to asbestos cement or colour steel when used in the proximity of housing estates, etc. on new town development sites.

Fig. 6 demonstrates the flexibility in design which can be achieved with a GRC sandwich panel construction. The panel shown is 18ft.high and about 7ft. wide; it consists of two layers of glass reinforced cement 3/8in. thick with a 4in. thick core of polystyrene. Such panels will span the full height between a horizontal floor and ceiling rail and involve only one lifting operation during erection. Since panels are full storey height, all joints are vertical and this minimises the risk of rain penetration through the joints which are made by hammering fluted heavy duty rubber strip into the ¼in. gaps between the individual panels.

The panels, which are subsequently finished with a rubberised mastic paint, provide in one total operation, a weatherproof exterior, a thermal insulating core of low 'U' value and a highly acceptable casing finish: one that is certainly acceptable for a factory building. The units are supplied either plain or with window frames, doors, louvres, etc. which are incorporated during production.

Fig. 7 demonstrates another GRC component in the form of a hollow hexagonal unit produced by vibration casting the GRC mix between a male and female mould. The total system allows for vertical soil revetment with little or no load-bearing back pressure on the units themselves. The overall effect is aesthetically pleasing and could make a major contribution to the architectural style of motorway and equivalent structures.

Fig. 8 shows GRC in the form of thin grooved sheets which, when bolted together in segments, are able to produce a flush lap jointed tube. This tube can be constructed inside existing old and decaying sewers of diameters up to ten or more feet and is used as permanent formwork; concrete grout can be pumped through holes in the tube to form the strong load-bearing substrate between the GRC and the old sewer lining. The same method can be used for driving tunnels through sand or gravel strata where the concrete grout serves the almost identical purpose of producing a dense annular ring around the outside of the GRC tube. In the case illustrated in the photograph the cement matrix was based on high alumina cement because of the need to resist heavy decay from sewerage. This particular application was specified by the Greater London Council as a field trial on a Portobello sewer section.

Fig. 9 shows a further use of GRC as permanent formwork for concrete. In this particular case the GRC is in the form of flat sheet with a slight corrugation to confer rigidity. These sheets are laid between parallel running beams, and in one operation form the substrate on to which the load bearing concrete can be poured. The permanent shuttering GRC units, which can have a plain surface or be faced with various types of aggregate, are left in-situ as an integral part of the bridge deck, once the poured concrete has set and hardened. There is, without doubt, a great potential market for this type of application particularly in cases where it is essential that road, rail or sea bridges are built without interfering with the traffic stream.

Fig. 10 represents a massive application of GRC permanent formwork for thick waffle floor construction. The units illustrated are 4 x 4 x 5ft. in size and are placed together in the form of a chequerboard on a supporting framework. Metal reinforcement bars are first placed between the units and then concrete is poured all over to produce the total floor thickness. Once the concrete has set and hardened the supporting framework is removed and the GRC units are left in-situ as an integral part of the waffle floor. The inner faces of the units are fair-faced, extremely smooth and need only a paint decoration - if that!

Fig. 11 illustrates a GRC form which is not being fully marketed: glass fibre reinforced cement composites for marine hull construction. Pilkington see this as a major potential outlet for this new material but consider that the development of this market should be carried out in a most circumspect manner. They have set up a Marine Applications Consortium involving the U.K. Department of Trade and Industry, Lloyds Register of Shipping and the U.K. Atomic Energy Research Establishment (AERE) Harwell, in conjunction with the Associated Portland Cement Manufacturers. Once the potential of GRC for this type of application has been proven by the evaluation of marine hull designs under actual working conditions, then the market for this particular application will be fully developed.

These few illustrations of real-life composite forms in use under practical working conditions should leave no doubt about the impact of glass fibre reinforced cement composites, based upon the new alkali resistant glass fibre, invented by the U.K. Building Research Establishment, and then fully developed by Pilkington Brothers Limited. GRC is without doubt one of the major new material developments, if not the most important, to be realised during the past 40 to 50 years.

ACKNOWLEDGEMENTS

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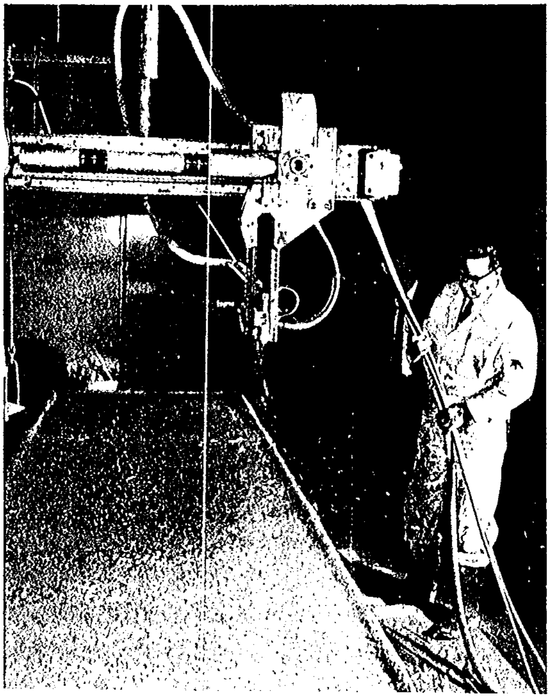

Figure 1 Method for spraying flat sheets of GRC developed at B.R.E.

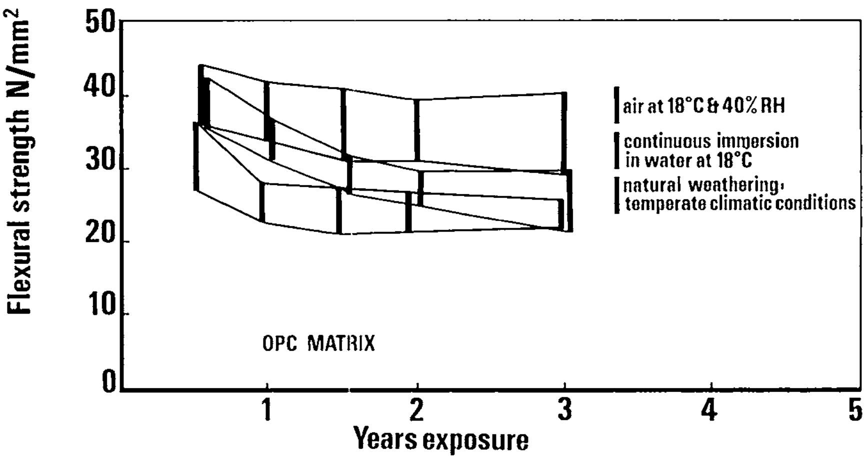

Figure 2 Variations of flexural strength with time for a GRC composite based on ordinary Portland cement

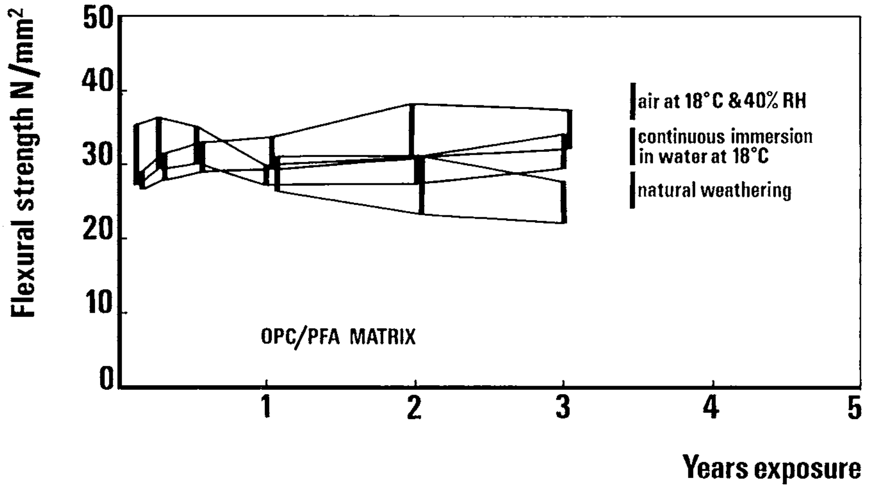

Figure 3 Variations of flexural strength with time for a GRC composite based on ordinary Portland cement plus pulverised fuel ash

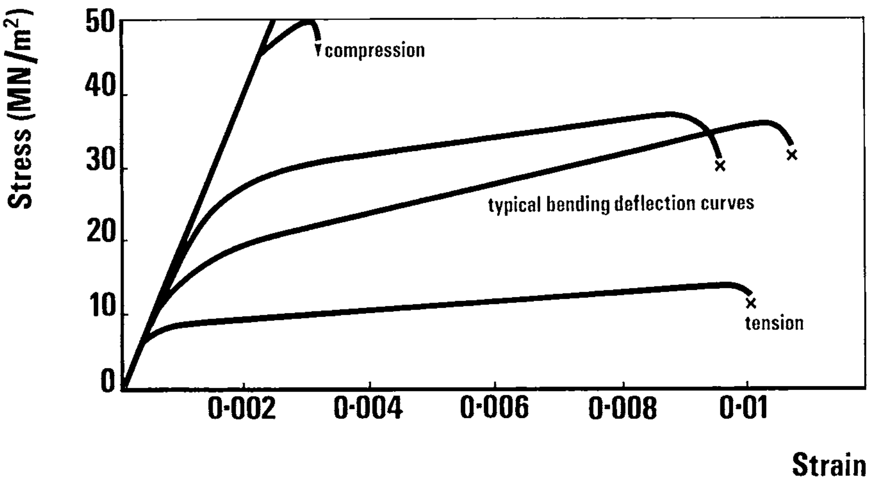

Figure 4 Typical stress-strain curves obtained with GRC composites

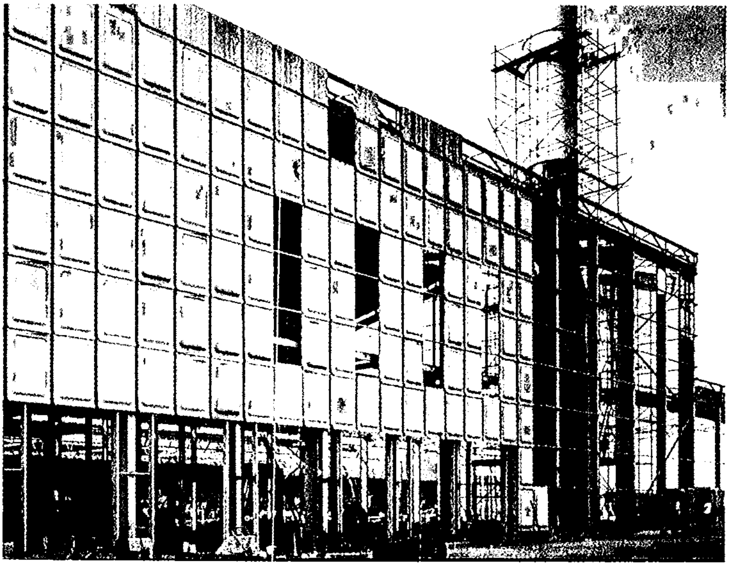

Figure 5 'Cem-FIL' reinforced cement panels, each 2 x 1.5 m (7'x5') are incorporated in the new Fibreglass Factory at St.Helens

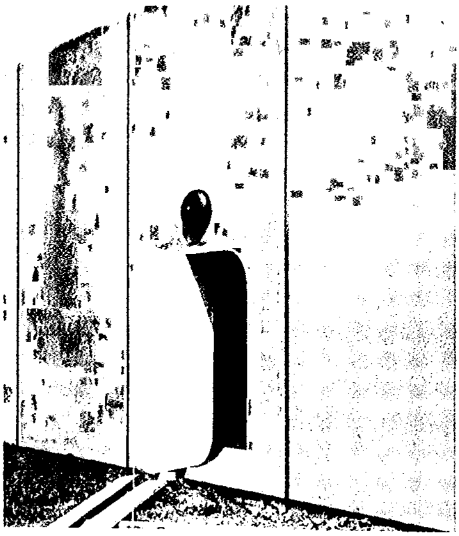

Figure 6 United Oriental Perfume factory at Tadworth, Surrey, consisting of storey height double-skinned sandwich panels $5\frac{1}{2}$ x $2\frac{1}{2}$ m (18ft x 8ft)

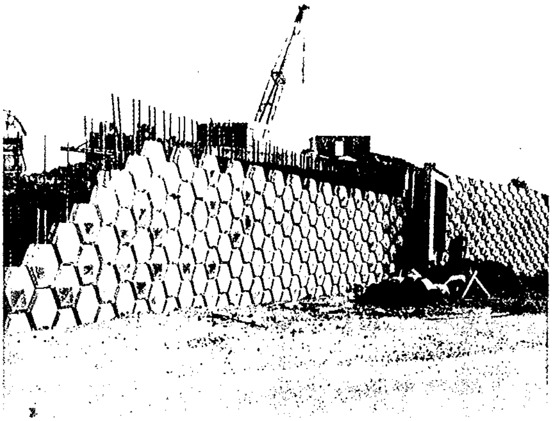

Figure 7 Easily handled 'Cem-FIL' reinforced cement units used to form an earth retaining wall. The hexagonal units have been commissioned by the West Riding County Council for use on the M62 Motorway

Figure 8 High strength thin section GRC segments were used to line a sewer beneath the Portobello Road, London. Three segments each weighing only 50 kg. are used to line the 1.75 m. dia. sewer and grout is then pumped in between the liners and the concrete backing

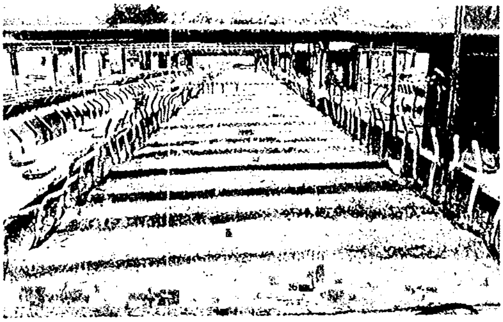

Figure 9 Bridge deck permanent formwork used on a bridge over the River Arun, near Arundel. The panels are ribbed to impart additional strength and to improve the bond with the concrete

Figure 10 'Cem-FIL' reinforced cement 'coffer' units which are being used to form a $1\frac{1}{4}$ m (4 ft) deep large span waffle floor at a major brewery in London

Figure 11 This experimental GRC work boat has been in daily operational use in Liverpool docks for well over 12 months. The boat is fabricated by spraying into a female GRP mould

SP 44-21

FIBERGLAS SURFACE BONDING

By
Thomas E. Pecuil and Henry N. Marsh, Jr.

Synopsis: Fiberglas surface bonding is a new block construction technique. It involves dry stacking a concrete block wall without mortar in the joints between the block and, after the wall is erected, trowelling a very thin coating of a cement-lime mixture reinforced with alkali resistant glass fibers on both sides of the wall. The finished thickness of the coating is 1/8 in (3.2 mm).

This paper shows that the resulting wall has approximately twice the flexural strength and 20% greater impact strength compared to a conventional mortar wall. Compressive strength characteristics which were 65% of mortar walls are within design loads for most concrete block construction.

The system meets the ASTM 2 hour fire endurance requirements for load bearing walls and has the added benefit of providing resistance to moisture penetration.

Studies on masons productivity indicate the surface bonded wall can be completed in 58% of the time required for a conventional masonry wall.

The data presented indicates the surface bonded wall results in improved physical properties and reduced installed cost.

Keywords: bonding; cements; compressive strength; concrete blocks; construction; fire resistance; flexural strength; freeze-thaw durability; glass fibers; impact strength; masonry walls; mix proportioning; mortarless masonry; reinforcing materials.

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INTRODUCTION

Masonry construction techniques haven't really changed since the Great Wall of China was built 2,000 years ago. For centuries the block and mortar system has prevailed.

Now, block construction has been updated with Fiberglas surface bonding (FSB). Basically, this technique involves dry stacking a concrete block wall without mortar in the joints between the block and, after the wall is erected, trowelling a very thin coating of a cement-lime mixture reinforced with alkali resistant glass fibers on both sides of the wall. The finished thickness of the coating is 1/8 in (3.2 mm). The footing is standard poured concrete upon which the first course of block is placed in a full mortar bed that allows the wall to be started plumb and level. Metal shims may be used as necessary to correct any variations as the wall is erected. The result: walls built faster and stronger than conventionally mortared walls -- plus built-in water resistance and greater finishing flexibility.

BACKGROUND INFORMATION

Studies on surface bonding of concrete block walls were originated by the Department of Mechanical Sciences of the Southwest Research Institute, San Antonio, Texas. In the Southwest Research Institute system, blocks were stacked dry and the joints coated with a sulfur-based, glass-fiber-reinforced material producing walls with mechanical properties superior in most respects to conventional mortared walls.

In 1965 the Ohio River Division Laboratories, Corps of Engineers, Department of Army initiated further feasibility studies of masonry systems utilizing surface-bond materials. Essentially, the Division Laboratories (1) initially tested bonding systems involving sulfur, polyester resin, two-component epoxy resin, oil based paint and latex based paint as matrices.

In the spring of 1967, the Agricultural Research Service, USDA in cooperation with the Agricultural Engineering Division, University of Georgia College of Agriculture commenced studies of surface bonding (2). The matrix material chosen for evaluation was Portland cement. Their interest in the method was primarily to allow the construction of low cost shelter for migratory farm workers and for other low income housing. A number of such units were erected, primarily in the Southeastern part of the United States under the Government self-helf housing programs (3).

The USDA personnel used conventional E-glass fibers in their work. Concurrent with their efforts, Owens-Corning Fiberglas had developed more alkali resistant glass fibers. The development work that will be described in this paper involves surface bonding using alkali resistant glass fibers.

FIBERGLAS SURFACE BONDING EVALUATION

Mix Formulation

The first phase of our program was evaluation of the mix formulation. As a result of this work we eliminated the calcium chloride which was used to accelerate the setting of the cement in the USDA mix. Normal setting of the cement was deemed adequate and the potential packaging problem with calcium chloride was a greater disadvantage than its quicker setting advantage. We established the following formulation which was used in all our subsequent work.

Material	% By Weight
Portland Cement	80
Hydrated Lime	15
Glass Fiber - 1/2 in (12.7 mm)	4
Calcium Stearate	1

Next we evaluated glass fiber variables which included length, filaments per strand, sizing, and strand dispersibility. Based on mixing and application characteristics, we selected 1/2 in (12.7 mm) long fibers having high strand integrity as our standard reinforcement.

Strength Testing

It was necessary to determine a screening test method that would give results comparable to conditions an actual block wall would encounter. The surface bonding concept was reviewed by Simpson Gumpertz & Heger, structural consultants. They suggested a block beam be made by stacking seven blocks, in a stack bond arrangement, and coating both sides. This beam would be tested in flexure. The beam arrangement simulates the same ratio of moment to shear as exists in a vertical wall with an 8 ft (2.44 m) span under uniform load (i.e., simulating lateral loads due to wind, earth and hydrostatic pressure). These results were compared to 7 block beams of mortar construction tested as controls.

Seven block beams with FSB typically have breaking loads between 800 (363 kg) and 1200 lb (545 kg). By comparison, seven block beams with conventional mortar joints and tested by the same procedure have breaking loads between 100 (45.4 kg) and 200 lb (90.8 kg). Encouraged by these favorable results on small sections, we then investigated the