FIBER REINFORCED CONCRETE

Present and Future

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THIN SHEET CEMENTITIOUS COMPOSITE

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ABSTRACT

Thin sheet fiber reinforced cementitious composites are used extensively in the construction industry for cladding and roofing. The first man made composite to be most widely used was asbestos cement. A variety of composites with different types of fibers and production processes have since been developed and are widely applied. These composites may look the same, yet their properties may vary quite significantly and their response to the environment can be considerably different. Inspite of the considerable difference in properties each of them can be successfully used in construction, but the method of application, incorporation and jointing to the structure should be different in order to adjust for the particular behavior and properties of each of these composites.. This chapter provides a review of the properties and test methods of these composites, the range of products made from them and outlines and the guidelines for their use in structures.

INTRODUCTION

Thin sheet cementitious composites are widely used in the construction industry mainly for cladding purposes. These thin, lightweight composites emerged at the turn of the century, as they offered considerable advantages over conventional construction materials. A good example of these advantages is the comparison of thin sheet composite slate, versus the brittle natural slate:

1. Massive and more expensive sub-construction in order to support the weight of the natural stone slate material.
2. Working with natural slate requires a certain amount of skill, for example drilling holes and cutting.
3. Only small elements could be used due to the practical handling implications.

The obvious move to faster and less complicated construction design criteria led to the development of cost effective fiber-cement composites which have been used since the invention of asbestos cement at the turn of the century.

The first thin sheet product in modern period was asbestos. It was invented by Ludwig Hatschek, an Austrian who in 1900 had a patent taken out on this procedure as "Verfahren zur Herstellung von Kunststeinplatten aus Faserstoffen und Hydraulischen Bindemitteln" (manufacturing process for "synthetic stone" sheets and hydraulic binding agents). Essentially, this invention consisted of manufacturing a sheet material on a rotating sieve machine, using a highly diluted suspension of Portland cement and asbestos fibers. Because of its excellent properties, this product subsequently became a major construction material and later was used for the manufacture of pipes and joints.

Today asbestos cement is understood to be a composite material with mechanical properties that largely depend on the interaction between the reinforcing fibers (asbestos) and the matrix (cement).

As with many other great inventions around the turn of the century, Hatschek's invention was a "lucky hit". Due to the potential health risk implied by the use of asbestos fibers (mining and processing of asbestos fibers on the Hatschek process), the need in some countries to replace asbestos and the requirement for a material of more versatile properties resulted in the development of a variety of thin sheet cementitious composites using different types of fibers and modified cementitious matrices. The properties of such composites can vary considerably (1,2), yet all of them can be used successfully, if they are properly applied in the structure, taking into account their specific characteristics. It became obvious that in the search for asbestos fiber replacements many industries and research organizations discovered that a whole range of new fiber types could be used in combination with cement.

Between the years 1975 to 1990 there was a considerable advancement in this field due to research (industrial, academic and research institutes) for the replacement of asbestos fibers in cement based materials. The textile industry and paper manufacturers offered more innovative fiber types during these years and the choice of possible fiber types was very large. For example: Glass, Steel, Carbon, Kevlar-29, Polypropylene, Polyamide-686, Polyester (PET), Rayon, Polyvinylalcohol, HM-Polyasrylnitril.

It was obvious that not all fiber types available could be used due to cost implications, durability aspects, industrial processing capabilities and compatibility with

cement. Therefore the choice of replacement fiber types became much smaller when it came to the transfer of research efforts into an industrial scale product.

In essence the large effort realized over the fifteen years of research which only really started taking off in 1975, bought about many innovative components and replacements for the existing product range in the asbestos cement industry.

Therefore, today there are many types of thin sheet fiber-cement products available on the market. It is possible to classify these into several groups based upon the fiebrs used:

- **Asbestos cement**-cement reinforced with asbestos fibers produced usually by the Hatschek process.
- **Cellulose cement sheets**-cement reinforced with cellulose fibers derived by pulping processes. These composites are produced by the Hatschek process and are applied in many instances as asbestos replacement or as part of the reinforcement which consists of two or more different types of fibers.
- **Wood particle cement sheets**-cement reinforced with wood chips obtained by a variety of processes. The methods of production of the board can be based on simple casting techniques or it can involve pressing and heat treatments.
- **Glass fiber reinforced cements known also as GRC or GFRC**-cements reinforced by glass fibers produced in a variety of processes such as spray techniques and simple premixing. The spray technique allows for the production of complex shapes, depending on the geometry of the mold on which the mix is sprayed.
- **Polypropylene fiber reinforced cement sheets** - the polypropylene could be made up of individual short fibers or a continuous net film.
- **Composite cement sheets** - sheets with a thickness of 10-15 mm, with a core of lightweight aggregate cement mortar and external skins of cement reinforced with a glass fiber mat.
- **Cement reinforced with a variety of modern fibers** such as carbon and PVA or a mix of these fibers with cellulose fibers (hybrid reinforcement).

Considering then the two aspects, i.e. first the search for lightweight replacement materials at the turn of the century for the traditional natural slate material and secondly, at a much later stage, the development brought about by asbestos fiber replacement programs, there are a large variety of innovative products available on the market today. Last, but certainly not least, it should be mentioned that the demand from modern architects for modern buildings has in addition brought about a wide variety of colors, shapes, and size. Today this potentially "dull" gray material has now taken on decorative aspects as well.

PROPERTIES OF THIN SHEET CEMENT COMPOSITES

Some characteristic properties of commercially available thin sheet products are presented in Fig.1 and Table 1. It should be noted that for each of the composites, the data is for one specific product, and it should be appreciated that for each individual type of thin sheet material a range of properties may be obtained by changing the fiber content and the production process. For example, the data in Fig.1

and Table 1 for the cellulose sheet is for a lightweight one. Higher strength levels can be achieved for a similar composite when the production process involves pressing, to obtain a denser product with densities of about 1600 kg/m^3. This is demonstrated in Table 2 which specifies properties for products of different densities.

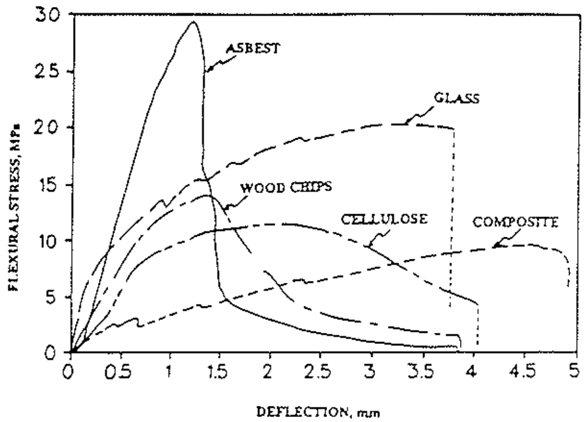


Figure 1: Calculated flexural strength versus deflection curves of some commercial fiber reinforced cement thin sheet composites tested in flexure (from reference 3).

Table 1
Properties of several commercial fiber reinforced cement sheet composites (Ref. 3).

type of fiber	density, kg/m^3	flexural strength, MPa	swelling, %
asbest	1600	32	0.09
glass	1700	25	0.13
cellulose	1100	10	0.30
wood particle	1000	9	1.75
composite	1200	10	0.15

Remark: the properties in this table represent results of specific products tested in ref. 3; properties of products of similar fibers can vary considerably from values presented here, depending on the density, production process and other variables.

Table 2
Flexural strength and unit weight requirements of cement thin sheets prepared from asbestos fibers and a mix of asbestos and cellulose fibers according to ISO standard 396.

category of composite	asbestos composite		asbestos-cellulose composite	
	minimum flexural strength, MPa	minimum density, kg/m^3	minimum flexural strength, MPa	minimum density, kg/m^3
1	16	1200	9	800
2	28	1600	16	1000
3	-	-	20	1300

The main conclusion drawn from the data presented here is that the properties of the thin sheets can vary over a wide range. This is true for mechanical properties (strength, modulus of elasticity, toughness) as well as physical properties, in particular volume changes on exposure to wet conditions (thickness swelling in Table 1). It should be noted that the differences in swelling are very significant; from an engineering point of view 2% change is more than one order of magnitude greater than that of mortar for rendering, and almost two orders of magnitude greater than that of typical concrete. In addition to that, it should be taken into account that the mechanical properties of some of the composites may change over time (1), due to changes in the moisture content of the material (e.g. cellulose fiber reinforced cement after exposure to humid environment-Fig. 2), or some aging processes triggered on exposure to the natural environment (e.g. reduction in strength and toughness of GFRC on prolonged exposure to a humid environment (5,6,7)-Fig.3).

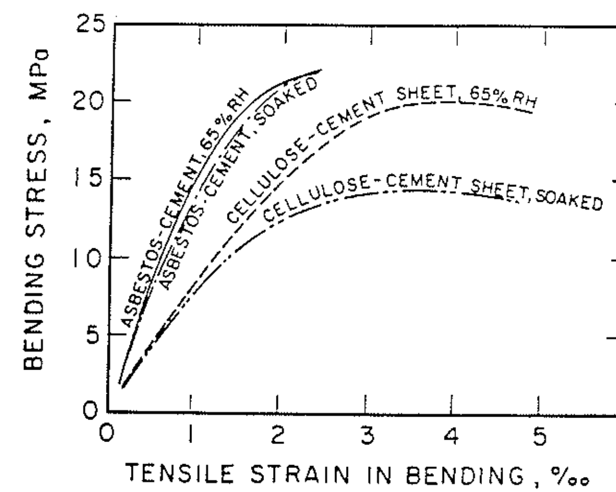


Figure 2: Influence of moisture conditions on stress-strain curves calculated from bending tests of asbestos-cement and cellulose-cement thin sheet composites (from reference 4).

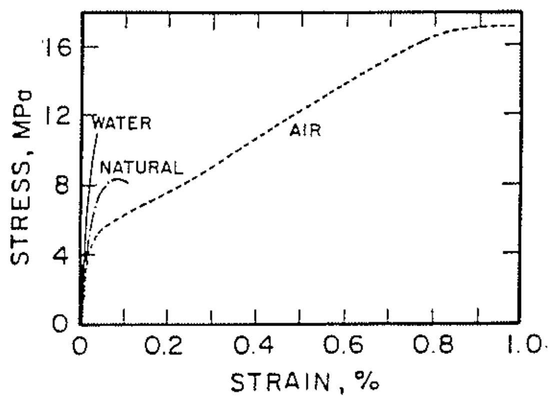


Figure 3: Stress-strain curves of glass fiber reinforced thin sheets after aging in dry, natural and wet environments (from reference 7).

LONG TERM PERFORMANCE

The processes leading to changes in properties over time can be quite complex, combining chemical and physical effects which are dependent on the nature of the fiber and the matrix, as well as on the interaction between the two. Sensitivity of mechanical properties to short term exposure to humid environment is characteristic of systems with hydrophilic fibers, which include usually wood particles and cellulose fibers (cellulose pulp); the reduction in strength and increased toughness on short term wetting reflects the changes in the properties of the fibers (4). These changes are smaller in cellulose composites (Table 1) when compared with wood particle composites, and they can be further reduced if the composite is produced in a process involving pressing: higher density matrices reduce moisture migration through the composite.

Changes in mechanical properties after long term exposure can be the result of chemical and physical processes or combinations of the two (5,6). Changes in the properties of GFRC can be due to chemical attack of the fibers by the highly alkaline cement matrix (8). However, even with the use of special formulations of alkali resistant (AR) glass fibers, changes can still occur (5,6,7), as seen in Fig.3. Such changes have been suggested to be the result of physical effects, associated with densening of the matrix in the vicinity of the fiber (5). If the matrix around the fiber is becoming too compact, embrittlement can occur, leading to a loss in strength and toughness. If alkali attack and interfacial growth of hydration products can lead to degradation in properties, then the long term performance would be sensitive to exposure conditions which are characterized by wet conditions and higher temperatures. In fact, this is the basis for accelerated aging tests based on immersion in hot water, in which the aging performance is assessed by comparing the flexural strength and toughness before and after the water immersion treatment (9). The temperature conditions for this kind of test in most standards are in the range of 50 to 60°C, with the latter value being the one chosen by the ISO standard 8336. It has been shown (9) that for a typical UK weather one month of accelerated aging is equivalent to about one year of natural exposure. It should be noted that in some special cases changes in properties due to densification processes over time can be associated with

carbonation. This has been shown to be the case in some formulations of cellulose fiber reinforced cements for which accelerated tests promoting carbonation have been suggested (10,11). Such tests are at present not included in standards but they are used by several producers for internal assessment of their products.

Degradation in properties may also result from other effects, associated with volume instability of the composite. This influence is more likely to be present in natural fiber reinforced cements which exhibit swelling on wetting and contraction on drying. Exposure of such composites to wetting and drying cycles can lead to reduction in strength due to internal damage (usually micro- and macro-cracks caused by frequent changes in dimensions). Thus, accelerated tests based on wetting and drying cycles are better suited for such composites.

In view of this discussion it becomes clear that tests for rapid evaluation of long term performance should be adjusted to the composite tested, and for that purpose initial assessment and prediction of the nature of the aging mechanisms should be made. It has been demonstrated in several studies that for the same composite, one type of accelerated treatment may show signs of degradation whereas the other will not lead to any changes. For example, in GFRC signs for reduction in properties may be seen in the hot water accelerated tests, but not in the wetting/drying cycle tests; with cellulose fibers and wood particle reinforced cements it may be the other way around (3,12,13) as demonstrated in Table 3. This is the basis for the requirement in the ISO 8336 standard for both types of accelerated tests.

Table 3
Retention of flexural strength after accelerated aging of some commercial fiber thin sheet composites consisting of different kinds of fibers (Ref.3).

type of fiber	flexural strength retention, %	
	60°C water	drying/wetting
asbestos	100	90
AR glass	70	100
cellulose	100	60

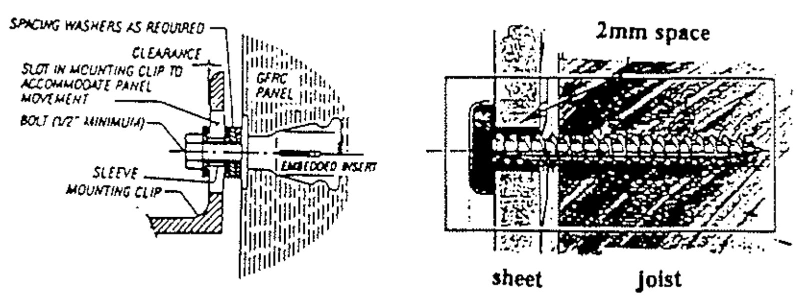
It should be emphasized that considerable advances have been made in the last decade in developing composites of improved performance in accelerated aging tests. This was achieved by modifying the composition of the fibers, applying special surface treatments and using modified cementitious compositions. Examples are surface treatments of glass fibers, modification of the matrix with polymeric latex and the use of a special low alkali-low lime cement (8,14,15).

SPECIFICATIONS AND CONSTRUCTION WITH THIN SHEET FIBER REINFORCED CEMENTS

In view of the wide variety of properties and long term performance of the various composites, there is the need to discuss how most of these materials can be used successfully in similar types of construction and what is the rationale behind the standards and specifications that guide us in their use. There are several key points that should be considered and discussed.

First of all, one should appreciate that although most of the standards address the flexural strength characteristics, the strength of most of the thin sheet composites is high (usually more than 7MPa in the wet conditions or after aging). This is a sufficiently high strength for a non-structural component which is usually supported between closely spaced studs. When failures occur, in many instances they are the result of a combination of internal stresses generated by length and thickness changes which are restrained by the studs and connections to the sheet. These internal stresses can be sufficiently high to cause cracking and bowing if the moisture and temperature movements are sufficiently large (16,17,18). This situation is aggravated if at the same time the composite becomes brittle due to aging effects. For example, many of the early problems with GFRC panels were related to cracking in sandwich type panels, due to differential movements in the panel and the joints (16,19). This was the main driving force causing cracking, rather than a decline in strength on aging (which is stabilized at a relatively high value of about 15 MPa in flexure).

These characteristics and complexities in the behavior of the thin sheet cement composites are usually taken care of in the construction practices. Although the principles of construction seem to be the same for most thin sheets (connecting the sheets to studs that are spaced at 400 to 600mm intervals), the detailing of construction can be quite different (different types of connections to the studs and the types of joints and joint sealing). On top of that, in some types of sheets, special requirements for coating and rendering may be specified. Their function is not only aesthetic, but also provides some protection from external weathering. Some examples are give in Fig.4 showing recommended connections for two types of thin sheet materials. Requirements for the use of coatings as an inherent part of the construction method is common in wood particle cement thin sheets as well as in some of the composite sheets when used externally.



(a) (b)

Figure 4: Examples of some connections allowing local flexibility recommended for use in (a) glass fiber reinforced cements; (b) cellulose-reinforced cement.

This discussion highlights the necessity to match the construction practice with thin sheets to the properties of the composite, thus allowing for widely different types of materials to be used successfully in practice. It is of interest to discuss how the standards deal with this kind of situation which is relatively complex, as it is not sufficient to base the specifications on simple materials properties such as strength and density. Distinction is usually made between the more common materials which have been used traditionally and in which acceptable and proven construction practices are well rooted. In such instances the standards typically refer only to materials properties such as flexural strength and unit weight. In materials sensitive to moisture additional requirements are made with regard to minimum strength in dry and wet conditions, resistance to pull out of screws and length and thickness changes. Examples of such requirements are provided in Tables 2 and 4 for asbestos-cement, asbestos-cellulose-cement and wood particle-cement thin sheets.

Table 4

Some typical properties of wood particle cement sheets according to British Standard.

property	flexural strength water MPa	flexural strength air MPa	modulus of elasticity MPa	resistance to screw pullout N	density Kg/m^3	swelling- 24 hrs. %	length, width change %
requirement	5.5 (min.)	9 (min.)	3000 (min.)	450 (min.)	1000 (min.)	2.00 (max.)	0.18 (max.)

A different approach was needed for newer types of composites where no established construction practices existed. Here, a combination of requirements addressing materials properties and overall performance for an assembly of sheets mounted and connected to studs had to be put forward. The requirements for the material itself are based to a large extent on flexural strength and durability performance of small coupons subjected to accelerated tests in hot water and alternating drying/wetting cycles. The requirement for flexural strength retention after aging is about 75% (ISO Standard 8336).

In recognition of the variety of composites which might be produced, depending on the type and content of fibers as well as the density of the sheet, the ISO Standard 8336 has subdivided the composites into several categories, each characterized by different flexural strength requirements (Table 5). Performance tests include full scale testing of a typical unit made from at least two sheets mounted on studs using the connections required in practice, having at least one joint treated as instructed by the producer. The ISO Standard specifies the heat-rain test for such a system, which is basically a large scale wetting/drying cycle test. Other full scale performance tests include resistance to impact and wind loading (e.g. ASTM E72, ISO 8336). If the thin sheet requires coating, then the performance test should be carried out with an assembly where the coat is included. It should be emphasized that these performance tests require considerable time and expenses. They are intended for testing and approving a prototype, whereas the testing of the materials properties can be later used for routine quality control.

Table 5
Classification of fiber reinforced cement thin sheet composites according to ISO standard 8336.

category	minimum flexural strength, MPa	
	type A-internal use	type B-external use
1	-	4
2	7	10
3	13	16
4	18	22

Remark: values for type A and B are for composites conditioned in water and air respectively, prior to testing.

PRODUCTION PROCESSES

Broadly speaking fiber-cement products used in the market place can be manufactured in many ways: e.g. standard Hatschek process or flow-on process, injection molding, extrusion, spray-on as used in GRC and wood chip particle boards and many others. The curing process after production can also vary according to the product range. A detailed description of these processes and curing procedures is beyond the scope of this chapter. However, in order to get a feel for how and why a particular fiber, process and curing procedure is chosen for a specific product, three examples will be given in order to elaborate on the principles involved. These are:

a) Autoclaved Products
b) Normal cured products and
c) GRC

Autoclaved Products

In this example the products produced are manufactured using the Hatschek process and cured at elevated temperatures and pressures (typically 180°C and 9 Bars). The main types of fibers which can be economically used according to this process are asbestos, cellulose and wollastonite. Synthetic fibers cannot take autoclave temperatures of 180°C. The use of cellulose fibers as a replacement for asbestos in FRC products has at present been adopted in South Africa, Australia, New Zealand, USA and parts of Europe.

These products consist of milled silica, cement, cellulose fibers and some minor additives. The product range varies from roofing slates, corrugated roofing sheets to internal partition boards.

Normal Cured Products

For normal cured products the choice for a particular fiber types is much larger than for autoclaved products. The use of synthetic fibers (such as polyvinyl alcohol) in combination with cellulose fibers is the approach which is normally used for these products, in particular in European countries like Switzerland, Germany, France, Austria, Belgium, Denmark, etc. The matrix components consist of cement plus other additives such as fly ash, silica fume, limestone powder and other fillers and reinforcing fibers.

Austria, Belgium, Denmark, etc. The matrix components consist of cement plus other additives such as fly ash, silica fume, limestone powder and other fillers and reinforcing fibers.

The range of products produced for normal cured material is also much wider than for autoclaved products. The manufacturing processes which can be used to produce these products are Hatschek, flow-on, injection molding, extrusion and others. After manufacture the products are cured in a stack under ambient conditions.

The use of polypropylene nets (Netcem), a development which was patented at the University of Surrey, UK, is being adapted for the production of corrugated sheets in a fiber cement company in Italy.

Glass Fiber Reinforced Cement (GRC)

The use of chopped glass fiber with cement is a well established process and much research has been done at the Building Research Establishment (UK) in developing this process. There are two basic methods used for the manufacture of GRC; these are the spray process and premix process.

Spray Process: The cement slurry and additives are pumped through a mono pump to meet the spray gun which chops the glass fibers. The cement slurry plus the fibers are then prayed into the molds for the required product. This process is a very versatile one which can be used to create all shapes and sizes for decorative facade panels. It is the most commonly used process for GRC. A typical spray unit can produce approximately 2 tons of GRC per shift.

Traditionally large flat sheets or sandwich panels with an insulating core and shaped/molded facade panels have been made by the spray process which lends itself to low volume economical production. The products produced have been used for high rise buildings in the USA, UK, parts of Europe, Australia and South Africa.

Studded frame panels have become common for the cladding of buildings and this follows the trend in the USA where they are being widely used to clad multistoried buildings. With this method a newly sprayed flat or semi-flat sheet is joined to a steel stud frame by flexible anchors and this frame is then fixed to the building after the GRC has cured. This construction method for GFRC is efficient in relieving internal stresses that might develop due to temperature and humidity changes.

Premix Process: Less commonly used because of the difficulty of mixing sufficient content of fibers into the mix without having the water/cement ratio too high. Various methods can be used to reduce the water content to the correct level afterwards, such as vacuum dewatering.

Glass fibers have a high modulus of elasticity and provide high tensile strength properties to the fiber cement composites. However, the properties of the composite may change with time, and strength and ductility may be reduced, particularly when in wet conditions. A variety of fibers have been developed to mitigate this effect and they are collectively known as alkali-resistant (AR). Many of them are based on formulations with high zirconia content, in combination with surface treatments.

PRODUCTS

Thin sheet cementitious composites can be used to manufacture a variety of products.

a) Slates and Shingles
b) Large facade sheets and flat sheets for external use
c) Flat sheets for internal use
d) Profiled sheets and consumer goods

Slates and Shingles

Roofing slates and shingles are suitable for use in a wide spectrum of applications - for roofing and vertical cladding of residential, commercial, institutional, agricultural and industrial buildings.

These versatile slates and shingles allow designers flexibility and individuality of expression. They are ideally suited for roof configurations featuring hips and valleys, and even circular applications are possible. (See table 6 for varied products available.) Cutting, sawing, drilling and fixing can easily be accomplished with ordinary slaters tools and are easily erected. To ensure a high standard of finish, it is essential that the supporting structure is good and sound. Warped, twisted or poor quality battens will reflect in the finished surface of the facade.

The existing range of lightweight products and systems provide architectural designers with considerable scope for design flexibility and creative expression. The material's ready acceptance of a wide variety of finishes is an added benefit.

Vertical or sloping walls can easily be accommodated. Facades can be treated sculpturally in three dimensions to provide relief. The product range comprises: flat and 3D cladding, Decor planks and different slate types. Molded corner panels can be incorporated into flat sheet systems. In addition, the wide range of base products are available in different surface textures which are imprinted during the manufacturing process. A choice of varied standard colors and metallic colors are available. This provides an almost limitless combination of color and texture to the creative and cost-conscious.

Fiber cement products are already well established in the market and are well known for their high degree of dimensional stability. They do not rot, are unaffected by vermin, will not burn, are not damaged by water and are impervious to salt, sunlight and air pollution.

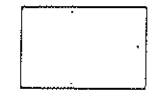
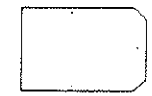
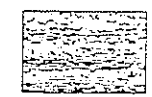
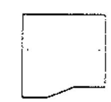
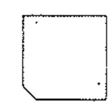
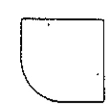
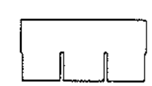
The product range is ideal for incorporating into new buildings and for use in renovation and upgrading facades on existing buildings. An entirely new facade can be given to building without major alteration and without greatly affecting foundation loads. Insulation and services can be accommodated behind the new facades.

The products and systems are equally well suited for non-residential and residential markets. Therefore attractive designs are possible by simply combining the decorative and structural qualities with traditional building materials.

A few examples of application of slate products in non-residential and residential buildings are given in Figures 5,6,7. Special finishing touches can be provided as demonstrated in Fig. 8 for the open valley combined with metal flashing, and in Fig. 9 for combinations of facade and slate.

Examples of fixing procedures are outlined in Fig. 10. The methods in Fig. 10 are suitable only for structures up to 6m high. For taller structures there is a need for specifications to be given by a structural engineer to take into account special considerations such as wind load.

Table 6
Examples of shapes and dimensions of commercially produced slates.

Product Description for slates and shingles	Thickness mm	Slates /m2	Mass kg/m2
Traditional Slate 	5	10	20
Traditional Slate Mitred 	5	10	20
Natural Slate (Simulate patern) 	5	10	20
Textrata Slate 	7,5	10	25,7
Beaver Slate 	5	11	22
Weave Slate 	5	16	22,5
*Honeycomb Slate 	5	9	12,2
*Scallop Slate 	5	13	17,5
*Brick Pattern Slate 	5	21	26

*** For facades only**

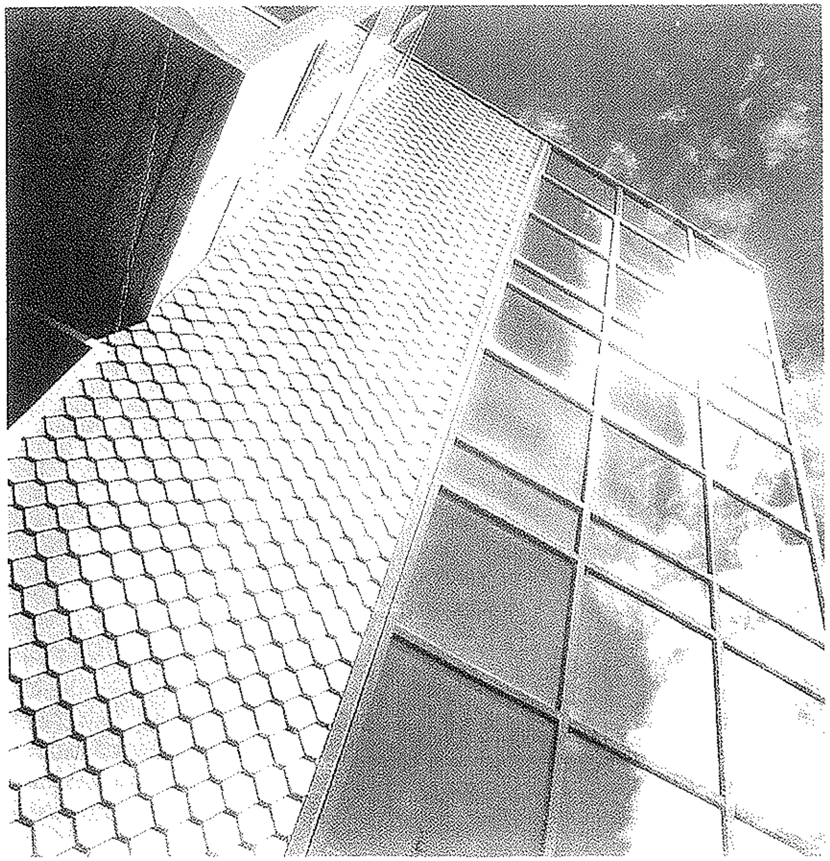


Figure 5: Cladding of non-residential building with slates.

Figure 6: Cladding of residential building with Beaver type shingles. These shingles are advantageous when accuracy is important, such as in this roof with its square dormer windows.

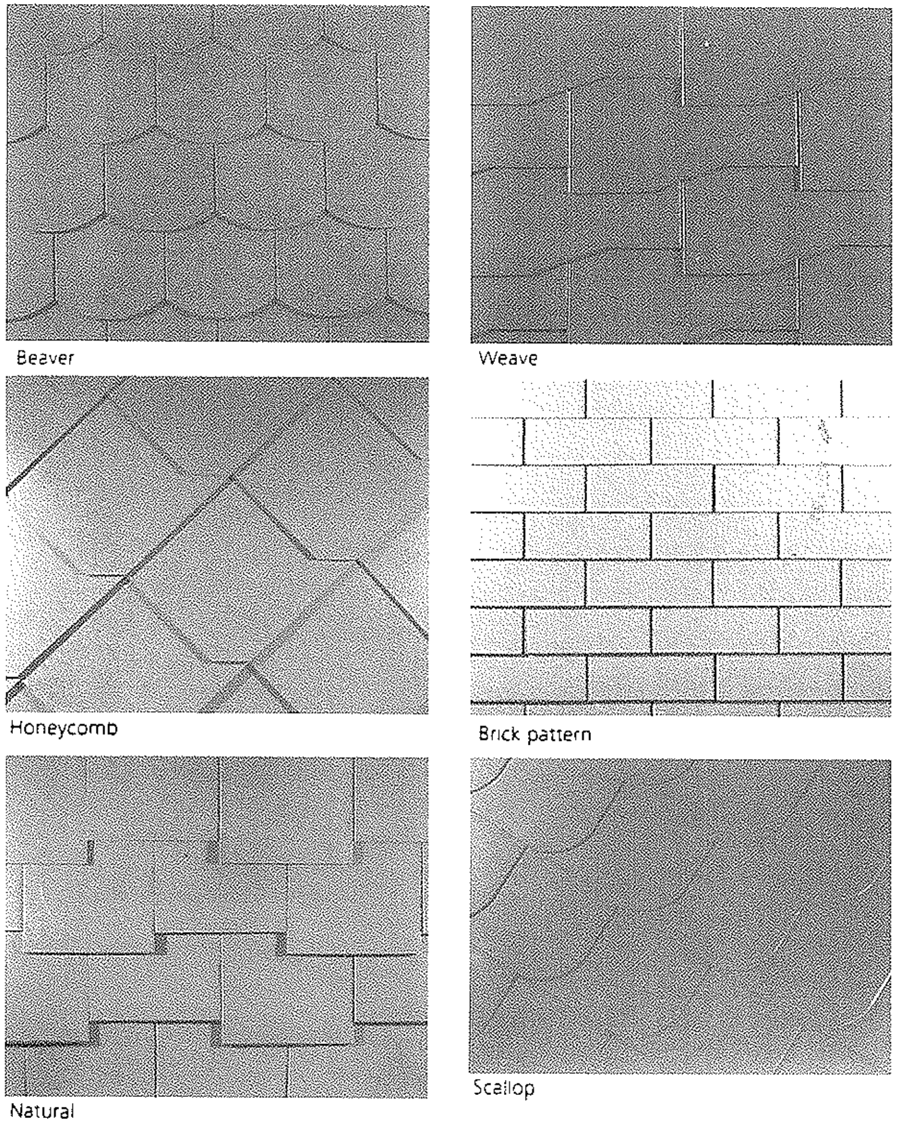


Figure 7: Variety of shapes achieved with the different types of shingles.

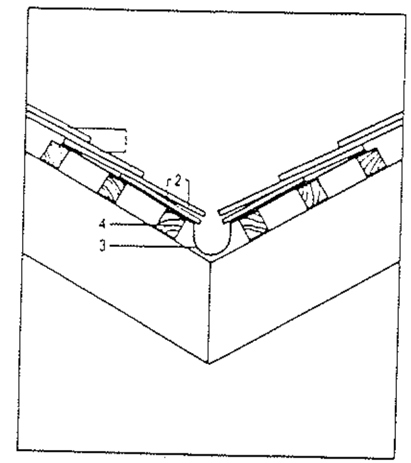
Section trough open valley

1 Full slates

2 Slates to be cut to suit on site

3 Inverted galvanised iron ridge piece

4 38 x 39 Batten



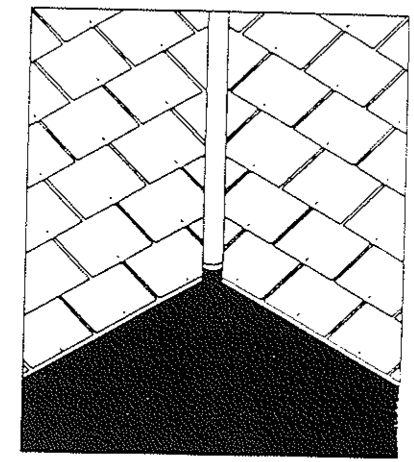
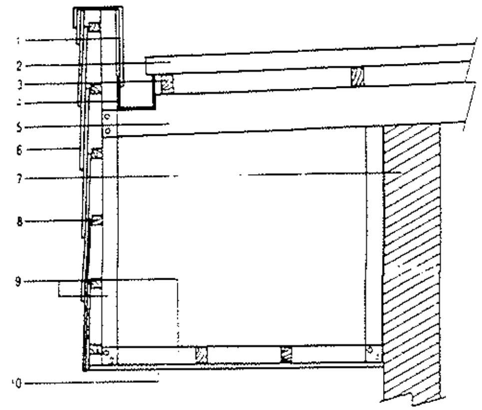
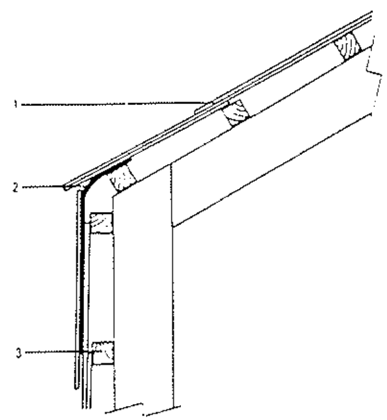


Figure 8: Finishing achieved with slates in an open valley shape.



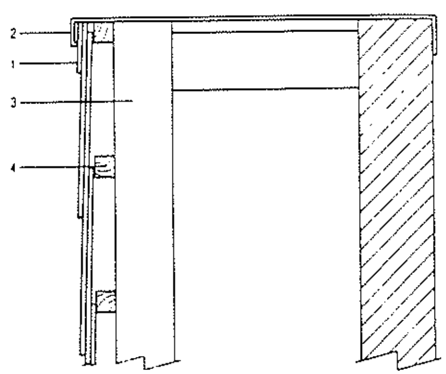
Facade-gutter flashing detail

1 Metall flashing taken into gutter
2 Roofing
3 Purlin
4 Gutter
5 Rafter
6 Wall
7 Wall
8 Battens
9 Timber frame
10 Ceiling nailed to timber frame



Roof-facade detail

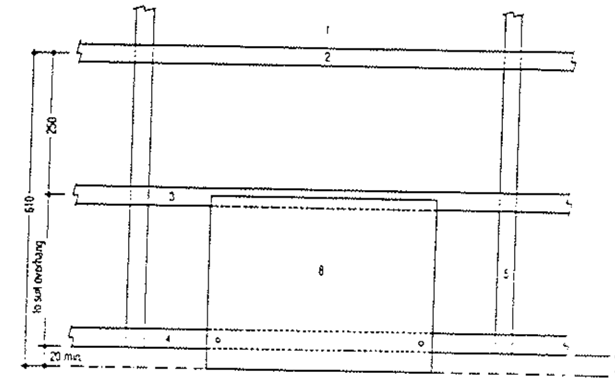
1 Slate
2 Bitumen impregnated membrane
3 Battens



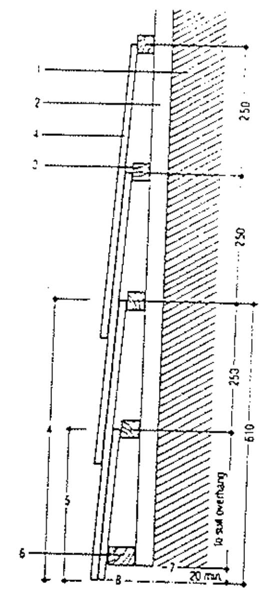
Metal parapet capping detail

1 Cut slate to suit on site
2 Special metal capping
3 Timber frame
4 Batten

Figure 9: Examples of combinations of facades and slates.



1 Wall
2 3rd batten
3 2nd batten
4 Tilter batten
5 Vertical counter battens
6 Sub-structure base line
7 Slate base line
8 Starter slate



1 Wall
2 Vertical counter batten
3 Battens
4 Full slate
5 Starter slate
6 Tilter batten 5 mm wider
7 Sub-structure base line
8 Slate base line

Figure 10: Example of fixing procedure.

Large facade sheets, Fascia boards and external cladding in general

Facade sheets are suitable for external applications (coated or uncoated). The joints may be concealed or exposed. The use of decorative paint adds color to these sheets in application of modern architecture. These sheets must fulfill the design criteria for wind loads. Fascia Boards are available in both pressed or unpressed material. They are suitable for use on residential, commercial and industrial buildings, where they serve to shield the projecting roof substructure from the elements and provide a neat and aesthetically pleasing finish to the roof edges.

Planks are suitable for external wall cladding, closure of gable ends, infill panels, fencing, and many other applications in which a durable product of these dimensions could be used. Building planks are available in a plain finish, as well as textured finishes.

The design criteria of structural supports required for large facade panels is significantly different from that of slates and shingles. Therefore in this application a structural engineer should be involved in the design and construction. Minimum design parameters are that they should be able to withstand 1.2 kPa wind loadings.

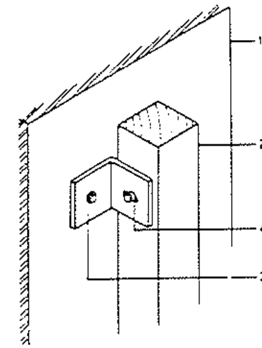
This does not apply to timber framing on single and double storey buildings where the framing is fixed directly onto a structural wall. The type and length of anchor will depend on the quality of the wall and on the mass of material the anchor has to support.

It is recommended that the rear of the facade is well ventilated, especially in humid and high rainfall areas. This will prevent any condensation and limit fungal growth.

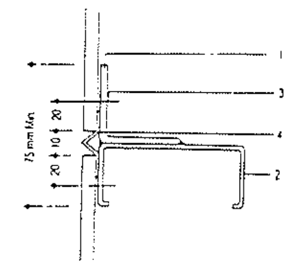
When designing the framing for the facade, the following suggestions should be considered:

- Timber or metal framing may be used.
- If timber is used, it should be selected structural grade timber. Where the cladding is being fixed onto horizontal girts directly onto the wall, vertical counter battens are recommended. These are easily plumbed and aligned and also provide space behind the facade for ventilation or insulation material if required.
- Where metal framing is used, cold formed sections are preferred for ease of fixing.
- Where spans permit, the most economical framing method is the horizontal girt system and the maximum girt spacing should not exceed 800 mm.

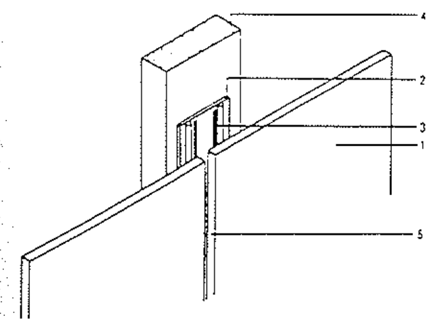
Examples of fixing systems for large panels are given in Fig.11.



1 Main structure
2 Timber runner at 600 centres
3 Angle secured to wall with Rawl bolt
4 Elongated holes to allow adjustment



Framing behind horizontal joints
1 Cold formed steel angle spot-welded or bolted to girt
2 Cold formed steel girt
3 Fixing points
4 10 mm open joint with chromaprep preformed flashing



Perspective of an open vertical joint

Figure 11: Examples of details for fixing large panels.
(a) simple connection, (b) framing behind horizontal joints, (c) perspective of an open vertical joint.

Internal application partition boards and ceiling boards

Internal partition boards are available in plain varied textured finishes. Internal partition boards are suitable for internal walling applications which can be painted after installation. They can also be used with confidence in damp areas such as bathrooms and kitchens. Handling during construction is important and these products should be nailable and resist impact loads.

Ceiling boards are available in a plain finish, as well as textured finishes. These boards can be nailed to the brandering, used in conjunction with timber cover strips or H-profile jointing strips, or be flush-jointed. Fiber-cement ceiling boards are suitable for use as exposed T suspended ceilings in industrial, commercial, institutional and residential building applications.

Profiled sheets and consumer articles

The Hatschek process provides an interesting aspect to the manufacture of fiber cement products in that the thin flat sheets immediately after the production, when they are at the fresh state (so called green sheet) can be molded into varied shapes.

The classical example of this is the profiled long span corrugated sheet which can be produced in a large variety of profiles, as shown in Fig.12 and outlined below:

- Bigsix and Canadian Pattern are available in lengths of 1500 to 3600 mm increments of 300 mm.
- Profile B (6 mm) is available in 3600 and 4500 mm lengths.
- Profile B (7 mm) is available from 4500 to 7500 mm in increments of 1000 mm (1 m).
- Span 2 is available in 3600 and 4500 mm lengths
- Span 3 is available in lengths of 4500, 5500, 6500 and 7500 mm
- Modulit is available in lengths of 4500 to 7500 mm, in increments of 100 mm (1 m).
- Canalit is available in 6500 and 7500 mm lengths.

These products can span varied lengths which are dependent on the profile. Different profiles have varied section moduli which are directly related to the depth of the profile. The extreme example being Canalit which can span up to 6 meters-clear span.

The mouldability of fiber-cement profiled sheets together with the extensive range of fittings, allows designers creative and individual expression. The use of purpose-made components, manufactured to the customers' specifications, widens the architectural scope of profiled products even more.

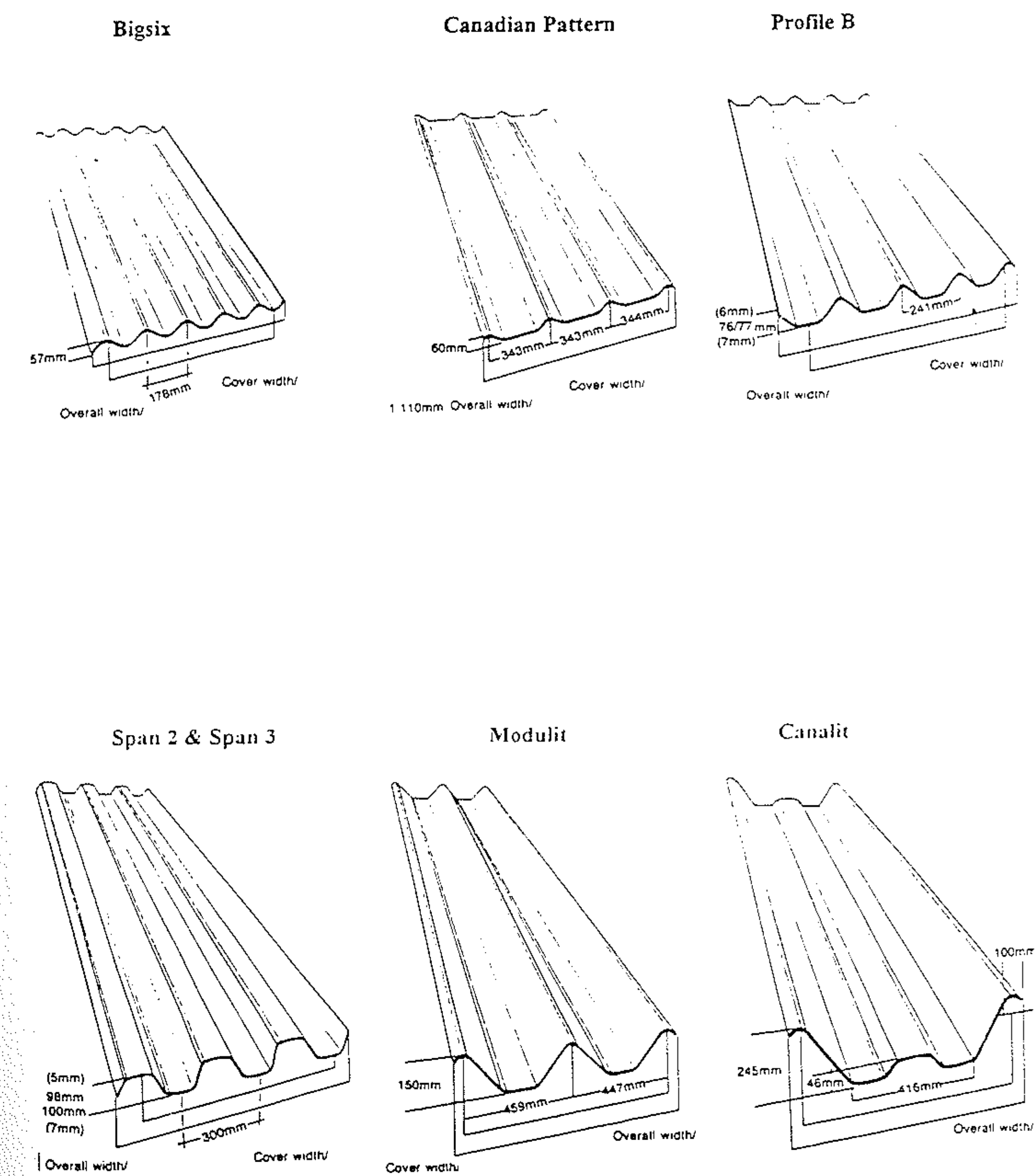


Figure 12: Examples of shapes and dimensions of long span corrugated sheets

CONCLUSIONS

A wide variety of thin sheet cement composites can be used for various cladding applications. New developments in the science and engineering of composite materials enables the use of new fibers and modified cementitious matrices to allow the production of materials with properties which are specifically tailored to the end use in the construction system. However, in order to successfully use these composites a systems approach has to be taken to provide optimum performance which is a function not only of the properties of the material itself, but its compatibility with the underlying structure. Engineering aspects related to sustained loads (snow) impact loads (hail) and fatigue (wind) should be considered in the design criteria for buildings.

This compatibility is achieved by means such as proper connections and, if needed, some measures to reduce moisture movement in the stud-thin sheet assembly system, which may include moisture barriers and external coatings. Therefore, when considering the use of such materials, and in particular the newer composites where there is less field experience, attention should be given not only to the composites material but to the construction with it, and its details. The standard and specifications now available provide reasonable tools to assess and test such materials and systems

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