Roofing Boards: The Next Generation

By Adriana Galli, Engineer

INTRODUCTION

The poor performance of one roofing component often leads to failure of the entire waterproofing system. Thus, roof consultants and building owners are realizing that the insistence on durable components throughout the assembly plays an important role in maximizing the structure's life cycle.

Finex Inc., a company in the business of developing proprietary non-combustible roofing systems, believes that the use of fiber cement underlayment/overlayment panels in roofing assemblies provides potential lifecycle advantages over traditional wood, gypsum, and even mesh-reinforced concrete boards. The company hired Advanced Building Materials to conduct practical comparison testing that would closely represent the jobsite and in situ reality.

In order to confirm the performance characteristics of fiber cement roofing boards, important field performance criteria, such as flute spanability and membrane adhesion, were comparison tested with other roof support boards. These field performance criteria were chosen to measure the resistance of roofing boards to cracking and damage during traffic, and the membrane compatibility under various climatic conditions.

The results of both the flute spanability and peel adhesion strength testing clearly demonstrated the superiority of fiber cement over gypsum and mesh reinforced concrete boards.

The test results indicate that fiber cement boards should enhance the roof assembly's life cycle when used in the following applications:

Underlayment (deck sheathing): Over steel deck to resist fire within the building and limit the spread of flame along the underside of the roof assembly (in either a protected membrane or conventional roof assembly)

Overlay board: To protect the insulation from being crushed by normal foot or equipment traffic. The fiber cement board can be adhered to the insulation or mechanically fastened over low compressive strength insulation.

Separation board: To keep the new roof separated from the old roof when chemical incompatibility between the systems is encountered, e.g., covering a standard BUR with PVC membrane.

Recover board (overlayment): Over an existing roof to provide an acceptable surface to receive the new membrane (commonly used when a new membrane is installed over an existing BUR system).

FLUTE SPANABILITY TESTING PROCEDURE AND APPARATUS

The objective of this test was to verify the flute spanability performance of fiber cement boards—48"x96"x1/4" in comparison to treated and reinforced gypsum board—48"x96"x1/4", treated and reinforced gypsum board—48"x96"x1/2", regular gypsum roof board—48"x96"x1/2", and mesh-reinforced concrete—36"x72"x3/8". Testing was conducted for a metal roof deck with a rib opening of 2-5/8" and a flute spacing of 6", and metal roof deck with a rib opening of 6-7/16" and a flute spacing of 12".

A roof assembly of 22 ga. metal deck and a mechanically-attached underlayment board was subjected to the weight of a wheelbarrow filled with a given load. The load (i.e. a concentrated dynamic load) was applied to the center of a rib opening until ultimate value was achieved. (Refer to *Figures 1* and *2*. This was accomplished by increasing the load in increments of 10 lb. until failure occurred. The following controls were used:

- The contact surface area was maintained within ±10%; i.e., width of the wheelbarrows wheel was equal to 4" ±0.4".
- The same area (at rib opening) was subjected to the applied load only once.
- The relative humidity and temperature were monitored.

The fastening pattern, the board dimensions and the staggering of the joints were equivalent for all specimens that were tested. Refer to *Figure 3*.

Once the ultimate load was achieved, the test was repeated a minimum of six times to ensure the accuracy of the results. The failure load was within ±10% repeatability.

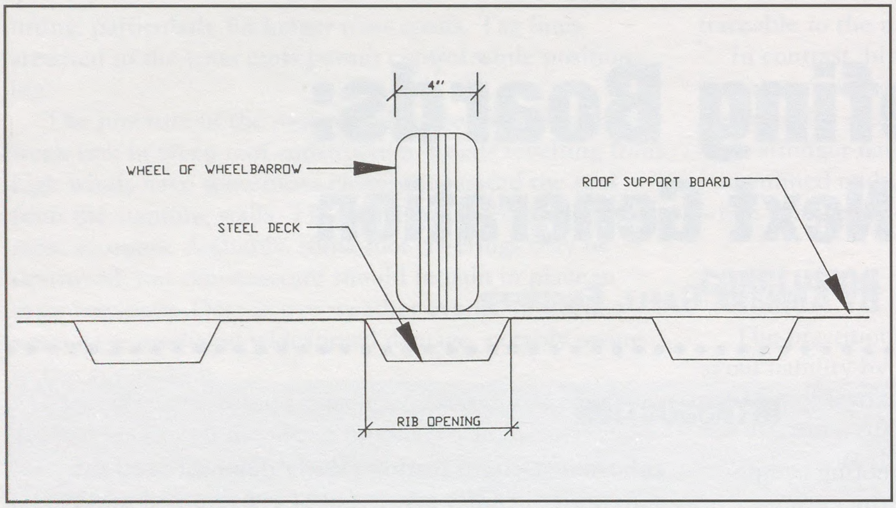

Figure 1—Detail of location of load on the roof support board.

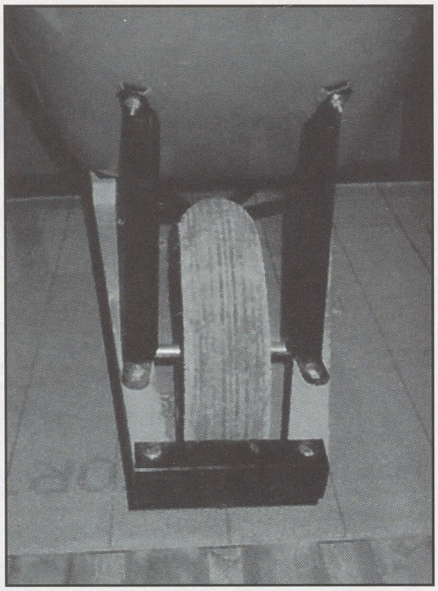

Figure 2—Photo of wheelbarrow.

The failure (ultimate) load as well as the type of failure that occurred were recorded. Failure was characterized as cracking, warping and/or collapse of the support board at the rib opening when subjected to the ultimate concentrated dynamic load.

The testing was conducted under the following two conditions:

- **Equilibrium: Interior Ambient Relative Humidity and Temperature** (for both metal decks with a flute spacing of 6" and 12"). Refer to *Table 1* for the test parameters.
- **1 Hour Exposure of Simulated Rainfall** (for the metal deck with a flute spacing of 6" only). Refer to *Table 1* for details about the test parameters.

The apparatus utilized for the test was a roof assembly that consisted of a structural framing of 8'x16' onto which a 22-ga. metal deck (with a 6" and 12" flute spacing) was installed. The underlayment boards were mechanically attached to the metal deck with roofing fasteners and 3"x3" square galvanized metal plates. A wooden platform was placed next to the roof assembly (parallel to the direction of the flutes) and level with the height of the roof assembly. This would allow for a smooth transfer of load onto the deck. The dynamic concentrated load was applied with a conventional wheelbarrow with a 15" diameter and 4" wide wheel. (Refer to *Figure 4*).

FLUTE SPANABILITY TEST RESULTS

Test results for underlayment boards at the equilibrium condition are shown in *Figure 5* for the 2-5/8" rib opening deck. *Figure 6* summarizes the results obtained with the 6-7/16" rib opening deck. The results obtained when roof support boards were subjected to 1 hour of simulated rainfall are recorded in *Table 2*. *Figure 7* shows the results obtained with the 2-5/8" rib opening deck.

ADHESION TESTING PROCEDURE AND APPARATUS

The objective of this test was to determine how various climatic conditions that involve moisture and temperature changes would affect the adhesion between

Table 1
Test Parameters for Flute Spanability Tests

Test Condition	Products Tested	Product Dimension	Dimension of Metal Deck's Flute Spacing
Equilibrium	• Fiber cement boards (1/4") • Treated & reinforced gypsum board (1/4")	• 4'x8' • 4'x8'	6"*
Equilibrium	• Fiber cement boards (1/4") • Treated & reinforced gypsum board (1/2") • Regular gypsum roof board (1/2") • Mesh-reinforced concrete board (3/8")	• 4'x8' • 4'x8' • 4'x8' • 3'x6'	12"
1 Hour of Simulated Rainfall	• Fiber cement boards (1/4") • Reinforced gypsum board (1/4") • Reinforced gypsum board (1/2") • Regular gypsum roof board (1/2") • Mesh-reinforced board (3/8")	• 4'x8' • 4'x8' • 4'x8' • 4'x8' • 3'x6'	6"*

** Treated and Reinforced Gypsum Board (1/4") was not tested with the deck that has a flute spacing of 12" because, as specified in the literature, it is not recommended to install the product on a metal deck with a 12" flute spacing. In addition, the treated and reinforced gypsum board (1/2") and the mesh-reinforced concrete board (3/8") were not tested on the metal deck with a 6" flute spacing because the objective of this study was to test the worst case scenario.*

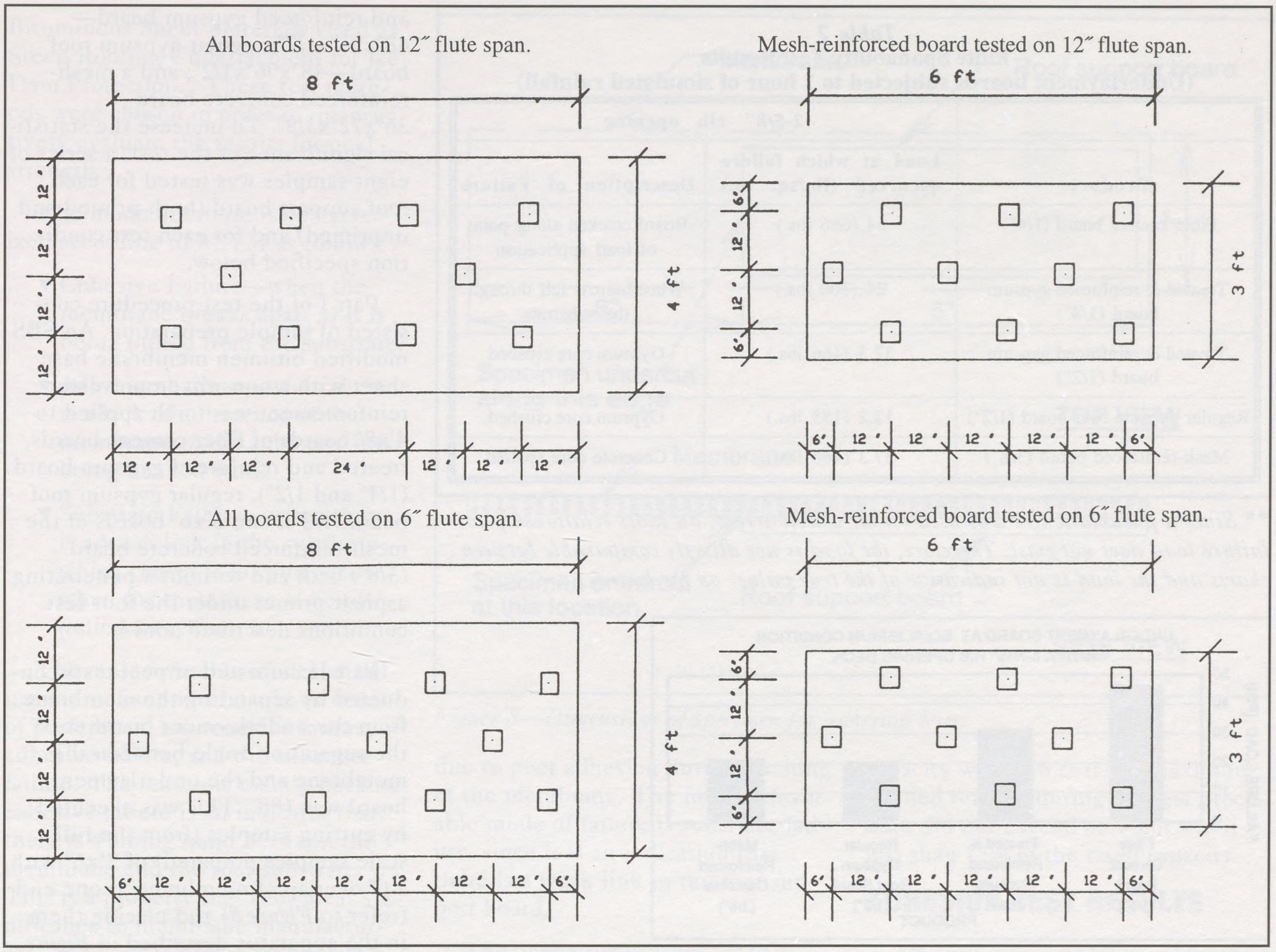

Figure 3—Fastening patterns of roof support boards.

primed and unprimed roof support boards and bituminous membranes. The following four test conditions were designed to simulate some of the most common occurrences:

Condition A—Ambient temperature and relative humidity.

This condition assumed an ideal situation for the membrane to be applied to the roof support boards where moisture or extreme temperature gradients were not present.

Condition B—30 minute saturation in water at 5°C before application of membrane; followed by 65 hours of exposure to -10°C after application of membrane.

This condition assumed a situation where the waterproofing membrane was applied to roof support boards that were exposed to a rainfall or snow. After the application of the primer and/or the membrane to the wet boards, the system was left exposed to cold winter conditions.

Condition C—24 hour saturation in water before application of membrane.

This condition assumed a situation where moisture would be introduced into the system during installation before the primer and/or membrane was applied to the wet boards. An example of such an occurrence can be if the roof support boards were installed and then left exposed to rainfall or snow.

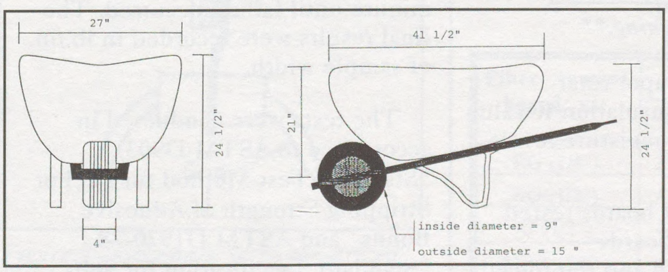

Figure 4 - Wheelbarrow used for flute spanability tests.

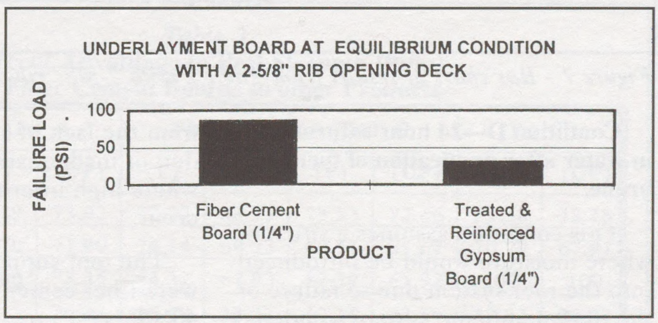

*Figure 5—Bar chart of results from Table 2 with 2-5/8" rib opening.***

Table 2
Flute Spanability Test Results
(Underlayment boards subjected to 1 hour of simulated rainfall)

	2-5/8" rib opening	
Product	Load at which failure occurred (lb./sq. in.)	Description of Failure
Fiber cement board (1/4")	54 (666 lbs.)	Board cracked along point of load application
Treated & reinforced gypsum board (1/4")	24 (300 lbs.)	Wheelbarrow fell through the substrate
Treated & reinforced gypsum board (1/2")	37.3 (466 lbs.)	Gypsum core crushed
Regular gypsum roof board (1/2")	12.2 (153 lbs.)	Gypsum core crushed
Mesh-reinforced board (3/8")	37.3 (466 lbs.)	Concrete core spalled

*** Since a pneumatic tire was used on the wheelbarrow, an exact relationship to failure load does not exist. Therefore, the load is not directly comparable between charts and the load is not indicative of the true values on the boards.*

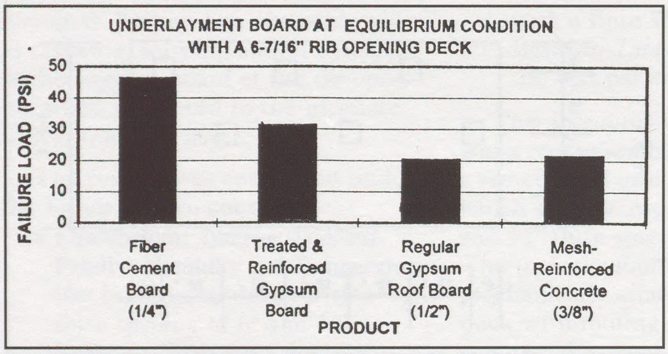

*Figure 6—Bar chart of results with 6-7/16" rib opening.***

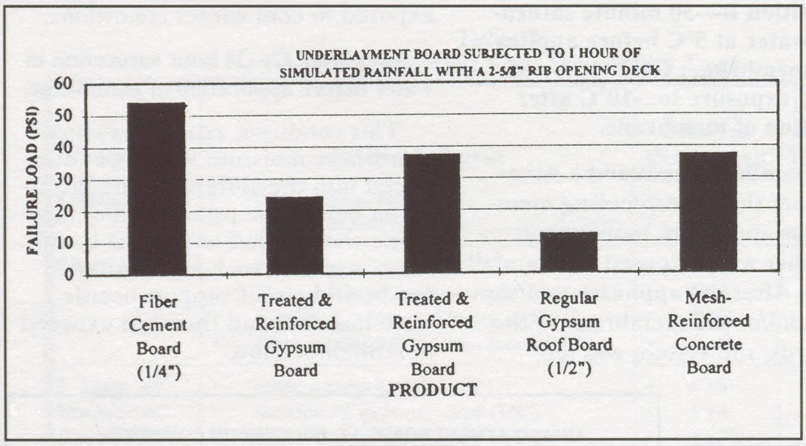

*Figure 7 - Bar chart of results from Table 2 with 2-5/8" rib opening.***

Condition D—24 hour saturation in water after application of membrane.

This condition assumes a situation where moisture would be introduced into the roof system due to failure of the roof membrane system; condensation within the insulation resulting from the lack of a vapor retarder; or inadequate insulation R-value where high interior moisture levels occur.

The roof support boards tested were fiber cement boards—48"x96"x1/4"; treated and reinforced gypsum board—48"x96"x1/4"; treated and reinforced gypsum board—48"x96"x1/2"; regular gypsum roof board—48"x96"x1/2"; and a mesh-reinforced concrete board—36"x72"x3/8". To increase the statistical significance of the test, a series of eight samples was tested for each roof support board (both primed and unprimed) and for each test condition specified below.

Part I of the test procedure consisted of sample preparation. An SBS modified bitumen membrane base sheet with a non-woven polyester reinforcement was torch applied to 4'x8' boards of fiber cement boards, treated and reinforced gypsum board (1/4" and 1/2"), regular gypsum roof board (1/2"), and 3'x6' boards of the mesh-reinforced concrete board (3/8") with and without a penetrating asphalt primer under the four test conditions described above.

Part II consisted of peel tests conducted by separating the membrane from the underlayment board until the separation angle between the membrane and the underlayment board was 180°. This was executed by cutting samples (from the full scale samples prepared) of 2"x6" with a 6" overlap of membrane at one end (refer to *Figure 8*) and placing them in the apparatus described in *Figure 9* and *Figure 10*. In this tensile tester, the substrate was clamped at one end and the membrane was clamped at the other end. However, before placing the specimens in the apparatus, they were undercut with a sharp blade along the shorter edge of the substrate where the membrane overlaps the support board to produce a proper separation at the interface of the membrane and the roof substrate and to prevent premature failure of the roof substrates during the test. The rate-of-jaw separation to remove the membrane from the substrate was 3 in./min and readings were tabulated every 5 seconds in pounds per minute until failure occurred. The final results were recorded in lb./in. of sample width.

The tests were conducted in accordance to ASTM D903, "Standard Test Method for Peel or Stripping Strength of Adhesive Bonds" and ASTM D1970-78, "Standard Specification for Self-Adhering Polymer Modified

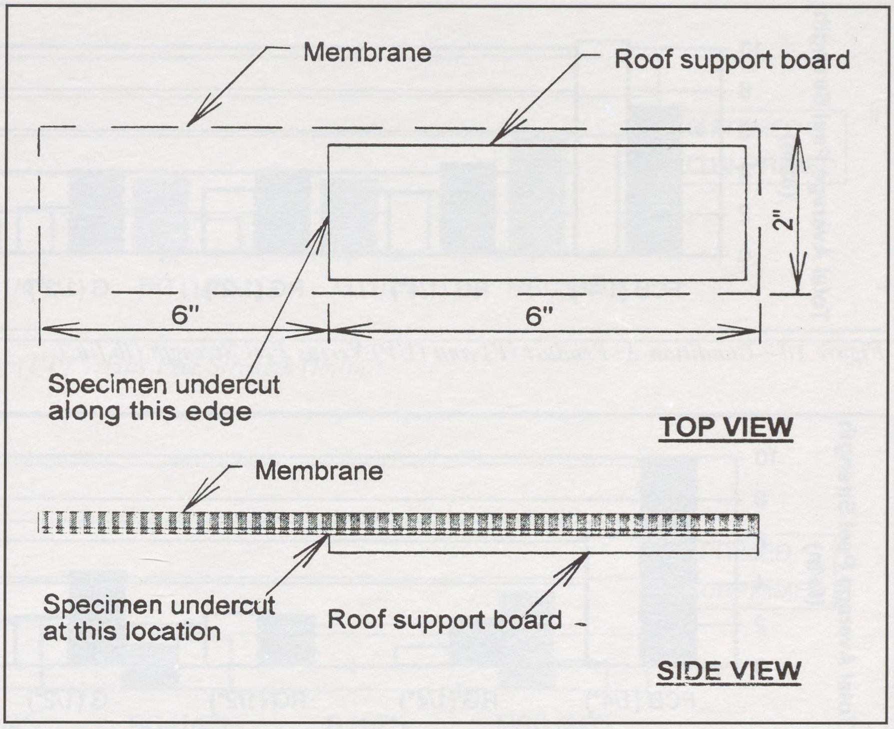

Figure 8—Dimensions of specimen for adhesion tests.

Bituminous Sheet Materials Used as Steep Roofing Underlayment for Ice Dam Protection." These test methods were chosen in order to quantitatively evaluate the results for peel strength.

The mode of failure is characterized according to ASTM as follows:

- ▼ Cohesive Failure—when the membrane breaks apart as it is being pulled from the substrate.
- ▼ Adhesive Failure—when there is a lack of adherence of the membrane to the substrate it is being bonded with.
- ▼ Substrate Failure—when there is a weak link in the substrate which causes it to come apart when the membrane is being pulled away from it.

The most favorable modes of failure for roof support boards, in order of preference, are cohesive failure, adhesive failure, and the substrate failure. The reason is mainly because cohesive failure is an indicator that there is a strong bond between the membrane and the roof substrate. This is a property that is of great significance to membrane manufacturers. Adhesive failure is still possible due to poor adhesion during torching of the membrane. The most unfavorable mode of failure is substrate failure, since it is an indication that there is a weak link in the roof support board.

The apparatus utilized for this test was a power-driven machine (refer to *Figure 9*) that maintained a constant crosshead speed of 3 in./min. throughout the tests. In this pendulum-type machine, the weight lever swung as a free pendulum without engagement of pawls. The applied tension as measured and recorded was accurate within ±1%. The specimens were held in the testing machine by grips which clamped firmly and prevented slipping at all times. The machine capacity was such that the maximum applied tension during the test procedure did not exceed 85% nor was it less than 15% of the rated capacity.

ADHESION TEST RESULTS

All products tested were abbreviated as follows:

FCB(1/4") = Fiber cement board, 1/4" thick

RG (1/4") = Treated and reinforced gypsum board, (1/4") thick

RG (1/2") = Treated and reinforced gypsum board, (1/2") thick

G (1/2") = Regular gypsum board, (1/2") thick

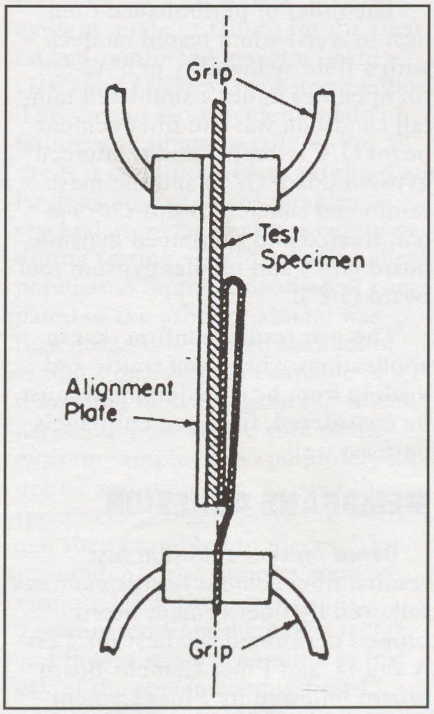

Figure 9—Schematic of power-driven machine per ASTM D 903-93 for adhesion (stripping strength).

Table 3
Percent Advantage in Peel Strength (lb/in) of Fiber Cement Boards to other Products

Fiber cement board vs:	Test A		Test B		Test C		Test D	
	(P)	(UP)	(P)	(UP)	(P)	(UP)	(P)	(UP)
RG (1/4")	39.89	73.92	77.77	88.73	73.55	72.56	67.38	58.16
RG (1/2")	42.70	71.90	76.14	60.23	60.17	81.67	70.29	67.91
G (1/2")	43.00	78.35	54.52	63.93	82.19	61.92	100	100
MRC (3/8")	43.12	54.48	25.79	33.33	40.15	23.59	32.82	82.27

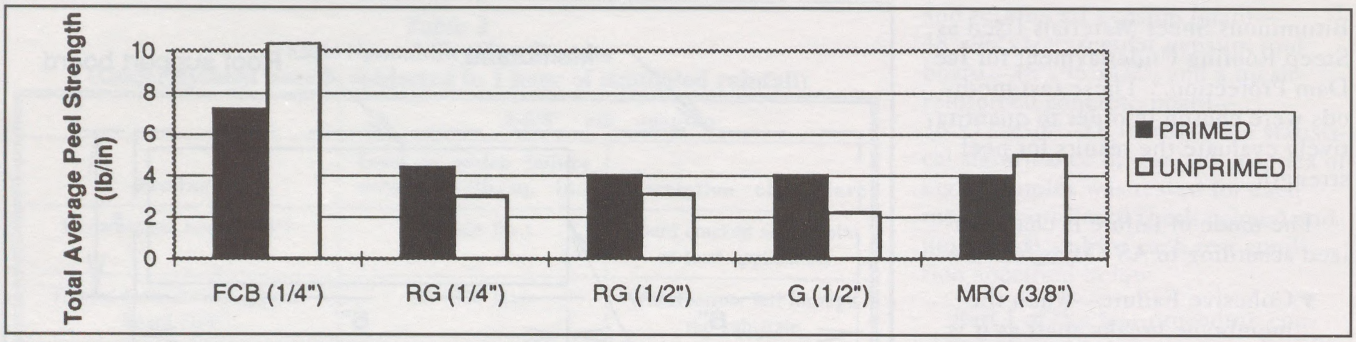

Figure 10—Condition A: Product (P) and (UP) Versus Peel Strength (lb./in.).

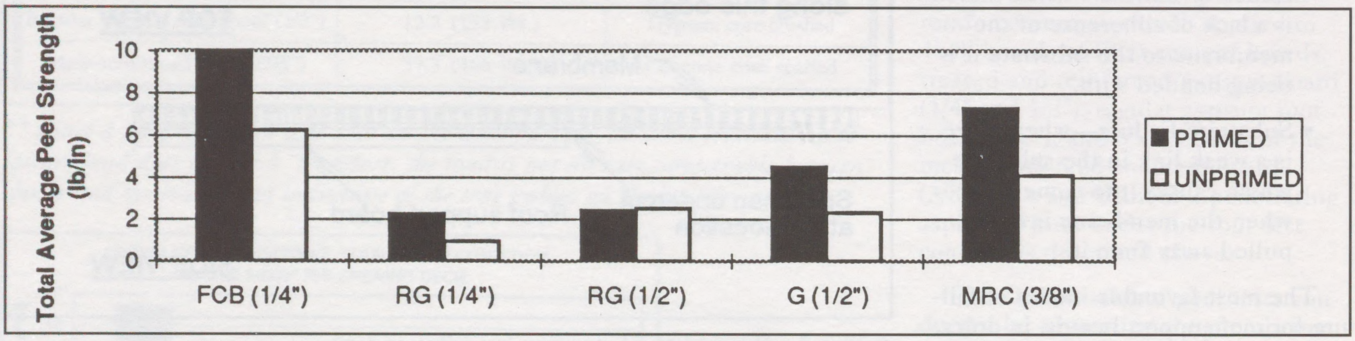

Figure 11—Condition B: Product (P) and (UP) Versus Peel Strength (lb./in.).

MRC (3/8") = Mesh-reinforced concrete board, 3/8" thick

where (P) = Primed roof support board, and (UP) = Unprimed roof support board

The peel strength data are summarized in the bar charts of *Figure 10* to *Figure 13*. The data from *Figure 10* to *Figure 13* were used to calculate the percentage increase in performance of fiber cement boards compared to the other roof support boards (for both primed and unprimed boards) as shown in *Table 3*. The mode of failure for each product is shown in the referenced figures as follows:

- Cohesive failure for fiber cement boards as shown in *Figure 14*.
- Adhesive and substrate failure for treated and reinforced gypsum board (1/4") as shown in *Figure 15* and *Figure 16*.
- Adhesive and substrate failure for treated and reinforced gypsum board (1/2") as shown in *Figure 17* and *Figure 18*.
- Substrate failure for regular gypsum roof board (1/2") as shown in *Figure 19*.
- Cohesive and adhesive failure for the mesh-reinforced concrete boards as shown in *Figure 20*.

Conclusions

FLUTE SPANABILITY

In every test condition, fiber cement outperformed the other types of materials. Common elements of moisture and cold working conditions were considered. The fiber cement boards widened the performance gap when compared to the other materials.

In the most common deck module of 6", the fiber cement boards demonstrated the most resistance to failure when subjected to a concentrated dynamic load from a wheelbarrow in the flute spanability tests. The order of performance from best to worst for the flute spanability tests under an equilibrium condition was the fiber cement board (1/4"), followed by the treated and reinforced gypsum board (1/4").

The order of performance from best to worst for a flute spanability of 12" (6-7/16" rib opening) under an equilibrium condition was the fiber cement board (1/4"), treated and reinforced gypsum board (1/2"), mesh-reinforced concrete board (3/8"), and regular gypsum roof board (1/2").

The order of performance from best to worst when tested on deck with a flute spanability of 6" (2-5/8" rib opening) under a simulated rainfall condition was the fiber cement board (1/4"), treated and reinforced gypsum board (1/2") and the mesh-reinforced concrete board (3/8") at par, treated and reinforced gypsum board (1/4") and regular gypsum roof board (1/2").

The test results confirm that in applications where roof traffic and loading from heavy equipment must be considered, fiber cement panels perform well.

MEMBRANE ADHESION

Based on the adhesion test results, fiber cement boards *unprimed* followed by fiber cement board primed performed the best for Test A and D, and Fiber Cement Board *primed* followed by Fiber Cement Board *unprimed* performed the best for Test B and C. The most evident mode of failure was cohesive failure

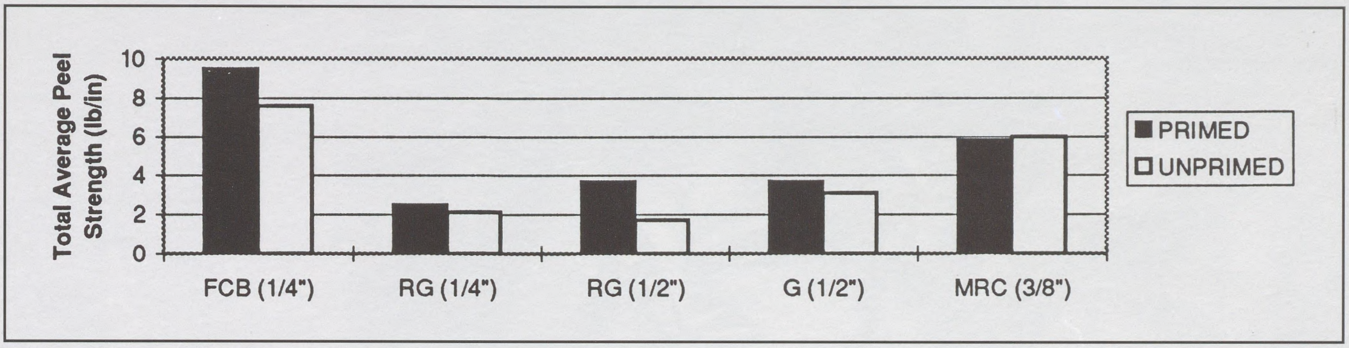

Figure 12—Condition C: Product (P) and (UP) Versus Peel Strength (lb./in.).

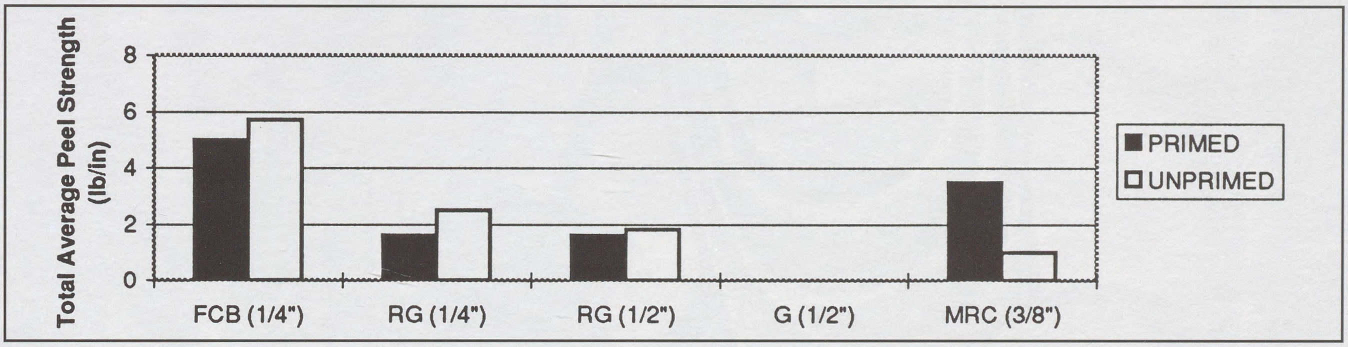

Figure 13—Condition D: Product (P) and (UP) Versus Peel Strength (lb./in.).

and in some instances, adhesive failure. The mesh-reinforced concrete board produced the second highest set of results for Tests A to D. Both cohesive and adhesive failure were noted, and substrate failure was recorded for Test A only. The most evident mode of failure for the treated and reinforced gypsum board (1/4") and (1/2") was substrate failure. The second most evident mode of failure was adhesive failure. For all the test conditions (A to D) the regular gypsum roof board samples cracked at midspan either before or during testing. Therefore, a smaller population (approximately half compared to the other products) was tested due to the large number of samples that were not capable of remaining intact. Due to the severe nature of Test D, the core of the gypsum samples was completely saturated and therefore, most of the specimens cracked along the width and then crumbled to pieces. The remainder of the samples were so saturated that the paper facing delaminated from the gypsum core and thus it was not possible to test any of the specimens for Test D. The most evident mode of failure for all the specimens was substrate failure. For those that were tested (from Test A to Test C), the mode of failure was also substrate failure where the paper facing would peel away from the gypsum core, taking with it some of the gypsum core.

Consequently, the fiber cement boards had the highest peel strength with and without primer in comparison to the other products. Fiber cement board also provided the best surface preparation in order for a membrane to be applied to it with or without primer, regardless of whether fiber cement boards are in a saturated or equilibrium state. This further confirms the recommendation that priming is a good practice, but not necessarily required before applying a waterproofing membrane onto its surface. In addition, fiber cement boards have the most favorable mode of failure (cohesive failure) compared to (for example) the substrate failure that occurred with the treated and reinforced gypsum board and the regular gypsum roof board.

The test results confirm that in applications where moisture may eventually be present, or where roof membranes are installed in inclement conditions, fiber cement panels perform better than gypsum and mesh-reinforced concrete board.

About The Author

Adriana Galli *graduated from the Center for Building Studies at Concordia University in Building Engineering, and is a registered engineer with the Order of Engineers of Quebec. As a research and development engineer with Materiaux de Batiment d'Avant Garde (Advanced Building Materials), she did testing on fiber cement products, including flat boards for roofing applications, and corrugated profiles for roof deck applications. Prior to joining MBA, Galli worked as a technical and marketing services manager with a fiber cement manufacturer. Galli is currently the marketing services manager of Sika Canada Inc., a manufacturer of construction chemicals and cementitious products for concrete repair and restoration, located in Montreal.*