Keyword Index - Florida International
54 entries, 7 reviewed

t. Carl Database Services

Current Article Index - "Roofing,Siding,Insulation"
26 entries, 26 reviewed

Current Article Index - "Construction Specifier"
14 entries, 14 reviewed

ii./iii. Identification and contact of relevant manufacturers developed from initial publication screening and from associations whose organizational interest is roofing and tile roofing. Lists were established, dialogue initiated and material solicited. Contact was made by phone, letters and personal interviews. The information gathered from those agencies and persons who responded to our requests was reviewed, classified, and analyzed.

Appendix A includes all the agencies and persons contacted, these are exhibited in the following tables:

- Table 1 contains an alphabetical printout of all roofing tile manufacturers contacted, including their addresses and/or telephone numbers.

- Table 2 contains an alphabetical printout of all concrete products (mortar) manufacturers contacted, including their addresses and/or telephone numbers.

- Table 3 contains an alphabetical printout of all organizations contacted, including their addresses and/or telephone numbers.

- Table 4 contains an alphabetical printout of all persons contacted, including their addresses and/or telephone numbers.

Appendix B contains a brief summary of the information received from agencies and persons who responded to our requests. This is shown in the following tables:

- Table 1 contains an alphabetical printout of all roofing tile manufacturers who sent information, the type of roofing tile produced, and the attachment method they recommend.

- Table 2 contains an alphabetical printout of all concrete product (mortar) manufacturers who sent information.

- Table 3 contains an alphabetical printout of all organizations who responded and the information they provided.

- Table 4 contains an alphabetical printout of all persons who responded and the information they provided.

Appendix C is a bibliography of references and products.

Appendix D is an annotated bibliography of all reviewed publications of relevance, including regulatory documents and product literature.

Appendix E is an annotated bibliography of the post-Andrew Metro-Dade County Protocols for product testing, approval, and installation of mortar set systems and components.

Appendix F is a listing of companies and related products approved by Metro-Dade County as of 22 July 1994.

IV. C. Analysis.

i. Tiles for Roofing.

Tile roofs have been in existence for hundreds of years and are regarded by many as the ultimate in roofing. Although this is largely personal opinion, tile is durable and has a characteristic beauty and richness. While such roofs will withstand severe weather and high winds well if properly secured, both cement or clay tiles are susceptible to breakage from large hail stones or thrown rocks.[5]

Tile can be manufactured from natural rock, cement, clay, and from metals or plastics. Many tiles have material fillers added for extra bulk and strength. Some fillers in common use are ground-up seashells, ground walnut shells, mineral fibers, and organic fibers. Other fillers can be used to impart special qualities. For example, perlite, an expanded volcanic stone, when added, will lighten the tile and give it insulative value. Liquid plastic resins, when added, will improve the internal bond strength and help prevent breakage.[6]

The National Tile Roofing Manufacturers Association (NTRMA) estimated in 1989 that approximately 10 millon squares of roof tile are sold in the United States annually. Of that amount, at least two thirds is concrete. Concrete roof tile is the most widely used tile in the world today because of its availability and cost. On the other hand, clay tile is the oldest roof tile in the world and is known for its endurance and use to achieve a desired aesthetic. Both are good roofing products selling to different markets.[7]

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[5] McElroy, William C. *"Roof Builder's Handbook,"* PTR Prentice Hall, Englewood Cliffs, 1993, 365-366.

[6] McElroy, op.cit. 367.

[7] Black, Clyde & Eichelberger, Robert & Florida Forum *"Tile: Clay vs. Concrete,"* Florida Forum, August 1989, 12-18.

Clay Tile Roofing.

Tiles are made from a mixture of clay, shale, and grog (reground fired clay). That mixture is reduced in moisture level, formed into profiles, cut to size, and fired. Under high temperature the clay vitrifies and a ceramic sort of material results, very similar to that of any clay roof that you might find dating back to the Graeco-Roman period. The process is basically the same now as then and the product nearly indestructible.[8]

Different clays can yield different colorations. Natural clay color is permanent throughout the tile. Also, clay tiles, just as concrete, can be colored with the addition of specially formulated colorants. Some less expensive clay tile is painted or glazed after demolding. This paint is a surface color and may not be as long-lasting or as damage-proof as the solid through coloring. The applied glaze can be matt, semi-gloss, or high-gloss finish.[9]

While both clay and concrete tiles have a Class A fire rating, use similar installation systems, and are lifetime products (fifty years warranty is common), there are some advantages that clay tiles have over concrete:

- Clay is a more dense product. Clay is fired quickly to roughly a 700 pound break strength, while concrete tiles will break after 28 days of curing at 500 pounds plus.

- Clay is lighter in weight than concrete and is almost twice as strong. This permits clay barrels to be one half inch thick. Concrete barrel tiles that thick will have comparatively low strength and break easily.

- Clay tends to mildew at a much lesser rate due to

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[8] Black, Eichelberger, Florida Forum op. cit. 12-13.

[9] Black, Eichelberger, Florida Forum op.cit., 13-14.

its lower water absorption and material density.[10]

An ASTM standard specification for clay roof tiles describes physical requirements that clay tiles should meet to provide a weather-resistant product. It was updated in 1992 in a manner insignificant to this present study. Nevertheless, the basic content of the standard is relevant and manufacturers should be guided accordingly.[11]

The NRCA classifies clay tiles as follows:

1. Roll Tile (Figure 1)
   A. Pan and cover shape (barrel/mission)
   B. S Shape (Spanish S).

2. Flat Tile (Figure 2)
   A. Flat shingle shape
   B. Flat ribbed shape (with interlocking features).

3. Ridge terminal tiles of Various Shapes (Figure 3)
   A. Ridge tile.
   B. Hip tile.
   C. Closed-ridge end tiles.
   D. Hipped terminal tiles.
   F. Gable terminal tiles.[12]

Concrete Tile Roofing.

Concrete roof tiles are not as old as clay, but handmade concrete slates were used in Greece and Rome for several hundred

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[10] Black, Eichelberger, Florida Forum op. cit., 16-17.

[11] ASTM "C 1167-92, Standard Specification for Clay Roof Tiles," Annual Book of ASTM Standards, American Society for Testing and Materials, Philadelphia, 1992, 1-5.

[12] NRCA "The NRCA Steep Roofing Manual," National Roofing Contractors Association, Rosemont, Illinois, 1990, 42-43.

years. The process of extruding concrete roof tile on an automated production line was developed in Europe in the 1920's. Still essentially the same, that primitive process has been refined over the years to yield uniform and consistently reliable products.

Concrete tile is composed of portland cement, sand, and water, in varying proportions. The mix is extruded under high pressure to form the tile product. Unlike clay, concrete tile does not require high temperature firing (1,600-,1800 degrees F). It is cured at 110 degrees F to remove residual moisture. Subsequent palletizing and stacking for seven to fourteen days permits final curing.

Concrete does not have the strong natural colors of clay. Top slurry or mix additives are frequently used to obtain desired effects.[13]

Basic differences and advantages of concrete tiles over clay tiles include:

- The use of inexhaustible and very competitively priced source of raw materials, meaning: silica sand, portland cement, water and iron oxide.

- During the manufacturing process, machines can run at higher speeds, because concrete does not need to be fired at higher temperatures, therefore energy costs are small compared to those required by clay.[14]

ASTM is currently developing a standard specification for concrete roof tiles.

The NRCA classifies concrete tiles in the following categories:

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[13] Black, Eichelberger, Florida Forum op. cit., 13.

[14] Black, Eichelberger, Florida Forum op. cit. 13.

1. Roll Tile (Figure 4).
   A. Pan and cover shape (barrel/mission).
   B. S shape (Spanish S).

2. Flat Tile (Figure 5).
   A. Flat-shake or slate-shaped tile with interlocking waterlocks.
   B. Flat-ribbed-shaped tile with interlocking waterlocks.
   C. Tile with as small roll centered in the tile with interlocking waterlocks.

3. Accessory Tiles of Various Shapes (Figure 6).
   A. Ridge and hip tile.
   B. Hip starters.
   C. Rake tile.
   D. Barrel ridge and hip tile.
   E. Apexes.[15]

ii. Tile Installation Procedures.

In a brief article in Roofer Magazine, Walter Pruter notes that in spite of many high quality construction materials being on the market today, proper installation is the real key to long term performance.[16] This feature is repeated in many of the references for this study, notably in the codes, association publications, and governmental standards.

The manufacturing process of products, in general, is much more thoroughly controlled than the installation process. With a high level of serviceability expected from products, most roof tile manufacturers consciously observe quality control procedures in their plants. Products are predictably consistent in physical

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[15] NRCA op. cit., 61.

[16] Pruter, Walter *"Above and Beyond,"* Roofer Magazine, January 1989, 3-4.

properties and performance. Long warranties up to fifty years are common in the industry.

Guaranteeing an installation is quite another matter. There are many important elements in a proper tile installation. Due consideration must be given to all of these, starting with the (supporting) framing.[17] A weak or improperly braced roof structure will result inevitably in fracture of a tile bond and eventual failure. Many other design and/or workmanship defects will lead to bond failure, not the least of which is sloppy procedure like walking around on the roof before the mortar is set.

Although the focus of this study is the loss of bond with mortar in the so called mortar set system, there is a companion technique for securing tile to a roof called nail-on. These two systems represent the primary means of attaching and securing roof tiles to underlying roof structures throughout the world.

Nail-On Systems.

Nail-on systems are referred to in many places throughout the literature. Provisions are set forth in many building codes and manufacturer's bulletins for their specific products. Nail-on applications are universally approved around the world. The term nail-on is used here to include the variants of wire tied, screw fastened, pegged or clamped fastening systems that are in common usage as mechanical fastenings in various countries.

These systems are applied over a variety of surfaces, some that are incorporated in system names include direct deck sealed system, batten systems, and the hot mop system. Many different variations of underlayment are specified for these systems, ranging from a single 30 lb. roofing felt to a 90 lb. mineral surface felt.[18]

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[17] Pruter op.cit., 17.

[18] Tait, Douglas C. "Nail-On vs. Mortar-Set Roof Tile Applications," Florida Forum, October 1990, 14.

The NRCA Steep Roofing Manual provides ample coverage of the nail-on concepts under both the clay and concrete tile sections. Manufacturers continue to develop new tile products that eliminate problems of weather resistance such as the interlocking flat concrete system in Florida. As roof pitches become steeper, the use of positive mechanical fastenings for tile becomes more important. This is reflected in the South Florida Building Codes which make mechanical fastening required even for mortar set on the tile starter courses, and for partial field tiles at 6/12 and 7/12 pitches. All tiles installed at pitches greater than 7/12 must be mechanically fastened regardless of basic fastening system. The South Florida Codes vary greatly in application specifics.

With regard to nail-on systems Tait notes:

On the positive side of these systems:
Can be used for steep roof pitches; Interlocking roof tile design; Less time to complete the job; No loose tile or underlayment slippage; There is less cost of installation.

On the negative side of these systems:
Cannot be used on lower roof pitches; Roof is not watertite until roof tile is installed (unsealed batten systems); Damaged or broken roof tile may result in roof leakage (unsealed batten systems); Not having trained installers in some parts of the state.[19]

Mortar-Set System.

Mortar-set systems have been used in Florida for many years . Originally devised to accommodate the need for secure fastening of tiles over a built up sub roof in high-wind and high-moisture areas, this concept also permitted the use of lower sloped roofs. The system allowed wind driven rain to pass under the tile and off the roof without leaking through.

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[19] Tait op.cit., 16-17.

This system, in South Florida, now requires a 30 lb. roofing felt tin-tagged and hot mopped under (90 lb.) mineral surface felt. All metal flashings should be sealed between these two underlayments.

Tait observes that many improvements to this system have been made over the years. With the steady increase in roof pitches, problems arose with underlayment slippage. Now most roof tile manufacturers recommend and code bodies require back nailing of the 90 lb felt, and nail fastening for a pitch dependent percentage of the roof tile, to eliminate underlayment or tile slippage. Nail penetrations must be sealed with an approved sealant.

On the positive side for this system:
Minimum of nail penetrations through the underlayment; Can be used on low roof pitches; construction schedules can be maintained with only the tile loaded on the roof; This system has been proven over time; Loose tile can now be re-secured using an approved adhesive. (Check your local codes).

On the negative side of this system:
Roof pitches over 7/12, all tile must be nailed in addition to using mortar; There are loose tiles due to mortar bond.
A. Due to improper mortar mix. B. No activity on the roof before 72 hours after tile installation.
Not having trained installers in some parts of the state.[20]

IV. C. iii. Causes of the Loss of Bond

According to the NRCA in their report "Roof Performance During High Wind Events," among causes of hurricane related roof covering damage are:

- Deficiencies in: Design (in part, this is due to deficiencies in design guides, or a lack thereof); Building code and code compliance; Application; and,

[20] Tait op. cit., 13.

Laboratory test methods.

- Wind driven missile (debris) damage.

- Increased pressure due to architectural features and/or building shape.

- Structural failure of the roof deck and/or deck supporting structure.

- Materials and/or system component interaction.

- Deterioration of components.[21]

The report presented to the Roofing Committee of the Dade County Board of Rules and Appeals Board by John Pistorino cites the following items which are discussed as reasons for the lack of bond between clay or concrete tiles and mortar. The word lack is used intentionally to emphasize that in many cases breakdown occurred before a bond had opportunity to form:

1. Poor workmanship.

    a. Improper mix of cement, sand, and water for mortar resulting in a strength of less than 1800 psi.
    b. Drying out of mortar before application.
    c. Walking on tile prior to set-up of the mortar.
    d. Not keeping tiles cool during curing of the mortar.
    e. Not enough mortar being used.
    f. Improper placement of mortar paddies.

2. Incompatibility of materials.

    a. Tile is so dense and smooth that mortar will not adhere.
    b. A bond breaker used to release the concrete tile

[21] NRCA *"Roof Performance During High Wind Events,"* Report to Dade County Ad Hoc Roofing Committee, Rosemont, Illinois, January 1993, 1.

from the steel form during production may affect the adherence of mortar to the tile.

c. Tile shape and interlocking may cause movement similar to expansion and contraction of concrete decks creating a shear plane at the mortar interface.

d. Tile so dark and dense that heat build up occurs rapidly robbing moisture from the mortar before it has a chance to hydrate (cure).[22]

Pistorino described a high density concrete tile brought out by Monier in 1981 in Australia as the precursor of installation practice leading to the above analysis. Originally intended to be used over spaced sheathing, this tile was ultimately used for mortar set applications. Other manufacturers followed suit and there was a proliferation of high density concrete tile being installed on Dade County roofs. The problems associated with such installations became apparent quickly as many tiles were seen to be loose short periods of time after placement. The fundamental problem behind this large scale disbonding seemed to be the lack of initial bond of the tile to the setting mortar. A smooth, high density concrete surface under the tile was inhibiting the desired action.[23]

> The observation is, however, that poor workmanship did not appear to be a factor of major consequence prior to the introduction of high strength concrete tile. We realize that there is a higher probability for loose tile occurring just due to the larger amount of tile being used in the past 10 years. However, the problem is so wide spread that if workmanship is now the only problem as suggested by the Tile manufacturers, then the mortar set system is not viable for that reason alone.
>
> But we do not see that the same problems are occurring with clay tile or with concrete tile which are fabricated for use

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[22] Pistorino op. cit., 4.

[23] Pistorino op. cit., 3-4.

specifically with mortar. For example, the Gory Vanguard Series which has a roughed under surface, has an excellent success rate for mortar-set applications. Observations of damage from hurricane Andrew also showed that despite the availability of good workmanship, clay and concrete tile produced in molds remains bonded in many more instances than did extruded concrete tile.[24]

A report from the American Plywood Association reinforced observance of bond loss and further noted that while flat concrete tiles appeared to have better resistance to wind forces than the clay barrels, the failure mechanism was essentially the same.[25]

Some concrete tile roofing that did survive was fully bedded in mortar as opposed to being attached with an occasional patch of mortar as was the rule. The more satisfactory performance of flat concrete tile roofing is generally attributed to reduced exposure at the edges to wind uplift.

While the concrete tile roofing had holes for mechanical fasteners, none were used on any of the failed tiles that we observed (Figure 35).

Due to the weight of the concrete tile roofing pieces, they caused considerable damage as projectiles to neighboring structures, as well as vehicles. It is likely that concrete tile roofing projectiles were the cause of many window failures, which subsequently led to further structural and water damage to the affected buildings.

The majority of the roof tiles used in Florida during the last 10 or 15 years are manufactured of concrete. It was reported that clay tiles used prior to the market emergence of concrete

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[24] Pistorino op. cit., 5.

[25] Keith, Edward L. and Rose, John D. *"Hurricane Andrew (-) Structural Performance of Buildings in Southern Florida,"* APA Report T92-21, American Plywood Association, Tacoma, November 1992, 9-11.

tiles adhered better to the mortar bedding system used.[26]

The Roof Consultants Institute published a special edition of their Interface devoted to assessment of Andrew related damage and causes in October 1992. In addition, Paul Siple drew together a strong comprehensive analysis in the January 1993 issue.
Excerpts from these writings include:

JAN 1993 Newsletter - Siple, follows

It can be seen that very small beds of mortar were used. p.3

Stronger and wider self-sealing strips can be designed. The development of new products will only come as a consequence of higher code requirements or demands by Roofing Design Professional. p.3

The mud-on system is very time-critical in getting the tiles set and bonded to the mortar bed. This system seems to have failed in the high winds of this hurricane. The proposed code changes to include nailing of the tile may solve the problem. But if nailing must be done, the question that must then be asked is, "Why not go to a total nail-on system?" p.4

In high winds, the tiles are lifted at the bottoms so the use of hurricane clips should be a must for all tiles. p.4

This report has explored the modes of roof failure and some of the remedies possible. Input from Code Officials, Roofing Manufacturers, Roofing Professionals and Roofing Contractors will be valuable in the process of making changes that will prevent the type of failures observed from "Andrew". p.7[27]

October 1992 EXTRA Newsletter - Roche, follows
In the aftermath of Hurricane Hugo, this Institute decided

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[26] APA Report op.cit., 10-11.

[27] Siple, Paul "Residential Roofing Failures," RCI Interface, January 1993, 3-7.

that the industry still had a lot to learn about the design and construction of roof systems as they relate to significant wind events. Roche, p.2[28]

In an article called Hurricane Warnings, Charles Miller of Fine Homebuilding makes a good appraisal of problems in South Florida construction revealed by Andrew. He described in plain language some of the major installation aspects affecting the loss or initial lack of bond between tiles and mortar.

> In order for a mortar-set concrete tile (flat or low profile) to have a chance in hurricane winds. it has to be fully bedded in a patty of mortar. Once cured, this elliptical patty of mortar should weigh 4 lb. or 5 lb., and it should be placed parallel to the slope of the roof to best grip the tile in the line with the tile's longest dimension. Roof after roof showed where the installers had done the opposite, or they had simply skimped on mortar. Criss Starr of Lifetile adds that the mortar must be made with cement that's been approved for roof tiles and must be mixed at the right ratio to ensure a good bond (18 shovels of sand per bag of cement). Though not required by code, it is also a good idea to wet the tiles before installation to keep them from drying out the mortar too quickly. Starr also points out that starter courses of concrete tiles should be held down by little metal brackets called hurricane clips. They are often left out.
>
> Several kinds of high-profile barrel tiles cover roofs in South Florida, and they seem to have fared differently. Instead of being completely blown away, the cap tiles would sometimes depart, leaving behind the trough tiles (..photo..). The older tiles are pretty porous, and evidence I saw suggests that they stayed on roofs better than the newer versions, which have smoother surfaces. John Pistorino, an engineer and consultant to the Dade County Building Department, says the mortar into which the tiles are bedded can get a better grip in the rougher surface of the older tiles. When barrel

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[28] Roche, Calvin "Disaster Response Team Blown Into Action," RCI Interface, October 1992, 1.

tiles are loosened by wind or foot traffic, Pistorino says, they can be re-bedded with good results by using an adhesive made specifically for that purpose (RT600, Ohio Sealants...).[29]

In his report on structural performance of buildings in Dade County during Andrew, Ron Zollo notes any roofing system is subject to wind removal unless installation procedures and material specs are strictly followed. And, "Mortar beds that were placed with full 10 inch trowel strokes did well even in areas of greatest storm intensity. Dabbed on mortar beds consistently failed to secure the tiles."[30]

Although the practice of mortar bedding tiles is used in the United Kingdom only on ridges, hips, verges (edges) or valleys, the Site Practice section of the Redland Roofing Manual notes the posibility of bond loss in fixing hip tiles. "Cutting bold-profile tiles often produces a deep mortar bed which may shrink on drying, resulting in loss of adhesion between mortar and tile."[31] This may account for many of the visible horizontal ribbons of mortar on Dade County roofs stripped of their covering tiles by Andrew. The wholesale improper placement of mortar not only precluded effective bedding of vertically aligned tile elements but created variable dimensioned ribbons that quite probably experienced differential shrinkage.

It is clear that a number of major issues contributing to loss of or lack of initial bond have been identified. Tile roofing, like any other specialty activity of construction, can be done well or not. If it is not done well, we can readily predict potential consequences.

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[29] Miller, Charles *"Hurricane Warnings,"* Fine Homebuilding, January 1993, 84.

[30] Zollo, Ronald F. "HURRICANE ANDREW: Structural Performance of Buildings in Dade County Florida," Univ.of Miami, Miami, March 1993, 22.

[31] Hastings, Ted ed. "The Redland Roofing Manual 1989," Redland Roof Tiles Limited, Reigate Surrey, November 1988, 12.7.

IV. D. Adjustment

i. Building Codes and Enforcement

Regulatory bodies in hurricane prone areas, especially in the South and South Florida area, have reacted strongly to improve the code provisions related to high-wind susceptible construction. The inspection process has also been tightened in many jurisdictions, with Dade County in the forefront of that action.[32]

In the past two years, major revisions of these building codes have occurred. New wind load standards, material properties and fastening requirements have been defined and promulgated. These include:

STANDARD BUILDING CODE (SBC).

After Hurricane Andrew, the SBCCI published the 1992/1993 revisions to the SBC 1991 Edition, which include changes to section 3207, concerning concrete and clay roof tile.

SBCCI also published a May/June 1992 supplement to the SBC which contained proposed changes. These included sections related to: wind loading on roof covering systems; overturning resistance of concrete and clay roof tiles; and, wind tunnel testing of concrete and clay roof tile.

SOUTH FLORIDA BUILDING CODE (SFBC).

Prior to Hurricane Andrew, Chapter 34 of the SFBC, concerning Roof Covering and Application, contained a modest set of requirements for clay and concrete tiles, their application and inspection of the installation. That is now history; but, in spite of being supplanted, is still useful to us in a comparative analytical sense.

After Hurricane Andrew, a prompt review of construction

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[32] Metro-Dade County "Sub-Section 3401.11, Inspections," South Florida Building Code, Miami 1994, 34-16.

techniques and safety standards were conducted and new emphasis placed on enforcement to preclude future large scale failure. On September 1992, the Board of County Commissioners presented an Emergency Ordinance amending the SFBC. This was the first of a series of ordinances addressing obvious post-disaster problems in the early to mid recovery months.[33]

In March 2, 1993 the Board of County Commissioners published ordinance No. 93-14. This ordinance implemented recommendations of the Grand Jury and the Hurricane Task Force. Some of the recommendations were based upon the 1993 amendment to the Standard Building Code. Revisions affecting concrete and clay roof tile included treatment of windloading and bracing of roof structures and the inspection requirements for roofing and reroofing.

On 1 September 1994, a new version of the South Florida Building Code went into effect in both Dade and Broward Counties. These codes incorporate massive revisions in the chapters covering wind loading, roof structures, roof sheathing, and roof tile installations. Code related ordinances after Andrew, except those citing emergency procedures, have been included in this code.

VI. D. ii. Manufacturers & Standards

Of the 13 manufacturers who responded to our solicitation, only 5 recommend the mortar-set system for their tile installation. All of these companies have factories or major distribution centers in Florida. Consequently, we suspect that this system is almost exclusively used in Florida (Appendix B., Table 1.).

Manufacturer and Association Specifications

The NRCA has a specification for mortar-set tile installation. The Florida Roofing Sheet Metal & Air Conditioning Contractors Association and the National Roof Tile Manufacturers Association

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[33] Barnes, Wilson C. & Mitrani, Jose D. "Critical Issues in Post Disaster Code Enforcement," Proceedings of ASCE Conference on Hurricanes of 1992,

jointly developed a specification in 1989 which is a consensus document summarizing good roofing practice and some of the industry standards for mortared on tile installation. This document is the most comprehensive specification for mortar-set tile installation available.

Based on these FRSA/NTRMA specifications, the recommendations made by each clay and concrete tile manufacturer who sent their specifications for mortar-set tile installation were analyzed. This analysis is presented in Appendix B. Special requirements cited by each manufacturer or differences with the FRSA/NTRMA specifications have been bolded for easy visualization.

Manufacturers Code Compliance.

Clay and concrete tile manufacturers/products approved by the Product Control Division of the South Florida Building Code Compliance Office as of 22 July 1994 are presented in Appendix F.

As can be seen in Appendix F, some concrete tile manufacturers such as Monier, Lifetile, Pioneer, and Bender who recommended the mortar-set installation are actually approved for the use of the nail-on system and not the mortar-set.

Mortar Standards.

The mortar itself is not without controversy. According to the SFBC and SBC, manufacturer and organization specifications for mortar-set that were reviewed, the mortar required for concrete or clay roofing tile installation should be a Type "M" mortar prepared according to the ASTM standard C-270 "Standard Specification for Mortar for Unit Masonry."

On the other hand, William McElroy states: "The cement or mortar mix I recommend is Type S mortar. Type S mortar has a high bond strength and is for extreme wind and weather exterior work. The mix is 1 part Portland cement, 1/4 hydrated lime, and 3-1/4 parts clean mortar sand. Mix with just enough water to make a workable paste. NOTE: Do not use ocean or river sand. Ocean sand has been rounded by the wave action and does not form a good grip

with the cements. Quarried sand is irregular in shape and does form a good bond."[34]

There are two relevant ASTM Standards treating mortar. The first is C-270 which addresses mortar for unit masonry. Since the traditional unit masonry products of clay brick and concrete block are closely related to roof tile products this standard has a good deal of relevance to the roof tile bonding problem. However, the differences in product material density and surface character alone raise concern about direct transferability of information.

In addition to prescribing proper physical composition, this standard discusses the masonry mortar properties in the plastic and hardened states. In the plastic state, workability and water retentivity are both important elements in achieving maximum bond. In the hardened state: bond, durability, elasticity and compressive strength are all cited as properties with bond being noted as the most important.

Appendix X1 of the ASTM specification includes non-mandatory information to allow a more knowledgeable decision in the selection of mortar for a specific use. This information is a comprehensive primer on mortar, what it is, what it does. how it came about, and what affects its performance. The following quote illustrates the nature of content in this document:

> X1.6 *Hardened Mortars:*
> X1.6.1 *Bond*--Bond is the most important single physical property of hardened mortar. It is also the most inconstant and unpredictable. Bond actually has three facets; strength, extent and durability. Because many variables affect bond, it is difficult to devise a single laboratory test for each of these categories that will consistently yield reproducible results and which will approximate construction results. These variables include air content and cohesiveness of mortar, elapsed time between spreading mortar and laying masonry unit,

[34] McElroy, William

suction of masonry unit, water retentivity of mortar, pressure applied to masonry joint during placement and tooling texture of masonry unit's bedded surfaces, and curing conditions.

.....

X1.6.1.3 The tensile and compressive strength of mortar far exceeds the bond strength between the mortar and the masonry units. Mortar joints, therefore, are subject to bond failures at lower tensile or shear stress levels. A lack of bond at the interface of mortar and masonry unit may lead to moisture penetration through those areas. Complete and intimate contact between mortar and masonry unit is essential for good bond. This can best be achieved through use of mortar having proper composition and good workability, and being properly placed.

X1.6.1.4 In general, the tensile bond strength of laboratory mortars increases with increases in cement content. Because of mortar workability, it has been found that Type S mortar generally results with the maximum tensile bond strength that can practically be achieved in the field.

.....

X1.6.3. *Compressive Strength--*

.....

X1.6.3.2. Perhaps because of the previously noted confusion regarding mortar and concrete, the importance of compressive strength of mortar is over-emphasized. Compressive strength should not be the sole criterion for mortar selection. Bond strength is generally more important, as is good workability and water retentivity, both of which are required for maximum bond. Flexural strength is also important because it measures the ability of a mortar to resist cracking. .....

.....

X1.6.3.3 Compressive strength of mortar increases with an increase in cement content and decreases with an increase in lime, sand, water or air content. Retempering is associated with a decrease in mortar compressive strength. The amount of the reduction increases with water addition and the time between mixing and

retempering. It is frequently desirable to sacrifice some compressive strength of the mortar in favor of improved bond. Consequently, retempering within reasonable time limits is recommended to improve bond. .....

.....

X1.7 *Composition and Its Effect on Properties:*

.....

X1.7.2. Each of the principal constituents of mortar makes a definiite contribution to its performance. Portland cement contributes to strength and durability. Lime, in its hydroxide state, provides workability, water retentivity, and elasticity. Both portland cement and lime contribute to bond strength. Instead of portland cement-lime combinations, masonry cement is frequently used. .....

.....

X1.7.7. *Water*--.....

X1.7.7.1. Water content is the most misunderstood aspect of masonry mortar, probably due to the confusion between mortar and concrete requirements. Water requirement for mortar is quite different from that for concrete where a low water/cement ratio is desirable. Mortars should contain the maximum amount of water consistent with optimum workability. Mortar should also be retempered to replace water lost by evaporation.

.....

X1.9.3 *Masonry Units*--Masonry units are absorptive by nature, with the result that water is extracted from the mortar as soon as the masonry unit and the mortar come into contact. The amount of water removal and its consequences effect the strength of the mortar, the properties of the boundary between the mortar and the masonry units, and thus the strength, as well as other properties, of the masonry assemblage.

X1.9.3.1 The suction exerted by the masonry unit is a very important external factor which affects the fresh mortar and initiates the development of bond. Masonry units vary widely in initial rate of absorption (suction). It is therefore necessary that the mortar chosen have properties that will provide compatibility

with the properties of the masonry unit being used, as well as environmental conditions that exist during construction and the construction practices peculiar to the job.

X1.9.3.2. Mortar generally bonds best to masonry units having moderate initial rates of absorption (IRA) from 5 to 25 g/min*30sqin (194sqcm), at the time of laying. More than adequate bond can be obtained, however, with many units having IRA's less than or greater than these values.

X1.9.3.3. The extraction of too much or too little of the available water in the mortar tends to reduce the bond between the masonry unit and the mortar. A loss of too much water from the mortar can be caused by low water retentivity mortar, high suction masonry units, or dry, windy conditions. When this occurs, the mortar is incapable of forming a complete bond when the next unit is placed. Where lowering the suction by pre-wetting the units is not proper or possible, the time lapse between spreading the mortar and laying of a masonry unit should be kept to a minimum. When a very low suction masonry unit is used, the unit tends to float and bond is difficult to accomplish. .....

X1.9.1.3.4. Mortars having higher water retentivity are desirable for use in summer or with masonry units having high suction. Mortars having lower water retentivity are desirable for use in winter or with masonry units having low suction.

.....

X1.9.3.6. Mortar bond is less to surfaces having an unbroken die skin or sanded finish than it is to roughened surfaces such as a wire cut or textured finish.

.....

X1.9.5. *Workmanship*--Workmanship has a substantial effect on strength and extent of bond. The time lapse between spreading mortar and placing masonry units should be kept to a minimum because the flow will be reduced through suction of the unit on which it is first placed. This time lapse should normally not exceed one minute. Reduce this time lapse for hot, dry and windy conditions,

or with use of highly absorptive masonry units. If excessive time elapses before a unit is placed on the mortar, bond will be reduced. Elimination of deep furrows in horizontal bed joints and providing full head joints are essential. .....

X1.9.5.1. Once the mortar between adjacent units begins to stiffen, tapping or otherwise attempting to masonry units is highly detrimental to bond and should be prohibited. The movement breaks the bond between the mortar and the masonry unit and the mortar will not be sufficiently plastic to re-establish adherence to the masonry unit.

.....

X1.10 *Summary*

.....

X1.10.2. Bond is probably the most important single property of a conventional mortar. Many variables affect bond. To obtain optimum bond, use a mortar with properties that are compatible with the masonry units to be used. To increase tensile bond strength in general, increase the cement content of the mortar (see Section 4.5.1.4); keep air content of the mortar to a minimum; use mortars having high water retentivity; mix mortar to the water content compatible with workability; allow retempering of the mortar; use masonry units having moderate initial rates of absorption when laid (see Section 7.3); bond mortar to a rough surface rather than to a die skin surface; minimize the time between spreading mortar and placing masonry units; apply pressure in forming the mortar joint; and do not subsequently disturb laid units.[35]

The second mortar standard of consequence is ASTM C-780, Standard Method for Preconstruction and Construction Evaluation of Mortar for Plain and Reinforced Unit Masonry. This is believed to be relevant for reasons similar to those for standard C-270 above,

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[35] ASTM "C-270 Standard Specification for Mortar for Unit Masonry," 1992 Annual Book of ASTM Standards, Volume 04.05, Philadelphia, 1992, 125-133.

mainly physical closeness of tile materials to unit masonry materials.

> 1. Scope
>
> 1.1 This standard covers procedures for the sampling and testing of mortars for composition and for their plastic and hardened properties, either before or during their actual use in construction.
>
> 1.2 Preconstruction evaluation of mortars permits a comparison of mortar systems and an approximation, by more complete identification, of the mortar mixture which will be produced at the construction project. On the other hand, construction site testing procedures permit the establishment of conformance to the proportion specifications and quality control of mortar production.[36]

The test methods prescribed by this standard and considered appropriate for use on roofing tile mortars are:

a. Consistency by cone penetration test method.
b. Consistency retention of mortars for unit masonry.
c. Mortar aggregate ratio test method.
d. Mortar water content test method.
e. Mortar air content test method.
f. Compressive strength of molded masonry mortar cylinders and cubes.
g. Splitting tensile strength of molded masonry cylinders.

Mortar Admixtures

> X1.7.8 *Admixtures*--Admixtures for mortars are available in a wide variety and affect the properties of fresh or hardened mortar physically or chemically. Some chemical

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[36] ASTM "C 780-91, Standard Test Method for Preconstruction and Construction Evaluation of Mortars for Plain and Reinforced Unit Masonry," 1992 Annual Book of ASTM Standards, Volume 04.05, Phildelphia, 1992, 418.

> additions are essential in the manufacture of basic mortar materials. The inclusion of an additive is also necessary for the production of ready mixed mortars. Undoubtedly there are also some special situations where the use of admixtures may be advantageous when added at the job site mixer. In general, however, such use of admixtures is not recommended. .....
>
> X1.7.8.1. Admixtures are usually commercially prepared products and their compositions are not generally disclosed. Admixtures are functionally classified as agents promoting air entrainment, water retentivity, accelerated set, and so on. Limited data are available regarding the effect of proprietary admixtures on mortar bond, compressive strength or water permeance of masonry. .....
>
> X1.7.8.3. The uncontrolled use of air entraining agents should be prohibited. .... Data on masonry grouts indicate that lower bond strength between grout and reinforcing steel is associated with high air content. .....[37]

In "Hurricane Warnings" Charles Miller notes Lifetile (one of the concrete tile manufacturers investigated) "is experimenting with mortars that have been modified with acrylic/latex admixtures or dolomite lime to increase the adhesion and to make it easier for installers to do a good job when heat is making the mortar set quickly."[38]

Despite some adverse references in the traditional literature to their use, the employment of mortar admixtures which can increase the bonding characteristics of mortar for concrete or clay tile installation is very promising and should be explored. No admixtures specially designed for clay and concrete tile roofing installation were identified.

There are many products available in the market, such as

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[37] ASTM C-270, op. cit., 193.

[38] Miller, Charles op. cit., 84.

mortar additives, premix mortars, and adhesives that have been used for other situations. Those products may be a transferable model to be implemented for tile roofing. For this reason, we requested information from concrete products manufacturers identifying the different products that might be implemented for clay and concrete roofing tile installation.

A list of these different products from the concrete products manufacturers who answered our request is presented in Appendix B., Table 2.

IV. D. iii. Research

Even before Andrew, research into the fundamental nature of roof tile lifting forces and restraint mechanisms was going on. The National Tile Roofing Mfrs. Association had commissioned the New Technology & Product Development Centre of Redland Technology Limited to do a wind uplift study on roof tiles toward the end of improving fixing specifications.

This study was completed in June 1990. It points out that tiling is significantly permeable to air and the fixings should reflect this rather than being based on tiling as a continuous layer impermeable to air. This study, based on 1988 versions of the SBC and UBC, addressed mechanical fastening (nail-on) versus prescribed design wind-loadings of the US environment. When wind loadings were adjusted per the permeable theory, fastening requirements were shown to be less stringent and more economical.[39] Another study, post-Andrew, was completed at Redland in 1993.

Dr Nigel Cherry, Director of the Redland Wind Tunnel, in personal interview noted: "Don't rely on mortar to hold tiles ever. Where mortar is used, hold down clips are vital." Also, he indicated that they did no mortar testing at Redland although they were beginning to test some foam.

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[39] Haig, J.R. "Wind Loads on Tiles for USA, Final Report," Redland Technology Limited, New Technology and Development Centre, Horsham, England, 1990.

At the same time as the second Redland study, work was going on at the Building Research Establishment (BRE) in England looking at wind tunnel measurements on full scale roof tiles and making comparison with earlier data taken from scale model instrumented wind loadings. This work was unpublished at the time of contact and is believed to be continuing on looking at a greater variety of tile arrays and positional relation to the wind stream.[40]

In the US, the NTRMA sponsored a test of bond among six tile and four mortar combinations. Manufacturer members of the association participated at the Center for Applied Engineering, Inc., in St. Petersburg, Florida, during May and June 1994. Tight procedures were followed for mixing and evaluating mortar and a uniform application of tile on simulated roof panels was conducted. Although the results of this test looking at a mix of standard and experimental products are documented, they have not yet been released for general information. It is not known at the time of this report if further testing of this kind will be conducted.

IV. E. Conclusions.

- The construction industry cannot afford to allow tile roofs to be installed which become loose over the life of the roof under normal conditions.

- Product suitability and proper installation are essential for effective long term roof performance.

- Code provisions and enforcement are key elements for achieving suitability and proper installation. To improve codes and standards, additional research is required.

- Education of designers and roofing contractors is also of critical importance to improving roof performance.

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[40] Woods, A R "Wind tunnel measurements on full scale roof tiles," to be presented at 2nd UK Wind Engineering Conference, Warwick, September 1994.

- Increased amounts of objective product testing is needed.

- Improved testing procedures are needed for clay and concrete roof tiles installed with the mortar-set method.

- Inspection during application should be required to verify compliance. The type of roof system being installed will dictate critical factors and the optimum time/frequency for inspection. The inspector should be knowledgeable of wind-related aspects of installations.

- Material developed under this study is of value and should be extended, especially in view of the recent, current, and likely initiatives in the area of interest.

- Despite extensive media and professional reporting of the loose tile issue, the problem is still unresolved and discovery of new "instances" continues to develop.

- The real life consequences of tile roofs being loose continue to be a serious concern; not just in South Florida, but across the state. These are:

    1. The actual missile damage from future storms.

    2. Appropriate action when tile is discovered to be loose prior to a disaster event:

        a. What are the consequences (potential liability for the developer,
                contractor,
                designer;
        b. What are the consequences for the home owner in costs of: inconvenience to have the roof fixed, or disclosure of the defect before sale of the property?

    3. Some roofers are going out of business due to colossal failure of tile-mortar bond.

V.

APPENDICES

APPENDIX A

Sources and Identifications

APPENDIX A. Sources and Identifications

TABLE 1: Roofing Tile Manufacturers contacted.

No	NAME	ADDRESS	ANSWER
1	ALMAR.	Phone: 1-800-54-TILE-1	YES
2	BENDER INDUSTRIES.	3100 SE Country Road 484 P.O. Box 190 Belleview, Florida 32620.	YES
3	BEST CLAY TILE CORPORATION.	Phone: (305) 826-8080.	NO
4	BORAL CONCRETE PRODUCTS INC.	P.O. Box 632 Lake Wales, Florida 33859.	NO
5	CANTERAS CERRO NEGRO S.A.	8280 College Parkway, Suite 204. Fort Myers, FL 33919.	YES
6	CERAMICA DE ESPANA MONIQUE.	Phone: (305) 559-5455.	NO
7	COMA CAST CORPORATION.	4383 SW 70 Ct. Miami, FL 33155.	NO
8	COLUMBIA CONCRETE PROD. LTD.	8704 120th Street, Surrey, BC V3W 3N7.	NO*
9	CRAYCROFT BRICK COMPANY.	2301 West Belmont Avenue Fresno, California 93728.	YES
10	DELCO CLAY TILE CO., INC.	600 Chaney Street, Lake Elsinore, CA 92530.	NO
11	ETERNA ROOF TILE CORPORATION.	1201 Northwest 18TH Street, Pompano Beach, FL 33069.	NO
12	GAF ROOFING PRODUCTS.	8601 NW 81st Road Miami, Florida 33166	NO
13	GLADDING McBEAN.	P.O. Box 97 Lincoln,California 95648.	YES
14	GORY ROOF TILE.	1100 Park Central Boulevard South. Suite 1800 Pompano Beach, Florida 33064.	NO*
15	INT. ROOFING PRODUCTS INC./GROUP 177.	1832 South Brand Blvd. # 200. Glendale, California 91204.	NO

No	NAME	ADDRESS	ANSWER
16	**LA MANCHA TILES.**	Phone: (305) 365-9411.	NO
17	**LIFETILE.**	P.O. Box 632 Lake Wales, Florida 33859-0632.	YES
18	**LIFETIME ROOFTILE COMPANY.**	800 West 5th Avenue. Suite 205 Naperville, IL 60540.	YES
19	**LUDOWICI CELADON.**	4757 Tile Plant Road New Lexington, OH 43764.	YES
20	**MARLEY ROOF TILES.**	4550 126th Avenue North Clearwater, Florida 34622.	NO*
21	**MARUHACHI CERAMICS OF AMERICA INC.**	1985 Sampson Avenue Corona, California 91719.	YES
22	**METRO ROOF TILE**	Phone: (305) 558-6712.	NO
23	**MID-FLORIDA CLAY TILE & SLATE.**	1020 Abernathy Ln #200 Apopka, Florida 32703.	NO
24	**MONIER ROOF TILE.**	135 NW 20 Street, Boca Raton, FL 33431.	YES
25	**MONTORO.**	Unit A, 566 E. 6th Street, Norco, CA 91760.	NO*
26	**PAN AMERICAN ROOFING SUPPLY, INC.**	610 NW 74 Ave. Miami, FL 33166.	NO
27	**PIONEER CONCRETE TILE.**	1340 SW 34th Ave. Deerfield Beach, FL 33442.	YES
28	**PROCLAY INC.**	1101 Brickell Ave. Suite 401 Miami, FL 33131.	NO
29	**PRODEK, INC.**	Phone: (305) 557-5737.	NO
30	**STACO ROOF TILE.**	3530 East Elwood, Phoenix, AZ 85040.	YES
31	**SUNCRETE ROOFTILE.**	P.O. Box 518, Thousand Palms, CA 92276.	NO*
32	**VANDE HEY RALEIGH.**	1665 Bohm Drive. Little Chute, WI 54140.	YES

No	NAME	ADDRESS	ANSWER
33	WESTILE, INC.	8311 W Carder Ct., Littleton, CO 80125.	NO

RETURNED MAIL.

TABLE 2: Concrete Products Manufacturers contacted.

No	COMPANY NAME	ADDRESS	ANSWER
1	ANTI HYDRO COMPANY.	265 Badger Avenue Newark, NJ 07108.	YES
2	ATLAS MINERALS & CHEMICALS, INC.	P.O. Box 38, Farmington Rd. Mertztown, PA 19539.	NO
3	BOSTIK, INC.	1500 Parker Road Conyers, GA 30207.	NO
4	C-CURE CHEMICAL COMPANY, INC.	305 Garden Oaks Blvd. Houston, TX 7018.	NO
5	CUSTOM BUILDING PRODUCTS.	6511 Salt Lake Ave. Bell, CA 90201.	NO
6	DAYTON SUPERIOR.	402 South First St. Oregon, IL 61061.	YES
7	E-POXY INDUSTRIES, INC.	14 West Shore St. Ravena, NY 12143.	YES
8	H.B. FULLER COMPANY./TEC INC.	315 S. Hick Road Palatine, IL 60067.	YES*
9	LARSEN PRODUCTS CORPORATION.	P.O. Box 2127 Rockville, Maryland 20847.	YES
10	LATICRETE INTERNATIONAL, INC.	1 Laticrete Park North. Bethany, CT 06524	NO
11	L&M CONSTRUCTION CHEMICALS.	14851 Clahoun Rd. Omaha, NE 68152.	NO
12	MAPEI CORPORATION	1350 Lively Blvd. Elk Grove Village, IL 60007.	YES

No	COMPANY NAME	ADDRESS	ANSWER
13	OHIO SEALANTS.	7405 Production Dr. Mentor, Ohio 44060.	NO
14	PERMAGILE INDUSTRIES, INC.	101 Commercial St. Plainview, NY 11803.	NO
15	SIKA.	P.O. Box 297 Lyndhurst, NJ 07071.	YES
16	SPRAY CURE COMPANY.	300 Edwards Medicine, OH 44057.	NO
17	THORO SYSTEMS PRODUCTS.	7800 NW 38th Street Miami, FL 33166	YES
18	W.R. BONSAL COMPANY.	5455 North 59th St. Tampa, FL 33610.	YES

TABLE 3: Organizations contacted.

No	NAME	ADDRESS	ANSWER
1	AMERICAN CONCRETE INSTITUTE. (ACI)	P.O. Box 15150. Redford Station. Detroit, MI 48219.	YES
2	AMERICAN INSTITUTE OF ARCHITECTS. (AIA)	1735 New York Ave., N.W. Washington D.C. 20006.	NO
3	AMERICAN NATIONAL STANDARDS INSTITUTE, INC. (ANSI)	1430 Broadway New York, NY 10018	NO*
4	AMERICAN SOCIETY FOR TESTING AND MATERIALS. (ASTM)	1916 Race Street Philadelphia, PA 1903-1187.	YES
5	AMERICAN PLYWOOD ASSOCIATION. (APA)	7011 S. 19th Street Tacoma, WA 98466.	YES
6	ASPHALT ROOFING MANUFACTURERS ASSOC.	6288 Montrose Road Rockville, MD 20852.	NO
7	BRICK INSTITUTE OF AMERICA. (BIA)	11490 Commerce Park Drive Reston, VA 22091.	YES

No	NAME	ADDRESS	ANSWER
8	BUILDING OFFICIALS & CODE ADMINISTRATORS INTERNATIONAL, INC. (BOCA).	4051 W. Flossmar Rd. Country Club Hills, IL 60477.	YES
9	CONSTRUCTION SPECIFICATION INSTITUTE	601 Madison Street Alexandria, VA 22314.	NO
10	INTERNATIONAL CONFERENCE OF BUILDING OFFICIALS. (ICBO)	5630 S. Workman Mill Rd. Whittier, CA 90601.	YES
11	MIDWEST ROOFING CONTRACTORS ASSOCIATION.	1440 Commerce Bank Building Kansas City, MO 64106-2123.	NO*
12	METROPOLITAN DADE COUNTY BUILDING CODE COMPLIANCE OFFICE.	140 W. Flagler St. Suite 1603. Miami, FL 33130.	YES
13	NATIONAL CONCRETE MASONRY ASSOCIATION.	2302 Pen Road Herndon, VA 22071.	YES
14	NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY. (NIST)	Building 226 Gaithersburg, MD 20899.	YES
15	NATIONAL TILE ROOFING MFRS. ASSOCIATION. (NTRMA)	Eastern Regional Office P.O. Box 915245 Longwood, FL 32971.	NO
16	ROOFING INDUSTRY EDUCATIONAL INSTITUTE.	14 Inverness Drive East Building H, Suite 110 Englewood, CO 80112-5608.	NO
17	SINGLE PLY ROOFING INSTITUTE.	104 Wilmont Road, Suite 201 Deerfield, IL 60015-5195.	NO*
18	SOUTHERN BUILDING CODE CONGRESS INTERNATIONAL. (SBCCI)	900 Monclair Rd. Birmingham, AL 35213.	YES
19	THE ROOF CONSULTANTS INSTITUTE. (RCI)	7424 Chapel Hill Road Raleigh, NC 27607.	YES
20	UNDERWRITERS LABORATORIES, INC.	333 Pfingsten Road Northbrook, IL 60062.	NO
21	WESTERN STATES ROOFING CONTRACTOR ASS.	400 Oyster Point Blvd. Suite 217 San Francisco, CA 94080.	NO

RETURNED MAIL.

TABLE 4: Persons contacted.

No	CONTACT PERSON	ADDRESS	ANSWER
1	Mr. Joseph Minor, P.E. **University of Missouri-Rolla.**	Department of Civil Engineering 14th & Pine St. Rolla, MO 65401	YES
2	Mr. Thomas Lee Smith. Director of Technology and Research. **NATIONAL ROOFING CONTRACTORS ASSOCIATION.**	O'Hare International Center 10255 W. Higgings Road Rosemont, IL 60018-1183	YES
3	Mr. John Pistorino. **ROOF CONSULTANT.**	7701 SW 62 Ave. Miami, FL 33143.	YES
4	Ms. Chris Septer. **SOUTH FLORIDA ROOFING CONTRACTORS.**	15601 SW 170 Ave. Miami, FL 33187.	YES
5	Mr. David Perez. **AMERICAN INSTITUTE OF ARCHITECTS.**	5040 NW 7th Street #690. Miami, FL 33126.	NO
6	Mr. Cris Starr. **LIFETILE.**	P.O. Box 632 Lake Wales, FL 33859-0632.	NO
7	Mr. Bob Ferrante **NATIONAL ROOF TILE MANUFACTURER ASSOCIATION.**	1900 NW 21st Avenue Ft. Lauderdale, Fl 33311.	NO
8	Mr. Rick Olson **NATIONAL ROOF TILE MANUFACTURER ASSOCIATION.**	P.O. Box 947 Eugene, OR 97440.	NO

APPENDIX B

Information Received

APPENDIX B. Information Received

TABLE 1: Roof Tile Manufacturers who responded to our request.

No	COMPANY NAME	TYPE OF TILE	INSTALLATION
1	ALMAR.	CLAY	NAIL-ON/MORTAR-SET
2	BENDER INDUSTRIES.	CONCRETE	NAIL-ON/MORTAR-SET
3	CANTERAS CERRO NEGRO S.A.	CLAY	NAIL-ON
4	CRAYCROFT BRICK COMPANY.	CLAY	NAIL-ON
5	GLADDING McBEAN.	CLAY	NAIL-ON
6	LIFETILE.	CONCRETE	NAIL-ON/MORTAR-SET
7	LIFETIME ROOFTILE COMPANY.	CONCRETE	NAIL-ON
8	LUDOWICI CELADON.	CLAY	NAIL-ON
9	MARUHACHI CERAMICS OF AMERICA INC. (M.C.A.)	CLAY	NAIL-ON
10	MONIER ROOF TILE.	CONCRETE	NAIL-ON/MORTAR-SET
11	PIONER CONCRETE TILE.	CONCRETE	NAIL-ON/MORTAR-SET
12	STACO ROOF TILE.	*	
13	VANDE HEY RALEIGH.	CONCRETE	NAIL-ON

TABLE 2: Concrete Products Manufacturers who responded to our request.

No	COMPANY NAME	INFORMATION RECEIVED
1	ANTI HYDRO COMPANY.	Product specs.
2	DAYTON SUPERIOR.	Product specs.
3	E-POXY INDUSTRIES, INC.	Product specs.
4	H.B. FULLER COMPANY./TEC INC.	*
5	LARSEN PRODUCTS CORPORATION.	Product specs.
6	MAPEI CORPORATION	Product specs.
7	SIKA.	Product specs.
8	THORO SYSTEMS PRODUCTS.	Product specs.
9	W.R. BONSAL COMPANY.	Product specs.

* The information hasn't been received.

TABLE 3: Organizations who responded to our request.

No	ORGANIZATION NAME	RESPONSE
1	AMERICAN CONCRETE INSTITUTE. (ACI).	They recommend to contact NCMA and BIA.
	AMERICAN SOCIETY FOR TESTING AND MATERIALS. (ASTM)	ASTM Publications list.
3	AMERICAN PLYWOOD ASSOCIATION. (APA)	APA Reports.
5	BRICK INSTITUTE OF AMERICA. (BIAC)	They don't have any information. They recommend to contact NTRMA.
6	BUILDING OFFICIALS & CODE ADMINISTRATORS INTERNATIONAL, INC. (BOCA)	Magazine's Article.
8	INTERNATIONAL CONFERENCE OF BUILDING OFFICIALS. (ICBO)	Answer by phone. They don't have any information. They would like a copy of our report.
	METROPOLITAN DADE COUNTY BUILDING CODE COMPLIANCE OFFICE.	- SFBC Ordinances. - SFBC Roofing Tile Tests. - Product Control Approval procedures. - Roofing tiles approved.
10	NATIONAL CONCRETE MASONRY ASSOCIATION. (NCMA)	NCMA publications list.
11	NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY. (NIST)	Answer by phone. Mr. Walter Rossiter said they have been investigating only with roofing membranes. Consequently, they don't have any information. They would like to help us, and also they want a copy of our report.
15	SOUTHERN BUILDING CODE CONGRESS INTERNATIONAL. (SBBCI)	They are presently finalizing the SBCCI Test Standard for Determining Wind resistance of Concrete or Clay Roof Tiles. As soon as the standards is completed they will send us a copy.

No	ORGANIZATION NAME	RESPONSE
1	**AMERICAN CONCRETE INSTITUTE. (ACI).**	They recommend to contact NCMA and BIA.
	AMERICAN SOCIETY FOR TESTING AND MATERIALS. (ASTM)	ASTM Publications list.
16	**THE ROOF CONSULTANTS INSTITUTE. (RCI)**	RCI Interface Newsletters. Mr. John Newark said they are willing to help us, and they want a copy of our report.

TABLE 4: Persons who responded to our request.

No	CONTACT PERSON	ANSWER
1	Mr. Joseph Minor, P.E. **University of Missouri-Rolla.**	- Mr. Minor research papers.
2	Mr. Thomas Lee Smith. Director of Technology and Research. **NATIONAL ROOFING CONTRACTORS ASSOCIATION.**	- Magazine's articles. - Changes to the SBC. - The NTRMA/FRSA specifications for mortar-set application. - SFBC. - The NRCA Step Roofing Manual. - ASTM standard for clay tile.
3	Mr. John Pistorino. **ROOF CONSULTANT.**	- Meeting.
4	Ms. Chris Septer. **SOUTH FLORIDA ROOFING CONTRACTORS.**	Answer by phone. She ask to the Tile Manufacturers in Florida to send us information about their products.

APPENDIX C

Bibliography - References & Products

APPENDIX C. Bibliography - References and Products

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Cash, Carl G. "The uplift of roofing materials," Roofs and Roofing: New Materials, Industrial Applications, Uses and Performance, Ed. J.O. May, England, Ellis Horwood Limited, 1988, 211-221.

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"Installation Guide," Bender Roof Tile Ind., Inc., P.O. Box 190, Belleview, Florida 32620

3. CANTERAS CERRO NEGRO S.A.
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12. VANDE HEY RALEIGH.
"Specification For Installing Vande-Hey Raleigh Tile To Sustain 120 MPH," Vande-Hey Raleigh, 1665 Bohm Drive, Little Chute, WI 54140.

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3. THORO SYSTEMS PRODUCTS.
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APPENDIX D

Annotated Bibliography

APPENDIX D. Annotated Bibliography i. Publications

Black, Clyde & Eichelberger, Robert "*Tile: Clay vs. Concrete,*" Florida Forum, August 1989, 12-18. In an interview for Florida Forum, Black of Monier and Eichelberger of American Clay Corporation discuss the common and relative merits of the two types of tile used in Florida today. They explain the manufacturing processes and physical characteristics of the two tile types. Some properties such as absorption rate and need for moistening to effect proper bond are discussed.

Cash, Carl G., " *The uplift of roofing materials,*" Roofs and Roofing: New Materials, Industrial Applications, Uses and Performance, J.O. May Ed., Ellis Horwood Limited, England, 1988, 211-221. Describes a laboratory test method for analysis of roofing material uplift resistance. Article is directed toward membrane roofs but wind lift values and general discussion are useful for comparison.

Gerhardt, Hans J. & Kramer, Carl, " *What are the effects of wind on tile roofs?,*" Professional Roofing, June 1993, R7-R10. Article gives results of extensive wind tunnel studies concerning the wind pressure distribution on pitched rrofs and around individual tiles. The influence of tile design and the use of underlay on batten space pressure, and therefore, on the net wind loads for common tile shapes are given. A strong rationale is developed for mechanically fastened tile.

Haig, J.R., "*Wind loads on tiles for USA - Final Report,*" Redland Technology Limited, New Technology and Product Development Center, Horsham, England, June 1990. A pre-Andrew study funded by the U.S. National Tile Roofing Manufacturers Association, Inc.
The report relates conditions of roof tile uplift from wind in the U.S. to those in the U.K. in earlier years. Recognition of tiling permeability and local aerodynamic effects led to findings which resulted in significant revisions of the British code quantifying wind loading and installation standards (codes) for roof tiles. Report proposed realistic and justifiable fixing specifications for roof tiles against severe wind conditions based on the British experience with mechanical fastening. The report advances proposals for the US tile industry.

Hazelwood, R.A., "*PRINCIPLES OF WIND LOADING ON TILED ROOFS AND THEIR APPLICATION IN THE BRITISH STANDARD BS5534,*" Journal of Wind Engineering and Industrial Aerodynamics, 6 (1980), Elsevier, Amsterdam, 113-124 is an analysis of pressures flowing over and under roof tiles applied in a nail-on batten manner. Projections of tile instability under extreme wind loading conditions are made. Tile coverings over underlay are used in analysis and the resulting data extended to non-underlay and wall cladding conditions.

Huff, Sam, CRC, "*Hurricane Andrew - Personal And Professional Impressions,*" RCI Interface Extra, Newsletter of The Roof Consultants Institute, Special Edition, p.2. discusses conditions which were responsible for structural damage to roofing. These conditions included securement of tile. The tiles on the majority of roofs in the area damaged by Hurricane Andrew were secured with mortar. Mechanical securement or hurricane clips were little used.

May, J.O., ed. "*The Uplift Of Roofing Materials,*" Roofs And Roofing: New Materials, Industrial, Applications, Uses, And Performance, Ellis Horwood Ltd, England, 1988. deals with adhered systems and tests for wind uplift on build up roofs.

McElroy, William C., "*Tile Roofing,*" Roof Builder's Handbook, Prentice Hall, Englewood Cliffs, New Jersey, 1993, p. 365 is a good general discussion of tile roofing materials, manufacturing and methods of application. It discusses the need to prepare mortar for roof tiles carefully to avoid problems with the tile-mortar bond. Text reviews ridge and rake tile applications with mortar but not full field installations.

Metro-Dade County, Florida, "*To The General Public,*" (Sept. 21, 1992). This public notice concerns the Emergency Ordinance of the Board of County Commissioners passed on September 15, 1992 regarding roofing methods and materials. It discusses the method of application of Cement and Clay Tile using mechanical fasteners.

Miller, Charles, "*Hurricane Warnings,*" Fine Homebuilding, December 1992, 82-84. A short but thorough plain language analysis of what went wrong and why. Hits the high points of both material and installation problems. Promotes nail-down as less vulnerable to poor workmanship and discusses some new manufacturer initiatives.

Minor, Joseph E., "*Performance of Roofing Systems in Wind Storms,*" Proceedings of the Symposium on Roofing Technology, Sept. 21-23, 1977. This article primarily discusses wind pressure as it acts on roofs during windstorms, and areas where failure occurs between building framework and roof system.

Pistorino, John C. "*Roof Tile Recommendations,*" January 5, 1993, unpublished letter. Sets forth insightful and important theory and recommendations for use of clay and concrete tiles in Dade County in the aftermath of Hurricane Andrew, including a brief background to the problems with the use of clay and concrete tile. Cites lack of bond between the mortar and tile surface as fundamental and discusses elements of poor workmanship and use of incompatible materials as reasons for the lack of bond. Interestingly, recognition of poor workmanship, while a problem, is not the key to a solution, and suggests materials themselves are the key factor in the loss of bond.

Pruter, Walter, "*Above and Beyond,*" Roofer Magazine, January 1989, 16-18. General discussion of roof tiles and need to install them properly. The "mudded-on" method is mentioned and type M or S mortar cited as appropriate. The need for mechanical fastening to supplement mortar bond in certain installations is emphasized.

Rastorfer, Darl, "*Roofing: A Pressing need For Commitment,*" Architectural Record, Feb. 1988, v. 176, n.2, p. 136. discusses the need for architects to pay attention to roofing design. "By far, the leading source of malpractice claims brought against architects is for the premature failure of roofs."

Rossiter, Walter J. Jr. "*Ninth Conference On Roofing Technology,*" National Institutes of Standards and Technology May 4-5, 1989, Journal of Research of the National Institute of Standards and Technology, Vol. 94, Number 5, Sept-Oct 1989 abstracts papers dealing with new roofing technology, including maintenance, insulation and vapor retarders and strength of adhesive bond in membrane roofing. Not relevant to the present study.

Schott, Tim "*Top-Of-The-Line Tile & Shake Roofing,*" Custom Builder, May 1990, p. 36. useful for data on the types of materials used on residential roofs and the percentage of their use.

Setzer, Steven W. and Richard Korman, "*Clocking Andrew$ Awful Gusts,*" ENR, November 23, 1992. discussed the standards for measuring peak wind gusts in storm conditions. Pointed out that the South Florida Building Code may have been too lenient on performance requirements for buildings because it did not contain a gust factor. Not otherwise relevant for the present study.

Siple, Dave, CRC "*Residential Roofing Failures,*" RCI Interface, Newsletter of The Roof Consultants Institute, p. 3Jan. 1993, This brief article is particularly relevant. It discusses typical modes of failure found in residential structures damaged by Hurricane Andrew. The article points out that "[t]he mud-on tile system is used almost exclusively in this region [South Florida]. The bonding of the tiles to the mortar is where the failure of the system usually occurs. The mortar usually bonds well to the surface of the #90 but not as well to the smooth surface of the back of the tiles."

Siple, Dave, CRC, "*The Effects of Hurricane Andrew on Buildings Located Near The Eye,*" RCI Interface Extra, Newsletter of The Roof Consultants Institute, Special Edition, p. 11, concluded that: "mud-on tile systems failed when there was no bonding of the mortar to the back side of the tiles," mechanical fastened roof tiles fared well.

Smith, Thomas Lee, "*Causes of Roof Damage and Roof Failure Modes: Insights Provided by Hurricane Andrew,*" describes 7 primary causes of the roof damage, and 10 modes of failure of roof systems. Causes include, design, code and testing deficiencies, and problems with application and deterioration of materials. Paper pointed out the modes of failure in clay and concrete systems, but rejects the idea of eliminating such material in hurricane prone areas because of their great aesthetic quality. Suggests exploring the use of high-ductility cement with tiles.

Smith, Thomas Lee, "*Roof Performance During High Wind Events,*" 25 January 1993, unpublished letter to Dade County ad hoc Roofing Committee. Discusses multiple causes for poor performance and makes recommendations for improvement. Includes proposed modifications to SBCCI specifically for roof tiles.

Unknown "*Storm Damage From Andrew Unveils Industry Short Cuts,*" ENR, September 7, 1992 quick, short blurb on what went Hurricane Andrew revealed was wrong with the South Florida construction industry.

Texas Tech Institute For Disaster Research "*Performance of Roofing Systems in Hurricane Hugo,*" discusses the experience of roofing systems in Hugo, but not directed to tile roofs since only clay and concrete tile roofs are not common in that area and only two were observed. More in depth as to the performance of other types of roofing.

Woods, A. R., "*Wind tunnel measurements on full scale roof tiles,*" to be presented at 2nd UK Wind Engineering Conference, Warwick University, 19-21 September 1994. Reports on work completed at Building Research Establishment, Garston, Watford in 1994. Study reinforces findings of model scale tests indicating high negative local pressures at the eaves, verge and ridge areas of tile installations and the overall flow dynamics. Work continues in a wider range of physical configurations

Wolfe, Ronald W., Ramon M. Riba, et al., "*Wind Resistance of Conventional Light-Frame Buildings,*" attributes failure of light-frame construction which resulted from Hurricane Andrew to misapplication of connections and missile damage rather than inadequate codes. Weakness in the attachment of roofing to roof sheathing was a common cause of damage, nevertheless no recommendations given as to methods of application or use of clay or cement tile.

Xianming, Kong, and Xu Zhaodong, "*Ancient Chinese Roofing Engineering,*" Roofs And Roofing: New Materials, Industrial, Applications, Uses And Performance. Ellis Horwood Ltd., England.

1988. historical study of ancient chinese roofing practices, methods and materials. Extensive discussion of tile development but nothing on bonding media other than mud.

Code Revisions:

A. 1993 Amendments (related to wind and roofing) in Chapter 32 of the Standard Building Code. Addresses wind loads and resistance to winds.

B. 1993 Amendments (related to wind and tiles) in Chapter 12 of the Standard Building Code. Relevant sections include:

1205.2.4.1	End Zones
1205.3	Roof Covering Systems
1205.3.1	Roof Deck
1205.3.2	Roof Coverings
1205.3.3	Rigid Tile
2505.5	Concrete and Clay Roof Tiles-Overturning Resistance
2505.6	Concrete and Clay Roof Tile-Wind Tunnel Testing
3207	Concrete and Clay Roof Tile
3207.1	General (Discusses material properties and characteristics to include tile and mortar.
3207.2	Cement Applied Tile
3207.2.1	Sub-roof Application
3207.2.2	Tile Installation

C. "South Florida Building Code 1988," Related sections:

3404	Cement and Clay Roof Tile
3404.1	Materials
3404.2	Application

D. "1989 Good Practice Specification adopted jointly by Florida Roofing Sheet Metal & Air Conditioning Contractors Association, Inc."

Division 7
07300 - Shingles and Roofing Tiles
320 - Roofing Tiles
Concrete Roofing Tiles Mortar-Set Specifications

Part I General
Part II Products
Part III Execution

This is a very detailed specification which <u>if followed</u> would result in high quality installations.

E. "South Florida Building Code 1994," Related Sections:

F. "The Redland Roofing Manual 1989 - A Guide to Good Practice and Redland Roofing Systems," Reigate Surrey, November 1988.

An outstanding comprehensive manual of practice for tile roofers. Although directed to installation of Redland products, there is much here which can be generalized for the industry as a whole. Professionally organized and richly illustrated, this manual shows what can be done to facilitate comprehension of process.

MANUFACTURER NAME: ALMAR.
TYPE OF TILE: CLAY.
WATER ABSORPTION: Avg. 1.28 %
BREAK STRENGTH: Avg. 710 Lbs.

I. **PRODUCTS.**

TILES	Altusa Spanish S
UNDERLAYMENT	30/90 Hot Mop
FASTENERS	
FLASHING	
ADHESIVE/ SEALANT	Asphaltic plastic cement heavy body composed of asphalt and other minerals, conforming to ASTM C-2822 and Federal Spec. SSC-153 type 1
MORTAR	1. Cements: a. Blended cement: conforming to ASTM C-91, Type M. b. Portland cement: conforming to ASTM C-150, Type I. c. Masonry cement: conforming to ASTM C-91, Type M. 2. Sand: conforming to ASTM C-144 uniformly graded, clean and free form organic materials. 3. Mixes: conforming to ASTM C-270, Type M Mortar (select one): a. Cement 1-a. b. Combination of cement 1-b and 1-c. 4. Mortar flow 110 + 5% conforming to ASTM C-230 Flow Table.
EAVE CLOSURE	**1. Clay eave closure** 2. Rubber eave closure. 3. Mortar filling with weep hole. 4. Metal closure.
COATING	
LUMBER	**1/2" minimum plywood sheathing.** Decking materials shall comply with local Building Codes.

II. EXECUTION.

LAYOUT	Horizontal and Straight bond methods.
EAVE TREATMENT	Eave drip metal shall be nailed or stapled along and directly on top of sheeting, fastened 6" o.c. and 1/2" in form top flange. At the eave line, clay, mortar, rubber or metal bird stop shall be used to boost the first row of tile.
TILE INSTALLATION	**In high winds areas, additional fasteners may be required at the eave course. Consult Local Building Codes.** Each tile shall be set over a full trowel of mortar placed directly under the projection of the flat side of the tile. Press tile down firmly to allow wet mortar to fill "Dove Tail Locks" for proper bond. **The area of tile coming in contact with the mortar must be wetted for a proper bond.**
FASTENING REQUIREMENTS	For pitches 4/12 and above nail eave course with one nail in addition to mortar. For pitches 6/12 up to and including 7/12, nail every third tile in every fifth course un addition to mortar. Apply plastic cement to seal all nail penetrations. For pitches above 7/12 nail every tile in addition to mortar.
HIP AND RIDGE	All hip and ridge tiles shall be set in a bed of mortar and **fastened with 2 1/2" nail.** It is then recommended that the mortar be pointed to a clean surface. **Tile should be cut along the hip boards. The joint between the cut tile and the hip nailer shall be sealed neatly with plastic cement.** **Where the tile overlaps flashing, tile must be secured with approved tile adhesive or cement in place.**
NAILER BOARDS	Install pressure tiles treated nailer boards where required for step roof pitch installation for use with hip and ridge.
RAKE/GABLE TILE	Fasten and cement all gable rakes at the horizontal guidelines.
RAKE GABLE FLUSH FINISH	
WALL ABUTMENTS	

VALLEYS	Tile must cut smooth and straight to maintain the proper with in the open valley. Width in the open valley may vary according to local conditions. It is recommended that the minimum width of exposed metal be 4".
PENETRATIONS	
COATINGS	
TILE REPLACEMENT	
OTHERS	**Pitches: 2 1/2 / 12 and greater (Refer to the Local Building Codes for minimum).** **Due to the vitrified surface of the field tiles, gloves are to be weared during the installation, to prevent small wunds in the hands.**

MANUFACTURER NAME: PIONEER.
TYPE OF TILE: CONCRETE
WATER ABSORPTION: Avg. 12 %
BREAK STRENGTH: Avg. 300 Lbs.

I. PRODUCTS.

TILES	Spanish S, Mission Barrel, Flat, Rustic Shake and Slate, Hacienda.
UNDERLAYMENT	30/90 Hot Mop
FASTENERS	Nails, Cap Nails, Staples, and Tin-Tags.
FLASHING	Minimum 26 gauge corrosion resistant metal or approved equal. (Refer to local codes).
ADHESIVE/ SEALANT	1. Asphaltic plastic roof cement - conforming to ASTM C-2822, Type II. Nonrunning, heavy body material composed of asphalt and other mineral ingredients. 2. Cold process liquid roof coating - conforming to ASTM D-3019, Type II. 3. Structural bonding adhesive - conforming to ASTM C-557 or ASTM D-3498. 4. Hot steep asphalt - conforming to ASTM D-312.
MORTAR	1. Cements: a. Blended cement: conforming to ASTM C-91, Type M. b. Portland cement: conforming to ASTM C-150, Type I. c. Masonry cement: conforming to ASTM C-91, Type M. 2. Sand: conforming to ASTM C-144 uniformly graded, clean and free form organic materials. 3. Mixes: conforming to ASTM C-270, Type M Mortar (select one): a. Cement 1-a. b. Combination of cement 1-b and 1-c. 4. Mortar flow 110 + 5% conforming to ASTM C-230 Flow Table.
EAVE CLOSURE	1. Prefabricated EPDM synthetic rubber conforming to ASTM C-1056. 2. Prefabricated minimum 26 gauge metal eave closure. 3. Mortar (color optional).
COATING	Paint - color coordinated paint for painting tile, flashing and/or accessories as required.

LUMBER	Note: Fire retardant treated material may require special consideration and special fasteners. A. Sheathing - Material to conform to APA minimum standards or local code approved equal. B. Nailer board - Pressure treated in accordance to local code requirements.

II. EXECUTION.

LAYOUT	Horizontal, Staggered/cross and Straight bond.
EAVE TREATMENT	a. Prefabricated eave closure - install closure strip along eave. b. Thickbutt tile - install thickbutt tile along eave. c. Mortar eave closure - start at lower lefthand corner (facing down roof). Install first course of tile elevating eave edge of tile with color coordinated mortar. Point and provide weep hole flush with deck to allow drainage and ventilation. d. Raised fascia/wood starter strip. 1. Install Type 30 felt. 2. Install fascia board approximately 1 1/2" above roof deck or 2 x 2 wood starter strip at roof edge. 3. Install tapered cant strip behind fascia/ starter strip to support metal flashing and mortar. 4. Install anti-ponding metal flashing of sufficient width to insure positive drainage over fascia/starter strip. Nail top edge of flange onto roof. 5. Apply 90# felt.

LOW PROFILE, HIGH PROFILE AND FLAT TILE INSTALLATION	Set tile in bed of type M mortar. Apply full 10" minimum length mason trowel full (approx. 4 to 5 pounds dry weight) of mortar vertically under pan/flat portion of tile. When tile has more than one pan/flat portion, place mortar under the pan closest to underlock of previously installed tile. For flat tile, place mortar adjacent to underlock of previously installed tile. Mortar should be placed from head of tile in previous course to within 2"-4" from head of tile being set. Make certain mortar is not placed under lugs, head of tile, or onto the underlock of adjacent tile which may create a tilted or cocked tile. Use half starter/finisher tile when provided cut/break tile for proper staggering of tile courses when using the staggered/cross bond method of installation. Set tile in stepped course fashion or in a horizontal and/or vertical fashion when utilizing straight bond method. Lay succeeding courses of field tile in same manner. Bed of mortar should make contact with head of the lower course of tile and underside of tile being set.
TWO-PIECE BARREL TILE INSTALLATION	Apply 10" mason's trowel full of mortar (approximately 4 to 5 pounds dry weight) vertically over chalk line and under center of each pan with narrow end facing down roof. Place mortar to make a two-tile bond between pan being set and pan below in previous course. Place bed of mortar along inside edges of pans and set covers with wide end facing down roof. Point mortar to next acceptable straight-edge finish insuring good strong contact along edges. Lay succeeding course of field tile in same manner. Bed of mortar should make contact with head of lower course of tile and under side being set.
FASTENING REQUIREMENTS	For pitches 4/12 and above nail eave course with one nail in addition to mortar. For pitches 6/12 up to and including 7/12, nail every third tile in every fifth course un addition to mortar. Apply plastic cement to seal all nail penetrations. For pitches above 7/12 nail every tile in addition to mortar. Elevation requirements - Tile installed 55' above grade or greater use two minimum hot dipped galvanized nails in addition to mortar.

HIP AND RIDGE	a.1. Miter tile as hip starter to match eave lines. a.2. Use standard hip tile as starter. b. Set hip and ridge tile in a continuous bed of mortar lapping tile a minimum 2". Point mortar and finish to match tile surface.
NAILER BOARDS	Install pressure tiles treated nailer boards where required for step roof pitch installation for use with hip/ridge and/or two piece barrel tile installation.
RAKE/GABLE TILE	a. Install first rake tile to the exposed length of the first course of field tile. Install factory finish end of tile toward eave. b. Nail rake tile with minimum of two hot dipped galvanized nails of sufficient length to penetrate framing minimum 3/4". c. Abut each succeeding rake tile to nose of field tile above and maintain constant headlap. d. Point with color coordinated mortar along inside edge to match tile surface.
RAKE GABLE FLUSH FINISH	a. Place color coordinated mortar bed along roof edge and set field tile in mortar flush with edge. b. Point smooth to straight edge finish.
WALL ABUTMENTS	Install tile adjacent to wall and fill voids with color coordinated mortar and finish to math tile surface.
VALLEYS	a. Closed Valley. 1. Miter tile to meet at center of valley. 2. Miter tile to form straight border on either side of two water diverters. b. Open Valley. 1. Miter tile to form straight border on either side of two water diverters. 2. Chalk a line minimum 2" on both sides valley center. Place bed of color coordinated mortar along outside edge of chalklines. Miter tile to form straight border and point to match tile surface. 3. Place minimum 2 x 4 on edge down center of valley. Apply continuous bed of color coordinated mortar along edge of 2 x 4. Install tile minimum 1" to approximately sistent through valley. Smooth and form mortar to match tile contour. After initial set
PENETRATIONS	Install tile to accommodate all roof penetrations and fill voids with color coordinated mortar and point to match tile surface.

COATINGS	
TILE REPLACEMENT	a. Damaged tile. 1. Break out and replace damaged roof tile. Do not disturb underlayment. Repair underlayment if necessary. 2. Apply minimum 1 square inch of approved adhesive on existing mortar bed. 3. Immediately set replacement tile in position assuring proper contact. b. Individual loose tile. 1. Elevate loose tile enabling application of a minimum 3/8" bead of approved adhesive at head of tile in previous course. 2. Immediately set loose tile in position assuring proper contact.
OTHERS	Traffic of any kind is not allowed on finished roof. Damage to roof tiles and/or subroof may result. Avoid activity by other trades which may affect the bond of tile for a minimum of 72 hours, i.e. installation of lath or any vibration of roof areas.

MANUFACTURER NAME: MONIER.
TYPE OF TILE: CONCRETE
WATER ABSORPTION: Meet or exceed codes requirements
BREAK STRENGTH: Meet or exceed codes requirements

I. PRODUCTS.

TILES	Villa, Roll, Mission "s", and Flat.
UNDERLAYMENT	30/90 Hot Mop
FASTENERS	Nails, Cap Nails, Staples, and Tin-Tags.
FLASHING	Minimum 26 gauge corrosion resistant metal or approved equal. (Refer to local codes).
ADHESIVE/ SEALANT	1. Asphaltic plastic roof cement - Conforming to ASTM C-2822, Type II. Nonrunning, heavy body material composed of asphalt and other mineral ingredients. 2. Cold process liquid roof coating - conforming to ASTM D-3019, Type II. 3. Structural bonding adhesive - conforming to ASTM C-557 or ASTM D-3498. 4. Hot steep asphalt - conforming to ASTM D-312.
MORTAR	1. Cements: a. Blended cement: conforming to ASTM C-91, Type M. b. Portland cement: conforming to ASTM C-150, Type I. c. Masonry cement: conforming to ASTM C-91, Type M. 2. Sand: conforming to ASTM C-144 uniformly graded, clean and free form organic materials. 3. Mixes: conforming to ASTM C-270, Type M Mortar (select one): a. Cement 1-a. b. Combination of cement 1-b and 1-c. 4. Mortar flow 110 + 5% conforming to ASTM C-230 Flow Table.
EAVE CLOSURE	1. Prefabricated EPDM synthetic rubber conforming to ASTM C-1056. 2. Prefabricated minimum 26 gauge metal eave closure. 3. Mortar (color optional).
COATING	
LUMBER	A. Sheathing - Material to conform to APA min. **Standards for min. 1/2" plywood.** B. Nailer board - Pressure treated in accordance to local code requirements.

II. EXECUTION.

LAYOUT	Straight bond method.
EAVE TREATMENT	a. Rubber closure - Apply front face of closure flush at eave edge for Villa, Flat and Roll tile, 1" from eave edge for Mission "S" tile for a max. 2" tile overhang. Adjust accordingly to accommodate up to a min. 3/4" overhang. Secure using min. 3 nails per closure strip long enough to penetrate through deck min. 3/4". Install one section at a time, prior to tile installation to determine correct alignment by using notches provided in closure. Closure to sit behind tile weatherchecks. b. Metal closure - Apply front face of closure flush at eave edge. Secure using nails 12" o.c. c. Mortar eave closure - Apply mortar horizontally along eave edge, insure enough mortar is used to elevate the eave end of tile on profile with the rest of the roof tiles. Apply min. 3/8" weep hole flush with roof deck min. 1 weep hole per tile. d. Raised fascia/wood starter strip. 1. Install fascia board approximately 1 1/2" above roof deck or 2 x 2 wood starter strip at roof edge. 2. Install tapered cant strip behind fascia/ starter strip to support metal flashing and mortar. 3. Install anti-ponding metal flashing of sufficient width to insure positive drainage over fascia/starter strip. Nail top edge of flange onto roof.
LOW PROFILE, HIGH PROFILE AND FLAT TILE INSTALLATION	Starting at lower left corner (facing down roof). Set tile in bed of type M mortar. Apply full 10" minimum length mason trowel full (approx. 4 to 5 pounds dry weight) of mortar vertically under pan/flat portion of tile **(with point of the trowel facing up roof - recommended not mandatory)**. Position mortar from head of tile in stepped course of vertical fashion maintaining consistent headlap. Cut/break tile to form a straight edge at center of hip/ridge or to meet wood nailers. Tile overhang at eave should be min 3/4' application of mortar to exposed roof areas.
TWO-PIECE BARREL TILE INSTALLATION	

FASTENING REQUIREMENTS	For pitches 4/12 and above nail eave course with one nail in addition to mortar. For pitches 6/12 up to and including 7/12, nail every third tile in every fifth course un addition to mortar. Apply plastic cement to seal all nail penetrations. For pitches above 7/12 nail every tile in addition to mortar. Elevation requirements - Tile installed 55' above grade or greater use two minimum hot dipped galvanized nails in addition to mortar.
HIP AND RIDGE	Set over field tile in continuous edge bedding of mortar lapping each tile min. 1". Point and finish to match tile surface. **Install each tile using one 8d. HDG nail driven into nailer in addition to edge bedding of mortar or Monier peel and stick tape.**
NAILER BOARDS	Install pressure tiles treated nailer boards where required for step roof pitch installation for use with hip and ridge.
RAKE/GABLE TILE	Nail rake tile with minimum of two 10d HDG corrosion resistant nails to penetrate framing minimum 3/4". after installing first and last row of field tiles at verge. Cut head of first rake tile to abut second course of field tile and position inside edge into flat portion of field tile. Where field tile makes contact with rake tile, point in mortar to match tile finish. Maintain constant headlap.
RAKE GABLE FLUSH FINISH	
WALL ABUTMENTS	Cut/break tile to fit adjacent to wall base. Place mortar along base of wall to fill any small voids between tile and wall and to provide consistent line along wall. Point to match tile contour.

VALLEYS	a. Closed Valley - Miter tile to meet at center of valley. b. Open valley. 1. Chalk parallel lines min. 2" on both sides of valley center. Place mortar bed along outside edge of chalklines. Miter tile to form straight border and point to match tile surface. 3. Place minimum 2 x 4 on edge down center of valley. Apply continuous bed of color coordinated mortar along edge of 2 x 4. Install tile minimum 1" to approximately sistent through valley. Smooth and form mortar to match tile contour. After initial set.
PENETRATIONS	Install tile to accommodate all roof penetrations and fill voids with color coordinated mortar and point to match tile surface.
COATINGS	Acrylic sealer for pointing exposed mortar (optional).
TILE REPLACEMENT	a. Damaged tile. 1. Break out and replace damaged roof tile. Do not disturb underlayment. Repair underlayment if necessary. 2. Apply minimum 1 square inch of approved adhesive on existing mortar bed. 3. Immediately set replacement tile in position assuring proper contact. b. Individual loose tile. 1. Elevate loose tile enabling application of a minimum 3/8" bead of approved adhesive at head of tile in previous course. 2. Immediately set loose tile in position assuring proper contact.
OTHERS	**Roof trafficking - when absolutely necessary to traverse roof, walk on the tile headlap (overlap) in a horizontal or diagonal fashion. Refrain from vertical movement where possible.**

MANUFACTURER NAME: BENDER.
TYPE OF TILE: CONCRETE
WATER ABSORPTION: Meet or exceed SFBC and SBCCI requirements.
BREAK STRENGTH: Meet or exceed SFBC and SBCCI requirements.

I. PRODUCTS.

TILES	Palema "S", Nordic Flat, and Nordic Slate.
UNDERLAYMENT	a. **Slope 2 1/2 / 12 to 3/12 : (1) layer type 30lb. felt, mop (1) layer type 15 lb.'s felt hot mopped to 1st layer, (1) layer of type 90 lb. mineral surface rolled roofing mopped to type 15 felt.** b. Slope 3/12 to 6/12 : (1) layer type 30 lb. felt, (1) type 90 lb. mineral surfaced rolled roofing hot mopped to 30 lb. felt. (90 lb. should be back nailed).
FASTENERS	Nails, Cap Nails, Staples, and Tin-Tags.
FLASHING	Minimum 26 gauge corrosion resistant metal or approved equal. (Refer to local codes).
ADHESIVE/ SEALANT	
MORTAR	1. Cements: a. Blended cement: conforming to ASTM C-91, Type M. b. Portland cement: conforming to ASTM C-150, Type I. c. Masonry cement: conforming to ASTM C-91, Type M. 2. Sand: conforming to ASTM C-144 uniformly graded, clean and free form organic materials. 3. Mixes: conforming to ASTM C-270, Type M Mortar (select one): a. Cement 1-a. b. Combination of cement 1-b and 1-c. 4. Mortar flow 110 + 5% conforming to ASTM C-230 Flow Table.
EAVE CLOSURE	1. Prefabricated EPDM synthetic rubber conforming to ASTM C-1056. 2. Mortar (color optional).
COATING	Acrylic Colored Sealer.
LUMBER	Sheathing - minimum 1/2" plywood sheathing.

II. **EXECUTION.**

LAYOUT	Horizontal, Staggered/cross and Straight bond.
EAVE TREATMENT	a. Prefabricated rubber eave closure. b. Mortar eave closure (color optional).
LOW PROFILE, HIGH PROFILE AND FLAT TILE INSTALLATION	Set tile in bed of type M mortar. Apply full 10" minimum length mason trowel full (approx. 4 to 5 pounds dry weight) of mortar under pan/flat portion of tile. Approximately 2" from eave and to within 3" to 4" from the head of the tile. **Each tile should be pressed down in the interlocking position so that the overlook rests firmly against the underlock of the adjacent tile.** Use half tile (starter/finisher) for proper staggering of tile courses when using the staggered/cross bond method of installation. (Nordic "flat" only). Set tile in a horizontal and/or vertical fashion when utilizing straight bond method. (Palema Profile). Lay succeeding courses of field tile in the same manner. The bed of mortar should make contact with the head of the lower course tile and the underside of the tile being set.
TWO-PIECE BARREL TILE INSTALLATION	
FASTENING REQUIREMENTS	**For pitches greater than 6/12 nail all courses with one nail per tile in addition to mortar. Apply plastic cement where nail penetrates underlayment.** **For pitches 7/12 and above refer to nail-on system recommendations. (Refer to local code requirements).**
HIP AND RIDGE	a.1. Miter tile as hip starter to match eave lines. a.2. Use standard hip tile as starter. b. Set hip and ridge tile in a continuous bed of mortar.
NAILER BOARDS	Install nailer boards for use with hip/ridge tile installation.
RAKE/GABLE TILE	Install first rake tile to the exposed length of the first course of field tile. Nail rake tile with minimum of two nails per tile.

RAKE GABLE FLUSH FINISH	**Place a sealant (Caulk) bed between the edge of the rake tile and field tile.**
WALL ABUTMENTS	
VALLEYS	
PENETRATIONS	
COATINGS	Acrylic sealer for pointing exposed mortar (optional). **For color coordinating flashing and accessories as required.**
TILE REPLACEMENT	Use tile glue (adhesive) a. For nominal damaged tile replacement. b. Re-adhering nominal loose tiles.
OTHERS	**Hurricane clips required on all eave tiles in areas subject to hurricane winds. Check with local code officials regarding compliance with local building codes.**

MANUFACTURER NAME: LIFETILE.
TYPE OF TILE: CONCRETE
WATER ABSORPTION: Meets ICBO Code.
BREAK STRENGTH: Meets ICBO Code.

I. PRODUCTS.

TILES	Espana, Capri, Sierra Shake and Super Shaketile, Colonial Slate and Shingle Blends.
UNDERLAYMENT	30/90 Hot Mop
FASTENERS	Nails, Cap Nails, Staples, and Tin-Tags.
FLASHING	Minimum 26 gauge corrosion resistant metal or approved equal. (Refer to local codes).
ADHESIVE/ SEALANT	
MORTAR	
EAVE CLOSURE	**1. Lifetile eave Riser/Closure strip.** 2. Nominal 2" x 2" wood starter strip. 3. Fascia raised 1 1/2" with metal flashing. 4. Fascia raised 1 1/2" with cant strip.
COATING	Color coordinated mortar. Consult a Lifetile representative for more information on color coordinated details.
LUMBER	Sheathing - Minimum 1/2" plywood.

II. EXECUTION.

LAYOUT	Horizontal and Staggered/cross method.
EAVE TREATMENT	
LOW PROFILE, HIGH PROFILE AND FLAT TILE INSTALLATION	4 to 5 lb. mortar pad set under pan section of tile on Capri on pan section closest to overlapping lug. Minimum headlap 2".
TWO-PIECE BARREL TILE INSTALLATION	
FASTENING REQUIREMENTS	**In areas designated by the local building departments as being subject to repeated wind velocities in excess of 80 MPH or where height exceeds 40 feet above grade, all tiles shall be attached in accordance with building codes or as set forth as follows, whichever is more restrictive:** **- The heads of all tiles shall be nailed.** **- The noses of all eave course tiles shall be fastened with a special Lifetile Grip Clip.** **- All rake tiles shall be nailed with two nails.** **- The noses of all ridge, hip and rake tiles shall be set in a bed of approved roofers' mastic.** **- Tiles cut too small for nailing should be set with approved roofers' mastic and/or wired into place.**
HIP AND RIDGE	**- Ridge nailer to be of sufficient height to maintain even plane of ridge tiles.** **- Underlayment carried over ridge nailer.** **- One nail per ridge tile of sufficient length to penetrate nailer 1".** **- Optional mortar fill end treatment.** **- Provide minimum 3" headlap.** **- Apply continuous bead of approved roofers' mastic at overlapping areas.** **Note: 1/8" weep hole through mortar in every water course.**
NAILER BOARDS	Install nailer boards for use with hip/ridge tile installation.

RAKE/GABLE TILE	- **Continuous bead of approved roofers' mastic at overlapping areas optional.** - **Factory finished butt end exposed (Place thick end toward ridge.** - **Butt rake tiles to course above.** - **Cut off head of first rake tile so factory finished butt end is flush with eave course tiles.** - **Two nails per rake trim of sufficient length to penetrate nailer 1".**
RAKE GABLE FLUSH FINISH	
WALL ABUTMENTS	Remove portion of tile headlug where tile rests on metal flashing to prevent water damming.
VALLEYS	Remove portion of tile headlug where tile rests on metal flashing to prevent water damming.
PENETRATIONS	- Apply 4 - 5 lb. mortar pad. - North tile to accept stack. - Install a standard G.I. top flashing and seal with approved roofers' mastic. - For Espana and other higher profile tiles, use lead or other flexible type flashing, minimum 18" skirt around roof projection. Attach to tile with approved roofers' mastic.
COATINGS	
TILE REPLACEMENT	
OTHERS	**Roof pitches below 4/12: Tiles to be considered as decorative only.**

MORTARS

MANUFACTURER NAME: SIKA.

PRODUCT	DESCRIPTION	USAGE	ADVANTAGES
SIKADUR 32, HI-MOD AND HI-MOD LPL	High modulus, high strength, epoxy/bonding grouting adhesive.	Structural adhesive for concrete, masonry, metal, wood, etc.	Super-strength bonding/grouting adhesive. Excellent adhesion to most structural materials.
SIKADUR 31, HI-MOD GEL	High modulus, high-strength, structural epoxy paste adhesive.	Structural bonding of concrete, masonry, metals, wood, etc. to a maximum glue line of 1/8 in.	Insensitive to moisture before, during, and after cure. Excellent adhesion to concrete, masonry, metals, wood, and most structural materials.
SIKADUR 22, LO-MOD	Low modulus, medium viscosity, epoxy resin binder.	Binder resin for epoxy mortar and concrete for patching and overlays.	Insensitive to moisture both before and after cure. Excellent strength development.
SIKATOP 111/121 /122.	Polymer-modified, portland-cement.	On grade, above, and below grade on concrete and mortar.	Bond strength insures superior adhesion. High early strengths. Simple to use. Fast setting. High compressive flexural strengths. Open to traffic fast.
SIKACEM 830	Latex/silica fume admixture for portland cement mortar and bonding slurry.	Bonding slurry additive. Admixture for portland cement mortar to improve physical properties.	Improves adhesion. Lowers permeability. Increases compressive, tensile, and flexural properties. Reduces absorption of water and chlorides. Improved workability.
SIKA-LATEX	Acrylic latex bonding agent admixture for portland cement mortar and concrete.	As bonding grout when mixed with sand and portland cement.	Improved adhesion to prepared substrates. Increases adhesive strength of mortar/ concrete when used as a bonding agent or as a bonding grout.

MANUFACTURER NAME: THORO SYSTEMS PRODUCTS.

PRODUCT	DESCRIPTION	USAGE	ADVANTAGES
ACRYL 60	Acrylic polymers and modifiers to use as an additive for portland cement mixes.	As an admixture to portland cement-base mixes. Cement mixes prepared with Acryl 60 are suitable for exterior or interior use when a hard tough, fast-curing surface is required.	Improve adhesion and mechanical properties to portland cement. To add extra bonding qualities when application is to be made over dense concrete or masonry.
THORO-CRETE.	A one-component, dry polymer modified cement-based patching material for concrete and masonry.	Patching concrete floors, driveways, sidewalks, steps, patios; patching concrete curbs, gutters, spalled horizontal concrete areas; leveling low spots in concrete slabs. As a setting bed for patio locks, flagstones, quarry tile, etc.	Is self-bonding, easy to apply and requires only the addition of clean water. Lower shrinkage and higher strength for mortars. Excellent bond to clean, structurally sound concrete, good color retention and self-curing.
THORO-RITE 400	A low-slump, cement based, polymer-modified, patching mortar for architectural concrete.	It is a fast-setting mortar with low slump properties suitable for trowel application to above grade, vertical, overhead or non-traffic bearing, horizontal surfaces without using formwork.	Modified with Acryl 60 diluted with water permanently bonds to properly prepared architectural concrete and masonry substrates to form durable, long-lasting patches which are waterproof to wind-driven rain.

MANUFACTURER NAME: W.R. BONSAL.

PRODUCT	DESCRIPTION	USAGE	ADVANTAGES
VINYL CON-CRETE PATCHER	Polymer modified cement repair material.	Chipped, spalled, scaled, and broken concrete tile roofs, driveways, ramps, etc.	Bonds to existing concrete and Masonry. Exceptional strength, twice that of concrete.
INDUS-TRIAL MORTAR MIX	A mixture of masonry cement and sand.	Brick, Block, Structural clay tile, Stone.	Eliminates problems of job-mixed mortar and stucco. Meets ASTM C-270 specifi-cations for Types N,S, or M mortar.
SAKRETE MORTAR MIX	A mixture of sand and mortar cement. Quality controlled. Design strength 1250 psi.	For laying brick, stone, block, pointing and stuccoing.	Exceeds ASTM C-387 for Type N mortar.
ACRYLIC ADDI-TIVE	Liquid acrylic polymer specifically designed as an additive for cement based products.	Cement based repair materials, Stucco, Masonry coatings, Mortar, Scratch and Brown coats, Plaster, Tile Grout, Surface bonding cements.	Increased bond strength. Outstanding abrasion and water resistance. Improves workability. Reduces shrinkage, cracking, and premature drying.
118 PRIMER	Liquid co-polymer used as a primer or bonding adhesive for cement based materials.	For use over concrete, mosaic, tile, quarry tile, brick, block, clay products, surface bon-ding cement, stone, con-crete masonry.	Increased bond strength. Works over difficult to adhere to substrates. Improves hydration and curing. Improves workability.

NOTE: According to the Manufacturer, these products has been used in the roofing industry.

MANUFACTURER NAME: ANTIHYDRO INTERNATIONAL.

PRODUCT	DESCRIPTION	USAGE	ADVANTAGES
A-H TILE MORTAR No. 813	A trowelable cementitious tile mortar.	For grouting new or repairing existing tile roof, where high bond, compressive and tensile strengths are required.	Excellent adhesion to all concrete and masonry surfaces.
A-H P.V.A. BONDER	Non-flammable, non-toxic, resin emulsion.	For bonding concrete, cement plaster, gypsum plaster, and stucco to all types of structurally sound materials.	It is the most economical method of bonding to concrete, tile, metal, wood, glass, and hard board.

NOTE: According to the manufacturer, these products are suitable for tile roofing.

MANUFACTURER NAME: LARSEN PRODUCTS CORP.

PRODUCT	DESCRIPTION	USAGE	ADVANTAGES
WELD-CRETE	Chemical concrete bonding agent.	For exterior and interior use. Bonds concrete, portland cement plaster, and cementitious mixes to structurally sound concrete floors, walls, columns, etc. Bonding to setting beds of ceramic tile, brick, block, and stucco mixes.	Improve bonding strength.
ACRYLIC ADMIX 101	Bonding agent.	For interior and exterior use. New concrete, portland cement plaster, and mortar mixes.	Improve bonding strength. Excellent water and weather resistant. Improve curing qualities. Reduces shrinkage cracking.

MANUFACTURER NAME: MAPEI CORPORATION.

PRODUCT	DESCRIPTION	USAGE	ADVANTAGES
GRANI/RAPID	Fast-setting latex hydraulic mortar.	For interior and exterior use. Ceramic tile, marble, and granite installation.	Excellent bonding and mechanical properties that make it resistant to impact, vibration, temperature changes, and ageing. Low shrinkage and quick hydratation characteristics allow tile surfaces to be ready for traffic in about 3 hours.
KERA-BOND	Portland cement with chemical additives mortar.	Interior and exterior use. Floors and wall dry-set.	Outstanding bond strength. Excellent sag resistance and adjustability.
KERA-LASTIC	Polymer additive designed to be used with KERABOND dry-set mortar.	Interior and exterior use. Floors and wall dry-set.	Increased bond strength. Improved vibration and impact resistance.
PLANI-CRETE W			
KERAPLY			
PLANI-CRETE 50	Multipurpose latex additive for leveling and priming.	For thick bed mortars and levelling coats. For latex cement bond coat. For a primer-sealer. As an additive to dry-set mortars.	Increase adhesion of the levelling or setting mortar prior to setting tiles.

NOTE: Kerabond/Keralastic mortar system should be used together.

MANUFACTURER NAME: E-POXY INDUSTRIES.

PRODUCT	DESCRIPTION	USAGE	ADVANTAGES
BONDER # 1	100% solid, two component modified epoxy adhesive.	For bonding cured concrete to cured concrete, steel, wood, or other construction materials.	Excellent bonding strength.
FLEX BOND # 11	Two-component elastomeric epoxy adhesive.	For bonding concrete, steel, and most material without a primer.	Excellent resistance to moisture and abrasion.
EVA-POX QUICK GEL # 24.	100% solid, non-shrink, two-part epoxy adhesive.	To be used as a fast-setting seal for vertical and horizontal surfaces for structural cracks.	Fast-setting. Excellent bond to moist and dry concrete.
EVA-POX EPOXY PASTE # 22.	100% solid, two-component, moisture insensitive, highly thixotropic epoxy paste.	Patching vertical and horizontal surfaces. Sealing crack and injection ports for concrete injection. The filler adhesive for bonding precast components.	Excellent adhesion to old and fresh concrete, steel, wood and damp surfaces. Is flexible enough to eliminate cracking and bowing due to shrinkage and thermal cycling stresses.
CEVA GROUT 10.	Three component, 100% solid, non-shrink epoxy based grout.	To seat base plates for heavy machinery and precast concrete beams.	It will bond two hardened surfaces together providing monolithic restoration/assembly. No preconditioning of components required. High impact resistance. High compressive strength.

MANUFACTURER NAME: DAYTON SUPERIOR.

PRODUCT	DESCRIPTION	USAGE	ADVANTAGES
DAY-CHEM AD BOND (J-40)	A non-reemulsifiable acrylic latex emulsion.	For use as a bonding agent or admixture for grouts, patches, mortars and masonry coatings. For bonding new to new or new to old concrete in interior or exterior applications.	Excellent bonding agent or admixture for numerous concrete applications. Interior and exterior use. Improve patches, masonry coatings, grouts, mortars, etc.
SUPERIOR CONCRETE BONDER (J-41)	A reemulsifiable/ rewettable polyvinyl acetate (PVA) emulsion.	For use as a bonding agent or admixture for grouts, patches, mortars, stucco and plaster. For bonding new to new or new to old concrete in interior or exterior applications.	Excellent for use in bonding mortar beds for setting tile and terrazzo. Promotes a strong bond. Improves the curing, long term durability and resistance to cracking of the finished product.
ANKER-TITE CEMENT	A dry cementitious product.	To set fence posts, sing posts, wood or metal in the ground or in concrete. To anchor bolts, rods, machinery mounts, railing.	Provides a fast, early strength anchoring cement. The mixed cement will achieve final set in ten to thirteen minutes, will reach a compressive strength of over 3,000 lbs. in one hour.

SURE-GRIP	High performance cement-based grout.	For interior and exterior grouting of architectural and structural precast concrete components, structural column base plates, machinery bases, anchoring bolts, cable anchorages, dowels, bearing pads, keyway joints and crane rails.	High compressive strength quickly. Non-shrink, non-corrosive, non-metallic, High density, high fluidity. Resist water and salt penetration damage.
SURE-GRIP UTILITY GROUT	A premixed construction grout containing selectively-graded silica sand, portland cement, and density and expansion controlling admixtures.	For grouting architectural precast components, machinery bases, anchoring bolts and columns base plates. It can also be used as a patching material for minor repairs or filling tie holes in poured concrete.	Non-shrink, non-corrosive, non-metallic, high flow. Provide an effective load bearing surface through its property of controlled expansion.
HD-50	Latex-modified, fiber reinforced, fast, setting, heavy duty concrete patch.	In areas where a rapid strength gain is required to minimize downtime. For the repair of heavy-duty surfaces such as concrete highways, freezer rooms, industrial and warehouse floors, and loading docks.	Bondable and compatible with portland cement concrete. High compressive strength. Can be open to traffic within 60 minutes.
DAY-CHEM PERMA PATCH	A fast-setting, fiber reinforced, heavy duty concrete patch.	In areas where a rapid strength gain is required to minimize downtime. For the repair of heavy-duty surfaces such as concrete highways, bridge decks, parking structures, airport runways, freezer rooms, industrial and warehouse floors, and loading docks.	Bondable and compatible with portland cement concrete. High compressive strength. Can be open to traffic within 60 minutes. Non-shrink, non-corrosive. Requires only water to mix.

Metro-Dade County Building Code Compliance Office PROTOCOLS:

- "Protocol PA 100-94, Wind Driven Rain Test Procedures For Discontinuous Roof Systems," 1994, a testing procedure to determine water infiltration resistance of discontinuous roof systems to wind driven rain.

- "Protocol PA 101-94, Static Uplift Test Procedure For Mortar or Adhesive Set Tile Systems," 1994, determines average weight of tile, restoring moment provided by the tile's weight, minimum resistance load and attachment resistance of mortar or adhesive bond.

- "Protocol PA 102-94, Static Uplift Test Procedure For Mechanically Attached, Rigid Roof Systems," 1994, determines average weight of rigid component, restoring moment, minimum resistance load and resistance of mechanical attachment.

- "Protocol PA 102(A)-94, Static Uplift Test Procedure For Mechanically Attached, Clipped, Rigid, Roof Systems," 1994, determines average weight of rigid component, restoring moment, resistance load and resistance of mechanical and clipped attachment.

- "Protocol PA 103-94, Test Procedure For Self-Adhered Underlayments For Use in Discontinuous Roof Systems," 1994, tests self-adhered, prefabricated, reinforced, polymer modified bituminous, and solid thermoplastic sheet roofing underlayment materials which assist in waterproofing of discontinuous roof systems.

- "Protocol PA 104-94, Test Procedure For Nail-On Underlayments For Use In Discontinuous Roof Systems," 1994, tests mechanically attached, prefabricated, reinforced, polymer modified bituminous, and solid thermoplastic sheet roofing underlayment materials which assist in waterproofing of discontinuous roof systems.

- "Protocol PA 105-94, Withdrawal Resistance Test Procedure," 1994, tests whether a particular mechanical fastener used to attach insulation, membrane and discontinuous roofing components to substrate provides sufficient resistance to static uplift.

- "Protocol PA 106-94, Field Static Uplift Test For Mortar OR Adhesive Set Tile Systems And Mechanically Attached, Rigid, Discontinuous Roof Systems," 1994, tests sufficiency of in-place applications for mortar or adhesive bonds in set tile systems and mechanical attachment for rigid, discontinuous roof systems.

- "Protocol PA 107-94, Test Method For Wind-Resistance of Asphalt Shingles," 1994, tests resistance of asphalt shingles to wind blow-up or blow-off.

- "Protocol PA 108-94, Wind Tunnel Testing For Air Permeable, Rigid, Discontinuous Roof Systems," 1994, determines coefficients of pressure along the top and bottom surfaces of the component; the coefficient of lift and moment, and aerodynamic multiplier in systems which are air permeable and in which the unsealed, overlapping, rigid components are between 1.0 and 1.75 feet in length, 0.73 and 1.25 feet in exposed with, and not thicker than 1.3 inches.

- "Protocol PA 109-94, Spray Applied Polyurethane Roof Systems, Application, Testing And Quality Control," 1994, test appropriate substrate environmental conditions for use of polyurethane roof systems.

- "Protocol PA 110-94, Physical Property Requirements of Roof Membranes, Insulation materials, Membrane Coatings And Other Roofing Components," 1994, lists ASTM Standards for asphalt built-up roof system components.

- "Protocol PA 111-94, Attachment of Perimeter Flashing And Wood Blocking," 1994, overview of perimeter and corner roof area design pressure determinations, minimum criteria for material fabrication and attachment of metal and attachment of woodblocking.

- "Protocol PA 112-94, Standard Specification For Concrete Roof Tiles," 1994, specifications for concrete roof tiles manufactured from Portland cement, water and mineral aggregates.

- "Protocol PA 112-94, Appendix A, Clarification of Testing Frequency And Sampling Method," 1994, defines frequency of testing and methods of sampling.

- "Protocol PA 113-94, Alternate Fasteners For Attachment of Asphalt Shingles To Nailable Decks Other Than Wood," 1994, conditions of shingle attachment to approved nailable deck, includes guide of fastener types.

- "Protocol PA 114-94, Standard 4450/4470, As Modified For The South Florida Building Code," 1994, fire, wind, hail, leakage, and metal corrosion standard details requirements for the approval of membrane systems; includes general glossary of terms which apply to other protocols.

- "Protocol PA 115-94, Attachment Calculations For Air Permeable, Rigid, Discontinuous Roof Systems," 1994, attachment calculations and procedures for attachment of a particular air permeable, rigid, discontinuous roof system on a particular building in SFBC jurisdiction.

- "Protocol PA 116-94, Air Permeability Testing For Rigid, Discontinuous Roof Systems," 1994, limited to manufactures of rigid, discontinuous roof systems who desire to have systems tested for wind characteristics in compliance with Dade County Protocol PA 108.

- "Protocol PA 117-94, Bonding or Mechanical Attachment of Insulation Panels to Various Substrates," 1994, recommendations for mechanical attachment and adhesive or bitumen bonding of insulation to steel, concrete, gypsum, cementitious wood fiber, lightweight concrete, and wood decks.

- "Protocol PA 118-94, System #2: Model Nail On Tile Specification Including Approved Underlayment Assemblies And Standard Flashing Details," 1994, model specification for installation of mechanically fastened tile system; includes table with choices of underlayment systems.

- "Protocol PA 119-94, System #1: Model Nail On Tile Specification Including Approved Underlayment Assemblies And Anti-Ponding Flashing Details," 1994, model specification for installation of mechanically fastened tile systems; includes table with choices of underlayment systems.

- "Protocol PA 120-94, System #3: Model Mortar or Adhesive Set Tile Specification Including Approved Underlayment Assemblies," 1994, provides a model method by which mortar or adhesive set tile systems can be installed; table illustrates choices available for underlayment systems.

- "Protocol PA 121-94, Requirements For Testing And Approval of Roofing Adhesives, Mastics And Coatings," 1994, procedures for adhesive, mastic and coating testing and approval process.

- "Protocol PA 122-94, Repairs of Existing Bituminous Roof Systems," 1994, repair and coating procedures for existing built-up bituminous membrane roof systems to extend roof life.

- "Protocol PA 123-94, Standard Specification For Mortar Used In Mortar Set Tile Systems," 1994, testing, and approval procedures for mortar used in set tile systems.

- "Protocol PA 124-94, Field Uplift Test Procedure For Existing Membrane Roof Systems," 1994, determines resistance to uplift pressure of newly installed, adhered, built-up bituminous roof systems over mechanically attached or adhered rigid insulation over various deck types.

- "Protocol PA 125-94, Standard Specification For Metal Roofing Systems," 1994, testing requirements for structural and non-structural (architectural) metal roof systems, and approval process; establish criteria for water infiltration resistance, impact, cyclic and uplift loading.

- "Protocol PA 126-94, Standard Procedures For Roof Moisture Surveys," 1994, provides non-destructive testing for moisture and subsequent destructive testing to confirm moisture content in roof assemblies.

- "Protocol PA 127-94, Standard Procedure For Determining Applicability of Tile System Installation," 1994, guidelines for

Uniform Building Permit applicants to determine whether a particular method of attachment may be utilized to install an approved tile system on a particular exposure 'C' building.

- "Protocol PA 128-94, Standard Procedure For Determining Applicability of Low Slope Roof System Assembly Installation," 1994, guidelines for Uniform Building Permit applicants to determine whether a particular approved low slope roof system may be installed in a particular exposure 'C' building.

- "Protocol PA 129-94, Standard Property Requirements For Liquid Applied Acrylic Roof Coating Used in Roofing," 1994, addresses lab testing of liquid-applied, water-dispersed 100% acrylic emulsions for roof coating to extend the life of the roof system.

- "Protocol PA 130-94, Standard Procedure For Determining Applicability of Asphalt Shingle System Installation," 1994, guideline for Uniform Building Permit applicants to determine an approved asphalt shingle system may be installed on a particular building.

APPENDIX E

Metro-Dade Approved Roof Tile Companies

APPENDIX E. Metro-Dade Approved Roof Tile Companies

APPROVED ROOF TILE COMPANIES

Revised 22 July 94

ALTUSA TILE: (Nail-On or Mortar Set System)

Alfareria del Turbio, S.A. (Altusa) 94-0106.18
Barquisimeto, Venezuela

Carlos Fernandez
Almar USA
6645 NW 77 Avenue
Miami, Florida 33166
Phone 471-5830
Fax 471-5833

ClayTile: Altusa "S" Elegant
Altusa Barrel

(Mortar Set Systems)
Clay Tile: Altusa "S" Elegant

ALFARERIA EL VOLCAN: (Nail-On or Mortar Set Systems)

Francisco Angulo 94-0106.31
Prodek Distributer
Hacienda El Volcan
Santa Lucia, Estado Miranda, Venezuela

Prodek
1101 Brickell Ave., Ste, 401
Miami, FL 33131
Phone 358-7251
Fax 358-7323

Clay Tile: Volcan "S"Clay Barrel
(Alfareria El Volcan)-

ARCHITEX, S.A.

De C.V. 93-1027.09
San Salvador, El Salvador, C.A.

(Mortar-set System)
Clay Tile: Arcitex Spanish "S"

Best Clay Roof & Tile Co.
2720 SW 37 Avenue
Miami, Florida Ph 826-8080

ALFARERIA HISPANO VENEZOLANA, C.A.

Carretera Vieja entre 94-0525.02
Los Guayos y Guarcara
Valencia, Venezuela

(Nail-On or Mortar-set System)
Clay Tile
Alfareria Spanish "S"

Tinaquillo Tile Corp
Miami, Fla Ph 716-0107

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ALFARERIA IN DUSTRIAL, S.R.L.
El Roble 94-0523.16 (Nail-On or Mortar-set System)
Los Guayos Clay Tile:
Valencia, Venezuela Spanish "S"

Best Clay Roof & Tile Co.
2720 SW 37 Ave
Miami, Florida Ph 826-8080

Coma Cast Corporation
4383 SW 70 Court
Miami, Florida Ph 665-3665

ALFAREIA TINAQUILLO,C.A.
Carretera Nacional Valencia-San Carlos 94-0525.01 (Nail-On or Mortar-set System)
Sector Tanguanes Clay Tile:
Tinaquillo, Venezuela Alfareria Tinaquillo Espanol "S"

Tinaquillo Tile Corp.
4456 NW 74 Ave
Miami, Florida Ph-716-0107

BENDER ROOF TILE INDUSTRIES, INC.
94-0106.12 (Nail-On or Mortar-set System)
3100 Southeast County Road 484 Cement Tile:
P.O. Box 190 94-0323.01 Palema double roll
Bellview, Florida 34421 94-0323.28 Nordic flat
800-527-5808

Robert D.Ruiz
P.O. Box 367
Estero, Florida 33928
Phone 813- 278-0919

CAMPOS FABRICA CERAMICAS S.A, (Nail-On System)
David Ward 94-0106.32
Estrada De Tabueira-Esqueira
3801 Aveiro Codex
Portugal

Marcelino F. Garcia Clay Tile: Spanish "S" Clay Tile
Campos, USA,Inc. (Telhas
Campos)
2615 N. Dundee Street
Tampa, Florida 33629

CEDEKSA
Avgd. Catalunya 96-98
087858 Cervello
Barcelona, Spain

94-0106.33

(Mortar-Set System)
Clay Tile
Two Piece Cedeksa Barrel

Carlos Fernandez
Almar USA
6645 NW 77 Avenue
Miami, Florida 33166
Phone 471-5830
Fax 471-5833

CERAMICA BOLLA S.A.
Guillermo Alvarez
Avenida San Martin 1259
2506 Correa (SF)
Republica Argentina

94-0106.21

(Nail-on or Mortar set System)

25 SE 2 Avenue, Suite 320
Miami, Florida 33131
Phone 305-373-2311
Fax 305-373-2611

Clay Tile: Barrel Clay Tile
("Bolla, made in Argentina")

COMA CAST CORP:
Mike Arronte
4385 SW 70 Street
Miami, Florida 33155
Phone 665-3664
Fax 667-0592

94-0106.25

(Mortar Set System)
Cement Tile:
Flat Shingle
Barrel Concrete

DELEO CLAY TILE CO., INC.
Cindy Deleo
600 Chaney Street
Lake Elsinore, California 92530
Phone 800-654-1119

94-0106.14

(Nail-on System)
Clay Tile: Bella Two-piece
Mission "S"

DUNTILE
Architectural Materials
2820 Mine Mill Road
Lakeland, Florida 33801
Phone-813-665-6309 / 800-845-8257
Fax 813-667-3100

94-0106.19

(Mortar set)
Cement Tile:
Spanish "S"
Flat
Slate
French Bar

ENTEGRA ROOF TILE CORPORATION:
Terry Johnson
1201 NW 18 Street
Pompano, Florida 33069
1-800-379-2717 / 305-979-2717
Fax 305-960-1347

Nail-on (both) 94-0103.10

Shake
(Nail-On or Mortar-Set Systems)
Cement Tile:
MortarSet 94-0323.30 Estate "S"
MortarSet 94-0323.29 Skandia Flat

FRANCISCO RAMON BORJA
Ctra. de Lliria a Pedralba
Rm. 3
Valencia, Spain
Phone- (96) 278-0762

94-0106.34

(Nail-on or Mortar set System)
Clay Tile: Modified Spanish "S"
Spanish "S"
All Marked "Alicante" Flat
Tapered Barrel

Ceramica de Espana Monique, Inc.
11865 SW 26 Street
Phone-559-5455
Fax 559-5455

Asia Commercial International Corp.
12265 SW 130 Street
Miami, Florida 33801
Phone 233-0657
Fax 233-9373

Almar (USA), Inc.
Carlos Fernandez
7270 NW 12 Street Suite #650
Miami, Florida 33126
Phone 471-5830 Fax 471-5833

GLADDING McBEAN:
Pete Pederson
P.O. Box 97
Lincoln, CA 95648
Phone 916-645-3341
Fax 916-1723

94-0106.06

(Nail-on System)
Clay Tile: Lincoln Clay Interlocking Flat

Zion Services Corp.
11300 NW S River Drive
Medly, Fl 33178
(305) 557-5737
Fax 557-0249

HIJOS de ANTONIO RAMON-BORJA, S.A.
Plaza de la Cova S/N
Aptdo. # 340
Alicante, Spain 03080
(96) 517-1611

94-0106.35

(Nail-On System)
Clay Tile: Spanish"S" Meridonial

(Mortar-Set)
Spanish "S" Meridonial
Curved Barrel
Flat French

MCC Marble Ceramic Center
9820 NW 77 Avenue
Hialeah Gardens, Florida 33026
Phone 823-0990 Fax 826-5473

Zion Services Corp.
11300 NW S. River Drive
Medly, Florida 33178
Phone 305-557-5737

Coma Cast Corporation
4383 SW 70 Court
Miami, Florida 33155
Phone 305-665-3665
Fax 305-667-0592

INTERNATIONAL ROOFING PRODUCTS, INC.
Ted Nakin
15430 Camarillo Street
Sherman Daks, California 91403
Phone 818-382-3511
Fax 818-382-3517

94-0106.29

(Nail-On System)
Clay Tile: Group 117-J Type Glazed

Ameri-Clay Roof Tile Company

LADRILLERA GUIGUE
Manuel Sandedro B.
Calla Boca de Rio
Edo Carabobo, Venezuela
(45)42049-42220

94-0106.20

(Mortar-Set Systems)
Clay Tile: Spanish "S"

Barro Clay Tile
13050 NW 30 Avenue
Opa Locka, Florida
Phone 681-0763 / Fax 688-5971

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LAMOTI ROOF TILE, INC:
1360 NW 29 Street
Miami, Florida 33142
Phone635-2641
Fax 635-7139

94-0106.22

(Mortar-Set Systems)
Cement Tile: Flat, Burmuda Shingle
Barrel-PortlandCement
(Both marked with "L.R.T.")

LIFETILE:
Boral Concrete Products Inc
P.O. Box 632
200 Story Road
Lake Wales, Fl 33859-0632
813-676-9405
1-800-282-3633

94- 0106.03

(Mortar Set System)
94-0323.02
94-0323.33
94-0323.32

(Nail-On Systems)
Cement Tile: Colonial Slate
Flat
Espana "S" Style
Capri
Espana "S"
Shake/Slate
Capri

LUDOWICI-CELADON, INC.
Bill Woellner
4757 Tile Plant Road
New Lexington, Ohio 43764
Phone (800) 945-8453
Fax 614-342-5229

94-0217.07

(Nail-On System)
Clay Tile: Flat Interlocking
Straight Barrel Misson
"S" Mission
Conosera
French
Ceramic Slate

LTG INC.
Collette Boisvert
CP 656
Boucaerville
Quebec, Canada J4B642
Phone 819-843-4220

94-0218.02

(Nail-On System)
Fiberglass reinforced polyester:
Tuiles de Geneve
Flat

Les Tuiles Europe LTEE
4025 Boul. Leman
Laval, Quebec
Canada H7E 1A2

(Nail-On [Screw] Systems)

Fiberglass reinforced polyester

MARGON-S.A. TILE:
Joao Marques
Director of Marketing
2840 Porto de Mos
Cruz da Lequa, Portugal
Phone 011-351-44-470102

94-0217.01

(Nail-On or Mortar Set)

ClayTile: Telha Lusa Clay
Spanish "S"

Clay Tile: Telha Lusa Clay
Spanish "S"

M.C.A. CLAY ROOF TILE, INC.
Yoshi Suzuki 94-0106.27
1985 Sampson Avenue
Corona, CA 91719
909-736-9590

(Nail-On Tile System)
Clay Tile:
"S" Mission

Bill Fernandez
P.O. Box 175
Estero, Florida 33928
Phone 813-267-5398
Fax 813-267-9304

METRO GEM ROOF TILE:
Fernando Arias 94-0217.04
11501 NW 117 Way
Medly, Fl 33178
Phone 305-558-6712
Fax 305-558-2608

(Mortar Set System)
Cement Tile: Wave
Double Roll

METRO ROOF TILE:
Fernando Arias 94-0106.06
11350 NW S. River Drive
Medley, FL 33178
558-6712
558-2608

(Nail-On or Mortar Set)

Cement Tile: Spanish "S"
Flat

MONIER ROOF TILE:
Reese Moody

1900 NW 21 Ave
Ft. Lauderdale, FL 33311
Phone 1-800-327-8453
Fax 305-485-7934

	Cement Tile: 94-0106.09	
	(Mortar-Set)	(Nail-On Systems)
94-0323.17	Mission "S"	Mission "S"
94-0323.22	Flat Vanguard II	Flat Vanguard II
94-0323.19	Classic 100	Classic 100
94-0323.18	Villa	Villa
94-0323.21	Shake	Shake
94-0323.24	Vanguard Roll	Vanguard Roll
94-0323.21	Slate	Slate
94-0323.23	Flat Vanguard I	Flat Vanguard I
94-0323.26	Mission Barrel	
94-0323.25	Spanish "S"	
94-0323.20	Bermuda Flat	

MULTI PRODUCTOS SANTA CRUZ:
Gabriel Guerra
Zecape, Guatemala / Quimistan, Central America

Zion Services Corp 94-0217.05
11300 NW South River Drive
Tile
Medly, Fl 33178
(305) 557-5737

(Mortar Set System)
Clay Tile: Clay Barrel

(Alahambra)

NIWA TILE COMPANY
Kazumasa Niwa 94-0217.03
5-32 Matsue Hekinan
Aichi, Japan
Phone 0566-41-1524

(Mortar Set System)
Clay Tile: Niwa lazy "S" shape

PIONEER CONCRETE TILE:
Dave Snyder, Gary Reed 94-0106.11
1340 SW 34th Avenue
Deerfield Bch, FL 33442
1-800-624-4152
(305) 421-2077
FAX (305) 426-2260

(Nail-On Systems)

Cement Tile: Hacienda
Shake/Slate
Rustic Shake
Spanish "S"
Flat 9

(Mortar Set System)
Cement Tile: 2 Piece Barrel
Spanish "S"
Flat '9'

94-0323.37 **Hacienda**
94-0323.39 Slate
94-0323.38 Shake
94.0323.36 Regal "S"

SANTA FE' Tile Corp:
Ladrillera Santa Fe 94-0106.17
Bogota, Columbia

(Nail-On or Mortar Set Systems)

Daniel Bernal
7225 NW 25 Street Suite #306
Miami, Fla 33122

Clay Tile: Spanish "S" Ladrillera Santa Fe
(Mortar-Set System)

Phone 305-593-8701 Fax 593-8701 Clay Tile: Mission Barrel
Flat Interlocking

STEEL TILE INC.:
Vesa Heino 94-0217.08
Technical Manager
Highway 400 Industrial Park
R.R. #1
Thornton, Ontario LOL 2NO
705-436-1723

Roland Nilsson
Vemtex Inc.
9954 SW 88 Street
Miami, Florida 33176
Phone 598-0216

(Nail-On System Metal Panel)
Steel Panel: Steel Tile Look

Katech Elite "Dutch Clay
Katech "Spanish Clay

SCANDINAVIAN PROFILING SYSTEMS, INC.
Timothy P. Carroll 94-0131.01
1951 Hamburg Turnpike
Buffalo, New York 14218
716-826-2593
Fax 716-826-2599

(Screw-On System)
Nordman Tile Panels

TBF ROOFING TILES INC.
723 W Oak Ridge Road 94-0506.02
Orlando, Florida 32809
Phone 407-857-9242

(Mortar Set System)
Roman Canal TBF

TEJAS CASTILLA LA MANCHA S. A. (MS)
Vereda del Prado, S/U 94-0217.09
Pantoja (Toledo), Spain A5290

(Nail-On or Mortar Set System)
Interlocking Spanish "S"

David Lowery
201 SW 14 Avenue
Pompano Beach, Florida 33069
Phone 305-942-0005
Fax 305-942-0046

VANDE HEY-RALEIGH MANUFACTURING, INC.
Donald Vande Hey 94-0217.02
1665 Bohm Drive

(Nail-On System)
Cement Tile: High Barrel Spanish Tile

Little Chute, Wisconson 54140
Phone (800)236-8453
Fax 414-766-0776

Riviera
Slate
Shingle
Shake
Custom Brush
Cotswold Stone

US CLAY TILE / LIFETILE

Dave Faulkner 94-0106.04
200 Story Road
P.O. Box 632
Lake Wales, Florida 33859
813-676-7405

(Nail-On System)
Clay Tile: "S" Style

roofco1.sam