Glass Fiber Lath in Exterior Portland Cement Plaster (Stucco)

William F. Egan
VP, Engineering & Development
BASF Wall Systems, Inc.
3550 St Johns Bluff Road
Jacksonville, FL 32224
Bill.egan@basf.com

Mark Newton
Product Development Manager
Saint Gobain Technical Fabrics
201 Hugel Avenue
Midland, ON Canada L4R 4G1
Mark.j.newton@saint-gobain.com

ABSTRACT

Glass Fiber Lath was introduced as an alternative to metal plaster bases which have been the primary mechanism used to secure Exterior Portland Cement Plaster (Stucco) to framed construction for many years. The product evolved, in part, as a result of recent technology that enables glass fibers to be woven as a three dimensional fabric that can be produced in various configurations and serve as a lath or plaster base for both One- and Three-Coat Stucco applications.

The primary objective of this paper is to create an awareness of the technology, its development, as well as potential features and benefits in stucco applications. This will be accomplished through discussion about the use and evolution of glass fiber reinforcement, lessons learned during development, as well as a review of testing and field/application trials. Additionally, there will be a summary of research and comparative testing that is underway at a major university.

INTRODUCTION

Exterior Portland Cement Plaster, or Stucco as it's commonly known, is a popular above grade, exterior wall cladding system that has and continues to be used on residential as well as commercial buildings throughout the world. Its popularity is due in large part to the products durability, cost effectiveness as well as desirable appearance.

Stucco is comprised of a base and finish coat. The base coat, which is a spray or trowel applied cementitious material, can range in thickness from 10 to 19 mm (3/8 inch to 3/4 inch). It's comprised of a mixture of various materials that can include cement, lime, aggregates, sand, water, fibers as well as admixtures. Depending upon the base coat thickness, the type of stucco is often referred to as One Coat 10 to 13 mm (3/8 inch to 1/2 inch thick) or Traditional, Three Coat which is maximum 19 mm (3/4 inch) thick. After the base coat has been applied and allowed to cure, a cementitious or non cementitious finish coat ranging in thickness from 1.5 to 3 mm (1/16 inch to 1/8 inch) is trowel or spray applied to the base coat. Non cementitious finish coats are

typically factory mixed products comprised of proprietary ingredients while cementitious products uses ingredients similar to those in base coats. For the base as well as finish coats, ingredients and their proportions will vary due to many factors such as project specifications, local practices, raw material availability, user preferences, building code requirements, type mix (field or factory), desired appearance and performance, project type, etc.

Stucco can be applied directly to a solid substrate such as unit masonry, cast in place, precast concrete, etc. or, in the case of steel or wood framed construction, to a lath or netting which is commonly referred to in the industry as a plaster base. On framed/sheathed construction as well as other surfaces which may not enable an adequate bond of the stucco to the substrate, the plaster base serves a number of purposes including reinforcement and more importantly a mechanical key or base for the stucco.

Years ago, plaster bases were created from wood lath or strips. Eventually these were replaced by metal materials due to limitations of wood products such as high cost of labor to produce and install, difficulty to accommodate various wall geometries, plus possible adverse affects due to moisture. Today, most plaster bases continue to be fabricated from metal although plastic lath is also available however it is not widely used. Metal plaster bases are available in various configurations or types which are commonly referred to as diamond mesh metal, high rib lath, flat rib lath, expanded metal, woven or welded wire lath. Various types and weights are available to accommodate the needs of specific applications. In the case of stucco applied to vertical, exterior walls, diamond or expanded metal mesh and woven or welded wire are the most commonly used types of metal plaster bases. For exterior applications, a galvanized coating is available to provide a higher level of corrosion resistance. Woven and welded wire lath is typically supplied in 0.91 m wide by 45.7 m (36 inch by 150 foot) long rolls while products such as expanded lath, diamond metal mesh, etc. are generally available in 0.71 m by 2.4 m (28 inch by 96 inch) sheets that are supplied in bundles and shipped on pallets.

Although metal is currently the most commonly used plaster base material, recent technology in the glass fiber industry has resulted in the development of Glass Fiber Lath that serves as an alternative to metal plaster bases. The significance of this technology is that it may address some of the recognized limitations of metal plaster base products. Specific improvements from Glass Fiber Lath technology may include enhanced speed/ease of application and handling, corrosion resistance, safety during application, as well as better resistance to cracking. Additionally, Glass Fiber Lath results in few, if any changes to types/spacing of lath fasteners, detailing, trim accessories, etc. that are commonly used with metal lath. This paper will provide insight on the product development from initial concept through testing as well as insight into potential features and benefits.

GLASS FIBER LATH TECHNOLOGY

The Owens-Corning Fiberglass Corporation first commercialized the production of continuous filament glass fibers in 1939. By the middle of the 1940's, woven fabrics and non-woven mats made from these fibers were already being manufactured, largely for the Fiberglass Reinforced Plastics Industry (FRP).

Today, glass reinforcing fabrics are used in an endless variety of ways in the composites, construction and industrial markets. In the Exterior Insulation Finish System (EIFS) market, which is a type of exterior wall cladding system, woven fiberglass fabric "meshes" have been commonly used since the 1950's to reinforce the cement based matrices that make up the external coating of the system. The mesh serves a variety of functions including prevention of cracking of

the exterior lamina due to thermal expansion and contraction as well as provide impact resistance to the system.

The mesh used in EIFS is an "open" construction to allow the passage of viscous cement through the mesh and thus effectively encapsulate the fibers and adhere them to the surface below (see Photo 1). Encapsulation of the fibers helps ensure load transfer from the matrix to the reinforcing fibers. Such open mesh fabrics are made by using "leno weave" or "knit" fabric formation methods and this helps stabilize the geometry of the mesh. The mesh is also saturated with a polymeric coating to further stabilize the mesh, protect it from damage due to handling and installation, and impart alkali resistance. Normally it is desirable to minimize the thickness of the mesh so that it is completely embedded within the required coating thickness.

Saint-Gobain Technical Fabrics (SGTF) has manufactured a line of fabrics for the EIFS market for almost 30 years while BASF Wall Systems has been manufacturing the components for wall systems since 1979. The idea to engineer a glass fiber mesh replacement came about to address recognized limitations of metal lath and netting used in stucco wall systems. As a result of collaborative efforts, PermaLath and PermaLath 1000 Glass Fiber Lath were developed and introduced to the market.

PermaLath is a, three dimensional, fiberglass grid (areal weight 150 g/m^2) (4.5 oz/yd^2) designed as an alternative to metal netting or metal lath in One Coat Stucco wall construction (see Photo 1). PermaLath 1000 is a heavier (areal weight 300 g/m^2) (9 oz/yd^2), stiffer product designed for Traditional Three Coat as well as One Coat stucco construction. The purpose of these products is to serve as a plaster base for the wet stucco and thus alleviate sagging, provide reinforcement and transfer the weight of the stucco to the fasteners and supporting substrate.

Proprietary weaving and coating technology are used to create the glass fiber lath or grid in an order of magnitude that is thicker than traditional leno woven fabrics of the same weight. The three dimensional effect can be induced in fiberglass fabrics weighing from 40 to 1000 g/m^2 (1.2 to 30 oz/yd^2). Although thicknesses exceeding 10 mm (3/8 inch) are possible, 3 to 6 mm (1/8 inch to 1/4 inch) are typically sufficient for stucco applications.

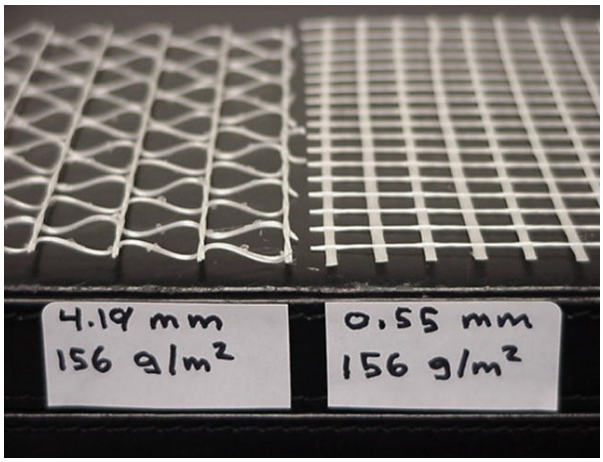

Photo 1 PermaLath Glass Fiber Lath (left) and reinforcing mesh for EIFS (right)

PRODUCT DEVELOPMENT

Fiberglass was the material of choice for the lath in part for the following reasons:

1) High Tensile Strength: 3448 MPa (500090 psi) at 22° C (72 F). Its strength-to-weight ratio makes it stronger than steel in some applications.
2) High Tensile Modulus: 72.5 GPa (10515255 psi). The fibers are able to bear high loads without significant deformation which is key for reinforcement of cement based matrices
3) Heat and Fire Resistance: due to its inorganic nature, fiberglass neither burns nor supports combustion. It is able to withstand elevated temperature fire tests due to its high softening point 841° C (1545 F) for E glass.
4) Chemical Resistance: fiberglass is not attacked by most chemicals nor is it adversely affected by fungus, bacteria or insect attack.
5) Moisture Resistance: fiberglass is not absorbent and therefore not prone to swell, stretch, corrode, rot or disintegrate.
6) Thermal Properties: fiberglass has a low coefficient of thermal linear expansion.
7) Widely Available: the materials are widely available from a variety of manufacturers, so supply is seldom a problem and prices are in check. There is also a wide range of glass yarn yields available for every design need.
8) Wide Range of Fabric Forming Methods: continuous fiberglass yarn can be formed into useful fabrics by traditional biaxial weaving; laid scrim; multi-axial weaving; three dimensional weaving; knitting; wet and dry laid mat; needling; preforming; etc. A reinforcement fabric can be optimally designed for virtually any application by the suitable selection of fabric forming method, fabric design and materials.
9) History in EIFS: as discussed in the introduction, fiberglass fabric has been used in cement basecoats for the EIFS industry for decades with success.

The design of the initial PermaLath product (150 g/m^2) (4.5 oz/yd^2) evolved rather quickly, mostly by empirical testing but guided by dimensions, strengths, etc. of existing plaster base products. Additionally, it was desirable for the product to utilize similar types of fasteners, fastener spacing, trim accessories (corner beads, etc.) and design details typical of stucco that incorporates metal lath.

Some of the properties and characteristics deemed to be most critical to the success of the fabric included thickness, hole or opening size and tensile strength. The lath must serve as a key or attachment mechanism for the stucco, and have sufficient bending rigidity or stiffness to support the stucco. These are discussed further below.

The minimum thickness of Glass Fiber Lath is largely determined by prevailing building codes for lath products although it was found through field trials that a thickness of approximately 3 mm (1/8 inch) was adequate for One Coat stucco applications.

Initial prototypes had a hole opening of about 13 mm by 13 mm (1/2 inch by 1/2 inch) however it was found through field trials to be too narrow for efficient passage of the stucco. Later designs with opening dimensions of 13 mm by 25 mm (1/2 inch by 1 inch) was shown in field trials to be more workable.

The initial prototype Glass Fiber Lath was secured to the substrate in field trials using fastener types/spacing, etc. typical of metal lath. As a result of the trials, it was determined the lath had less than the desired amount of rigidity or stiffness since the weight of the wet stucco during application caused less than optimum deformation and sagging of the stucco. Although supplemental fasteners improved resistance to sag, later designs used heavier glass yarns spaced

wider apart, as well as a different coating system than the initial design. The later design has proven reliable for use in One Coat Stucco over polymeric type weather resistive barriers (Tyvek, etc.). In the case of asphaltic based weather resistive barriers (building paper), it was found these types of barriers may be subject to significant swelling due to moisture pick up from the environment as well as wet stucco, As a result, in some cases, the PermaLath followed the contours of the "pillows" formed by the paper which may lead to a surface with less than desired flatness.

As a result, PermaLath 1000 (300 g/m^2) (9 oz/yd^2) was designed for use over asphalt weather resistive barriers in both One as well as Three Coat Stucco Systems. It has greater tensile strength than the original PermaLath product as well as higher bending rigidity or stiffness and is nominal 6 mm (1/4 inch) thick.

The tensile load and extension characteristics of the PermaLath product were compared to both 17 and 20 gauge metal wire netting. See Table 1, 2 and 3 below. It was found that:

A. PermaLath has a higher tensile rigidity than either the 17 or 20 gauge wire netting. This is true at all strain levels and regardless of the direction of testing.
B. PermaLath has a higher load to failure than either the 17 or 20 gauge wire netting. While this result is interesting, loads high enough to break the meshes are not likely to be encountered in practice.

Note that the load-extension curves were very non-linear. Thus the strength of the fabrics had to be considered at several points along the curves, though the data generated under the initial column are most relevant considering the small load 2 N/cm (22.5 lbf/inch) imposed by the wet stucco.

From a performance standpoint, the ultimate breaking strength of the PermaLath is not a significant factor in the early life of the wall as the lath is many times stronger than required to support the weight of wet stucco. From the installation side, PermaLath and PermaLath 1000 are sufficiently stiff and rigid to accept and serve as a key for the wet stucco.

Based on static load considerations alone, the PermaLath retains more than adequate tensile properties to support the weight of the cured stucco.

In conclusion, some advantages of PermaLath include:

I. Lighter weight for a given length of material: PermaLath has an areal weight of 150 g/m^2 (4.5 oz/yd^2) as compared to 1830 g/m^2 (3.4 lbs/yd^2) for the heaviest weight metal lath that is commercially available. In this case, a 45 m long by 1 m wide (150 ft by 39 inch wide) roll of PermaLath weighs approximately 7.2 kg (16 lbs) while an equivalent quantity of the heaviest metal lath would weigh approximately 77 kg (170 lbs). PermaLath 1000, for use in thicker stucco systems, weighs 300 g/m^2 (9 oz/yd^2) so at 14.5 kg (32 lbs) is still lighter than the equivalent amount of the heaviest metal lath. This translates to ease of handling, particularly at the job site as well as shipping advantages.
II. Faster installation means it is cost effective to use. A 50% faster installation time has been realized on some jobs using PermaLath as compared to metal plaster bases.
III. Easier to handle and safer to cut. PermaLath can be cut with scissors or a utility knife. It lays flat on the wall and the three dimensional profile provides self furring capabilities.
IV. Discoloration of stucco due to corrosion, as can occur with metal, is not a potential issue.
V. Higher tensile rigidity and strength than many metal wire meshes, as discussed above.

Table 1 Tensile Modulus of Elasticity* Comparison

Tensile Modulus

MESH/PRODUCT TYPE		INITIAL MD	INITIAL CD	PLATEAU MD	PLATEAU CD	ULTIMATE MD	ULTIMATE CD
PermaLath	(N/cm)	8526	346	14192	544	14192	15764
	(lb/in)	4872	198	8110	311	8110	9008
20 Gauge	(N/cm)	180	96	60	30	1092	404
	(lb/in)	103	55	34	17	624	231
17 Gauge	(N/cm)	499	138	192	28	2863	1004
	(lb/in)	285	79	110	16	1636	574

*Note: tensile modulus is calculated by assuming that the stress on the wire is in units of N/cm (lbs per inch) of width and neglects the thickness of the mesh. Also, the modulus is calculated at all displacements by using the initial 50 mm (2 inch) specimen width and neglecting the loss in width that happens with the metal netting at high elongations.

Table 2 Strength Comparison

MESH TYPE		Ultimate Load	Strain to Ultimate Load (%)	Ultimate Load Occurs at Break or Yield Point?
PermaLath MD	(N/cm)	460	3	break
	(lb/in)	263		
20 Gauge MD	(N/cm)	122	27	break
	(lb/in)	70		
17 Gauge MD	(N/cm)	350	28	break
	(lb/in)	200		
PermaLath CD	(N/cm)	490	8	break
	(lb/in)	280		
20 Gauge CD	(N/cm)	40	33	yield
	(lb/in)	23		
17 Gauge CD	(N/cm)	87	42	yield
	(lb/in)	50		

Table 3 Deformation of Various Mesh/Products Due to Weight of Stucco

ΔL **

MESH/PRODUCT TYPE		MD	CD
PermaLath	(mm)	0.0086	0.216
	(inches)	0.00034	0.0085
20 Gauge	(mm)	0.4064	0.762
	(inches)	0.016	0.030
17 Gauge	(mm)	0.1499	0..533
	(inches)	0.0059	0.021

**Note: this is the change in length of a section of mesh that is 15 cm (6 inches long) which is exposed to a load of 0.49 N/cm (0.28 lb/in). The load of 0.49 N/cm (0.28 lb/in) is equivalent to that of stucco applied at approximately 3 g/cm^2 (6 lbs/square foot).

FIELD TRIALS AND PRODUCT INTRODUCTION

After the product was developed and small scale installations were completed, field trials commenced to validate application of the Glass Fiber lath as well as determine the impact, if any, on the stucco application under actual field conditions. Several residential as well as commercial projects in New Jersey, Pennsylvania, Rhode Island as well as New Mexico were selected for initial field trials. Project selection for the field trials was based on numerous factors such as location, size, complexity, time of year products were to be applied, project availability, etc. Photos 2 and 3 of New Jersey and Rhode Island projects are shown below and are fairly representative of the size/scope of the trials. Applications were completed by plastering contractors using a One Coat Stucco System and PermaLath Glass Fiber Lath marketed by BASF Wall Systems, Inc. Specific feedback gathered as part of the field/application trials included production rates, ease of installation, pros/cons versus metal plaster bases, roll size, flatness, resistance to sag, means of attachment, detailing, effect of weather exposure prior to stucco application, integration with trim accessories, any suggested modifications, and impact, if any, of the type of weather barrier as well as the application of the stucco including ability to key and bond to the lath. Final product designs and installation methods were based on input obtained through field/application trials, regulatory requirements, performance testing, etc. Additionally, the trials further confirmed there to be little, if any, difference in detailing, trim attachment, or fastener type/spacing whether the lath is Glass Fiber or metal.

Photo 2 Providence RI Field Trial

Photo 3 Toms River NJ Field Trial

BASF Wall Systems, Inc. began marketing Glass Fiber Lath in early 2005 and as noted previously currently offers Glass Fiber Lath products sold under the names PermaLath and PermaLath 1000 for use in One Coat as well as Traditional, Three Coat Stucco Systems. The authors are also aware of one other company that currently markets Glass Fiber Lath products for use in Stucco applications. The Glass Fiber Lath products are being used in all types of applications that range from small residential to large commercial both in the United States as well as other parts of the world. Additionally, interest has been expressed to use the patent pending Glass Fiber Lath technology in other applications such as tile, concrete countertops, and masonry stone veneers which historically have used metal plaster bases. The products are gaining acceptance in Stucco sytems mainly as a result of ease of handling, labor savings which has ranged up to 50% on some projects, inherent resistance to corrosion, and ability to handle safely since the product does not contain sharp edges.

BUILDING CODES

The International Code Council Evaluation Services (ICC ES) is a United States based organization that provides technical evaluations of building products, components, methods, and materials. Since standards and building codes in the United States were developed around the use of metal plaster bases, ICC ES was contacted to determine the tests and other criteria needed to enable recognition of Glass Fiber Lath as an acceptable alternative to metal plaster bases. As a result of various meetings with ICC ES as well as public hearings to consider proposed criteria/guidelines for this technology and application, Acceptance Criteria for Glass Fiber Lath used in Cementitious Exterior Wall Coatings or Exterior Cement Plaster (Stucco) was initially issued in December 2004 and modified in June 2006. This document, which is also referred to by ICC ES as AC 275, provides the Acceptance Criteria that Glass Fiber Lath products must meet to demonstrate compliance with the International Building as well as Residential Code requirements as an alternative to metal plaster bases used in One Coat as well as Traditional, Three Coat stucco. The acceptance criteria primarily consists of minimum test and performance criteria such as tensile strength, structural loads (transverse and racking), attachment, vertical load, fire, etc. however it also contains requirements such as minimum embedment or thickness of the lath which is essentially 3 mm (1/8 inch) for One Coat Stucco Systems and 6 mm (1/4 inch) for Traditional or Three Coat Stucco Systems.

Numerous challenges can be expected when a new technology is introduced as an alternative to long accepted products and practices. Amongst the challenges that might be expected are validation of expected features/benefits, overcoming perceptions, changing norms, as well as market acceptance of a new, innovative technology. To help overcome possible challenges to Glass Fiber lath technology, the authors companies contracted with the University of Florida Building Construction Department in Gainesville, FL to independently research the use and performance of Glass Fiber Lath in Stucco. The program is intended to provide a comparison of various properties of BASF Wall Systems PermaLath and PermaLath 1000 Glass Fiber Lath to typical metal plaster bases used in Stucco. The tests will incorporate various sample configurations that will differ with respect to Stucco thickness (One Coat and Traditional), type of plaster base (various weights and configurations of metal as well as two types of Glass Fiber lath) as well as weather resistive barriers (polymeric and traditional building or 'black' paper). Specific objectives of the program include determining if there is quantifiably more/enhanced crack resistance with stucco reinforced with Glass Fiber Lath rather than metal plaster bases, develop minimum material properties (tensile strength, etc.) needed for use in Stucco, as well as review the alkali resistance of Glass Fiber Lath reinforcement in Stucco. Means to accomplish these objectives are as follows:

- Literature review of past and present practices related to the use of glass fiber materials in cementitious materials such as concrete, mortars, etc.
- Alkali resistance using current industry standard tests as well as newly developed methodology
- Minimum physical properties of Glass Fiber Lath for use in stucco applications as determined through Finite Element Analysis modeling.
- Mechanical and environmental testing such as impact strength, flexural bending, tensile adhesion, plastic shrinkage, thermal crack evaluation as well as chemical compatibility testing using ASTM Standards as well as other tests that are either published or have been developed specifically to address Glass Fiber Lath technology.

The following is a brief summary of completed impact tests. The remainder of the tests are scheduled to be complete later this year.

Impact is one of several tests used to determine the effect, if any, of different types of plaster bases on mechanical properties of One Coat as well as Traditional, Three Coat Stucco. For the One Coat Stucco samples, plaster bases tested included 17 gauge metal stucco netting, 20 gauge metal stucco netting, 2.5# expanded metal lath, PermaLath and PermaLath 1000 Glass Fiber Lath by BASF Wall Systems Inc. For the Three Coat Stucco samples, plaster bases tested included 17 gauge metal stucco netting, 2.5# expanded metal lath, 3.4# expanded metal lath and PermaLath 1000 Glass Fiber Lath by BASF Wall Systems Inc. None of the samples contained backing or sheathing so as to eliminate possible contribution of the substrate. The laboratory test set up as shown in Photo 4, consisted of securing a stucco sample to a steel channel and subjecting the sample to one drop of a Humboldt 4.5 kg (10 lbs) drop hammer such as described in ASTM D 1557. The impact test loads used were 18 J (160 inch lbs) for the One Coat Stucco and 36 J (320 inch lbs) for the Three Coat Stucco samples. Although other loads could have been chosen, the 18 J (160 inch lbs) was deemed reasonable since it is an impact load imposed on Exterior Insulation and Finish Systems (EIFS) and there are not any standard impact tests for stucco.

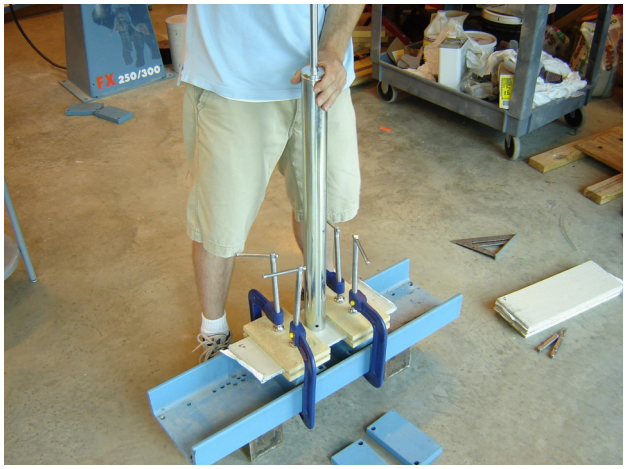

Photo 4 Impact test set up

After the each sample was subjected to the impact device, a visual inspection was conducted to determine crack patterns, deformation/indentation, and if broken lath was evident. Photographic results of the tests are shown for the One Coat Stucco in Photo 5 and Photo 6 for the Three Coat Stucco sample. For the One Coat Stucco samples, the specimen with PermaLath, which is a lighter and thinner Glass Fiber Lath than PermaLath 1000, visually appeared to have the least amount of cracking and indentation of all the samples. The authors attribute the results to the design of the lath including the choice of glass fiber lath which is more flexible and ductile than metal plaster bases and tends not to take a permanent set. For the Three Coat Stucco, the samples appeared pretty much the same visually which is attributed to the thickness of the stucco which, in and of itself, is able to withstand much of the impact load.

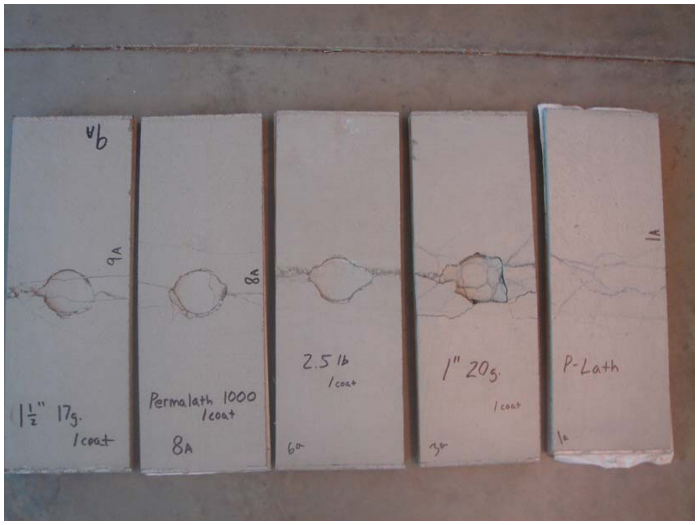

Photo 5 One Coat Stucco - post impact testing
Plaster bases (left to right): 17 ga metal wire, PermaLath 1000, 2.5# expanded metal lath, 20 gauge metal wire, and PermaLath

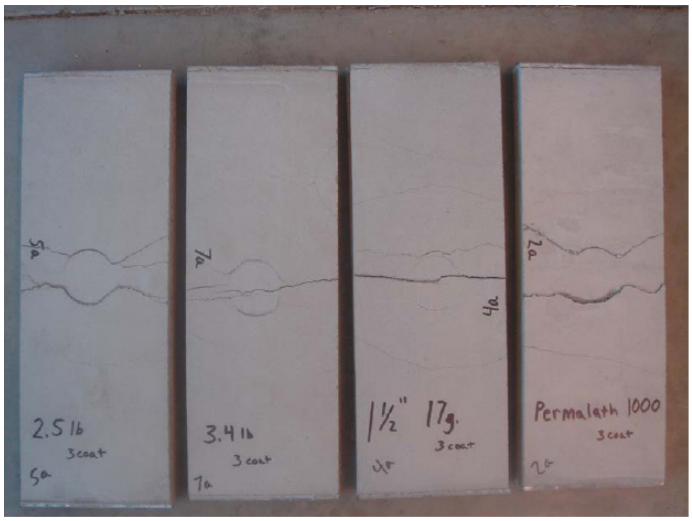

Photo 6 Three Coat Stucco - post impact testing
Plaster bases (left to right): 2.5# expanded metal lath, 3.4# expanded metal lath, 17 ga metal wire, and PermaLath 1000

CONCLUSIONS

Although metal continues to be the most commonly used plaster base material for Stucco, recent technology has resulted in development of Glass Fiber Lath which has been shown through testing as well as application to be a viable alternative to metal plaster bases. Additionally, since it is comprised of a glass fiber material, it provides benefits such as no possibility of corrosion as well as ease of handling and installation.

RECOMMENDATIONS

Complete the research program currently underway at the University of Florida as well as consider what other tests/research might be helpful to substantiate the use as well as features and benefits of Glass Fiber lath. Additional research can also be undertaken to determine if other designs/configurations as well as if alternative glass fiber materials and coatings might offer additional benefits over the current Glass Fiber Lath designs. Further investigation is needed to consider other potential uses such as reinforcement for tile applications, countertops, etc. Finally, standards should be developed through a consensus process such as ASTM to address the specific characteristics of non metallic laths including those fabricated from Glass Fibers.

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ICC Evaluation Service Inc.
5360 Workman Mill Road
Whittier, CA 90601

Comparison of PermaLath Reinforcement to Metallic Lath Reinforcement in Stucco Cladding Systems
A Thesis presented to the Graduate School of the University of Florida in Partial Fulfillment of the requirements for the degree of Master Of Science in Building Construction, 2006
Patrick Murray