Guide to Premix Manufacture

CONTENTS

INTRODUCTION

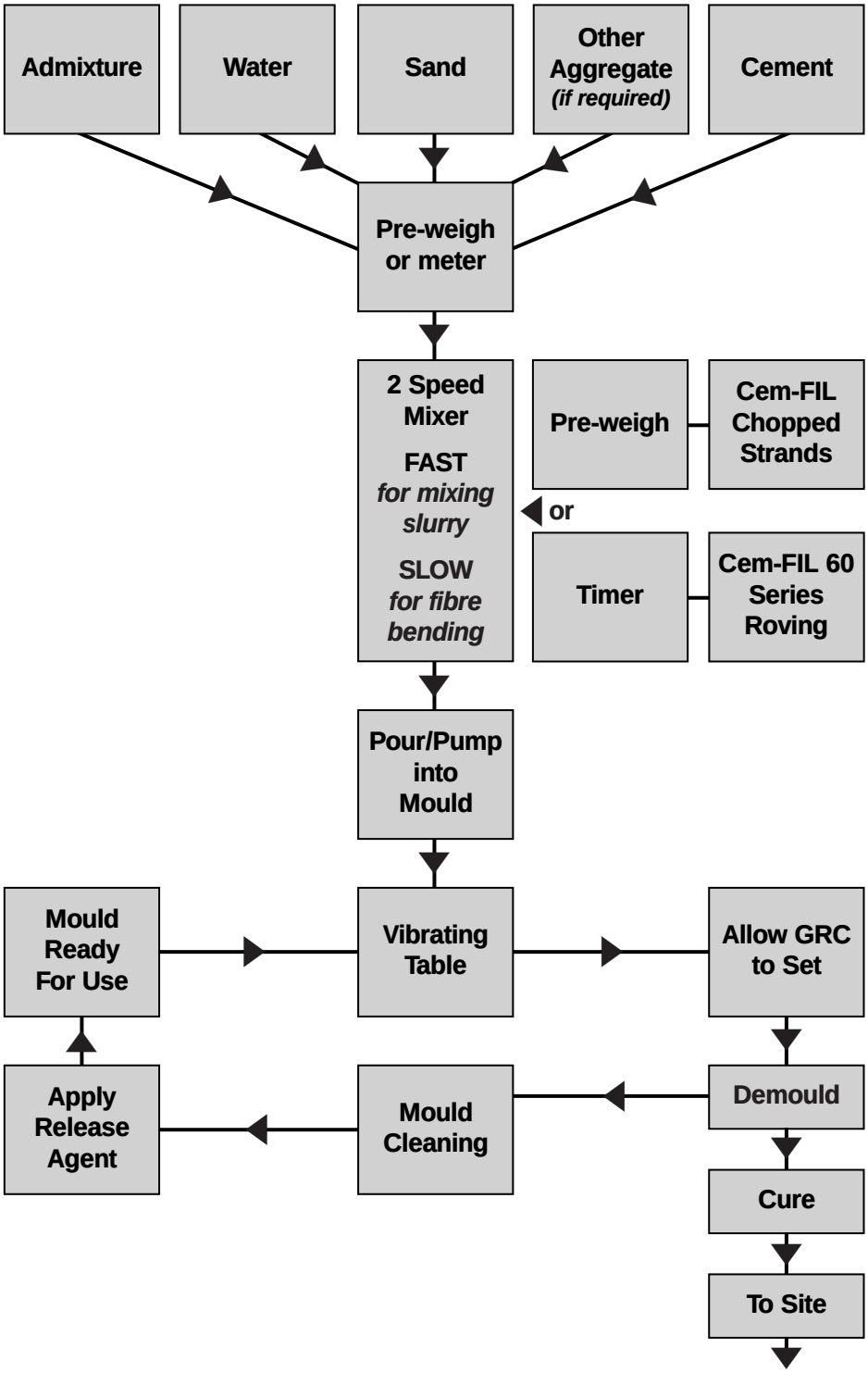
Premix GRC products are made from a mixture of cementitious slurry and chopped strands of Cem-FIL AR glass fibre which is then poured into a mould under vibration.

The vibration casting process is relatively simple to control and mechanise. It is capable of producing products with good dimensional control and complex components can be produced with relative ease.

The process has low material losses together with accurate and reproducible control of product weight.

This guide covers the basic techniques for manufacturing premix GRC products by the vibration casting process, and provides guidelines on mix design and mould design.

VIBRATION CASTING BY PREMIX MANUFACTURE



1. MIX DESIGN

1.1 Typical Mix Formulations

Since a wide range of raw materials are used for premix GRC and each product has its own particular requirements it is only possible to provide guideline mix designs.

There are general rules for mix design:

I) **Keep the water content as low as possible.**
Use admixtures. Adding more water reduces GRC strengths.

2) **Use an adequate fibre content.**
Less than 3% may not provide adequate mechanical properties, depending on fibre type.

3) **Do not use sand/cement or filler*/cement ratios less than 0.67**.
Too much cement causes shrinkage problems. Use as much sand or filler as is practicable.

There is a wide range of possible formulations for premix GRC

A particular GRC product or process may require:

– A superplasticiser for increased workability at low water-cement ratios

– Higher sand/filler content to reduce shrinkage

– Acrylic polymer for air curing.

– Flow aids, desegregation aids

Experience can be quickly obtained and a separate formulation derived for each product type starting from a general purpose formulation.

A useful general purpose formulation is given below: it contains 3.5% fibre *(by weight)*.

GENERAL PURPOSE MIX	**Kg**	**%**
Cement	50 (1 bag of cement)	48.5
Sand	33	32.0
Water	16	15.5
Plasticiser	0.5	0.5*
Cem-FIL Chopped Strands *(60/2) (12 mm or 24 mm)*	3.61	3.5

A selection of different mix designs is given in Appendix 1

1.2 Secondary Processing

If the premix is being subjected to secondary processing such as pumping it is usually necessary to modify the mix in order to prevent segregation. It is normal to add a cellulose compound to the premix to prevent this segregation. The most suitable material for this purpose is Hydroxy Propyl Methyl Cellulose.

A suitable mix for preventing segregation during secondary processing is:

Pumpable Mix	**Kg**	**%**
Cement	50.0	47.8
Sand	33.0	31.5
Water	17.5	16.7
Plasticiser	0.5	0.5
Cellulose *(HPMC)*	0.02	3.5
Cem-FIL Chopped Strands	3.66	

1.3 Setting Time

Premix GRC product can usually be demoulded 4-16 hours after casting depending on mix formulation, ambient temperature and product form.

Mould turn-round time can be reduced by using:.

1.3.1 Regulated set cements *(see Cem-FIL Information Bulletin No. 40)*. These should allow demoulding to take place within 30 minutes but the workability time is short *(5 minutes)* and retarders are often added to ease production.

1.3.2 Accelerators: Normal calcium chloride accelerators can be used provided there are no embedded steel parts and it is not excluded by specification. This should allow demoulding to take place within two hours depending upon the size of the component and the ambient temperature. Many accelerators are solutions blended with a plasticiser. The water content of the mix should be adjusted to keep the water/cement ratio constant. The following is a typical example:

Accelerated Mix	**Kg**	**%**
Cement	50.0	41. 3
Sand	50.0	41.3
Water	14.5	12.0
Calcium Chloride	2.25	1.9
Accelerator *	2.25	
Cem-FIL c/s	4.23	3.5

* A typical plasticised accelerator containing 34% approximately of calcium chloride, a specific gravity of 1.34, and a solids content of about 50%.

1.3.3 Using heat: Curing the cast GRC in its mould at a temperature no higher **than 50°C** is allowable and will shorten the demould time. This may be combined with the use of accelerators.

It is important that the GRC is not allowed to dry out during the curing cycle and wet steam may be used for this purpose.

1.4 New formulations containing special metakaolins *(Cem-FIL Star GRC system)* have been made available which offer greater long term stability on specialist projects. The properties of impact strength and strain to failure are enhanced using these new Cem-FIL formulations.
Further information will be provided by Cem-FIL on request.

2. MIXING PROCEDURE

2.1 Mixing Process

The mixing process is an extremely important aspect of premix and it is important to follow the recommendations.

Even a small deviation can have a large influence on the workability of the wet GRC and on the properties and appearance of the final composite.

Mixing of premix GRC must NOT be carried out in the same manner as the mixing of concrete.

To produce a premix of the correct quality it is necessary to mix in two stages. The first stage is designed to produce a high quality slurry which is essential for the uniform incorporation of fibre and to achieve the necessary workability. The second stage is the blending of fibres into the slurry.

It is more convenient to carry out both stages in the same piece of equipment, but separate mixers can be used for each stage.

Stage 1

Preparation of a slurry. This should be creamy in consistency and free of lumps. The slurry is prepared at high shear which can be achieved using a conventional High Shear mixer or alternatively using a specially designed two speed mixer at its high speed setting. Admixtures should be added towards the end of this mixing cycle.

When using a mixer where the water is added to the previously blended dry solids, the best slurries are produced by adding the water in two portions. Approximately 75% of the water should be added first to produce a stiff mortar. After mixing for 45 seconds this mortar should be diluted by slowly adding the remaining 25% water. The above operation is eased considerably by using a water meter *(see Cem-FIL Information Bulletin 43)*. The water is normally added over periods of 30 seconds and 15 seconds. Admixtures are best dispensed in accordance with Cem-FIL Information Bulletin 45.

Stage 2

Adding the fibre. This stage of mixing is carried out at low speed and low shear. The objective is to achieve a uniform fibre distribution with no fibre damage. The addition of fibre to the slurry is carried out at a rate which is fast enough to avoid fibre damage due to over-mixing but not too fast so as to produce a poor distribution. Fibre is best introduced into the mix by cascading chopped strands from a vibratory feeder or by using a heavy-duty glass fibre chopper and chopping 60 Series Roving directly into the mix. In general, it is best to add the fibre to the mix in less than 11/2 minutes. A typical fibre feeding rate is 3 kg/min. *(See Cem-FIL Information Bulletin No 42 Fibre Feeding Techniques and Section 2.2 below)*

After addition of the fibre the mixer should only be allowed to run for a sufficient time to fully incorporate the fibre, normally only a few seconds.

A typical time to prepare a batch *(50-200 kg)* of premix is 6-10 minutes.

Notes on Mixing

1) Although it is possible to use a concrete-type mixer to produce both the slurry and blend the fibre it is likely to result in a mix of poor workability causing production difficulties and hence a product of reduced strength and inferior appearance

2) The fibre must be blended with the slurry in a mixer which gives a good distribution and little fibre damage (splitting a bundle into single fibres). Too much fibre damage reduces the workability of the slurry. Poor fibre distribution should be avoided: this is noticeable by fibres being knotted together to form dry clumps.

3) To minimise fibre damage it may be necessary to adjust the mixing blade position. This is particularly true with the pan and paddle type mixer where the blades are normally in close proximity to the drum. This must be avoided by adjusting the blades to produce a 2-3 mm gap.

4) Wet premix GRC must not be left in the mixer while another mix is made.

5) Superplasticisers are necessary. They reduce the water-cement ratio, and improve the workability of the mix

6) In general the slurry should be mixed to a consistency which is self levelling when it is poured. Small variations in the water content will be required to maintain this consistency with varying raw materials.

7) Do not use old cement - this gives poor strengths.

8) Do not use sand/filler which contains an excess of fine grading - this increases the water demand of the mix.

9) It is very important that the mixer blades are kept clean. A buildup of hardened premix on the blades reduces the mixing efficiency and it is very difficult to remove.

10) If wet sand/fillers are being used remember to correct the amount of water being added to the mix. Too much water gives low product density and strength.

2.2 Putting the fibre into the slurry *(Fig. 1)*

(Fibre feeding)

This can be done in three ways:

2.2.1 Hand feeding

Pre-weighed batches of fibre are fed into the mix by sprinkling the fibre into the mixer during mixing. Handfuls of fibre must **not** be allowed to fall into the mix: these will cause lumps in the premix.

2.2.2 Vibration Feeder

Pre-weighed batches of fibre are placed in the hopper of a vibrating feeder. The best results are obtained when two vibrators operating in sequence are used, with the second vibrator operating at a higher speed than the first. This reduces fibre clumping.

2.2.3 Direct Chopping

Cem-FIL AR 60 Series rovings can be used together with a heavy duty chopper to feed chopped strands directly into the mix. An air-mover operating at about 0.7 bar *(10 psi)* enables the strands to be directed into the mix Since the roving has a known weight/unit length it is convenient to connect the chopper motor to a timer so that the batch weights of chopped strands are consistent.

Whatever method is chosen DO NOT OVER-MIX the fibre.

2.3 Chopped Strand Lengths

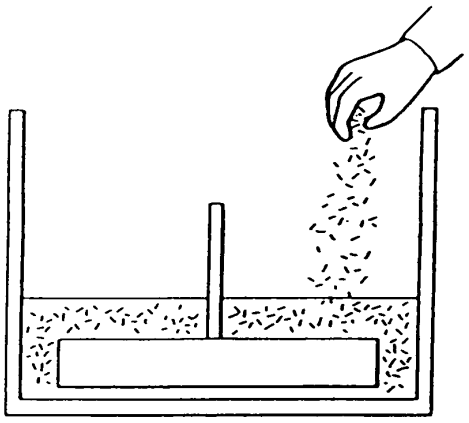
Cem-FIL Chopped Strands are available in standard lengths of 6 mm to 40 mm depending on fibre type

In theory longer strands should produce a stronger product. In practice there is often little difference and the 12 mm strand length is more commonly used because it is easier to incorporate and the wet GRC premix has better workability.

In general 24 mm chopped strands are suitable for simple open or thick section products and 12 mm strands more suitable for complex shaped, narrow section products.

If a heavy duty chopper is being used, strands of length 12 mm, 18 mm or 24 mm can be produced by altering the blade configuration.

Fig 1 FIBRE FEEDING TECHNIQUES

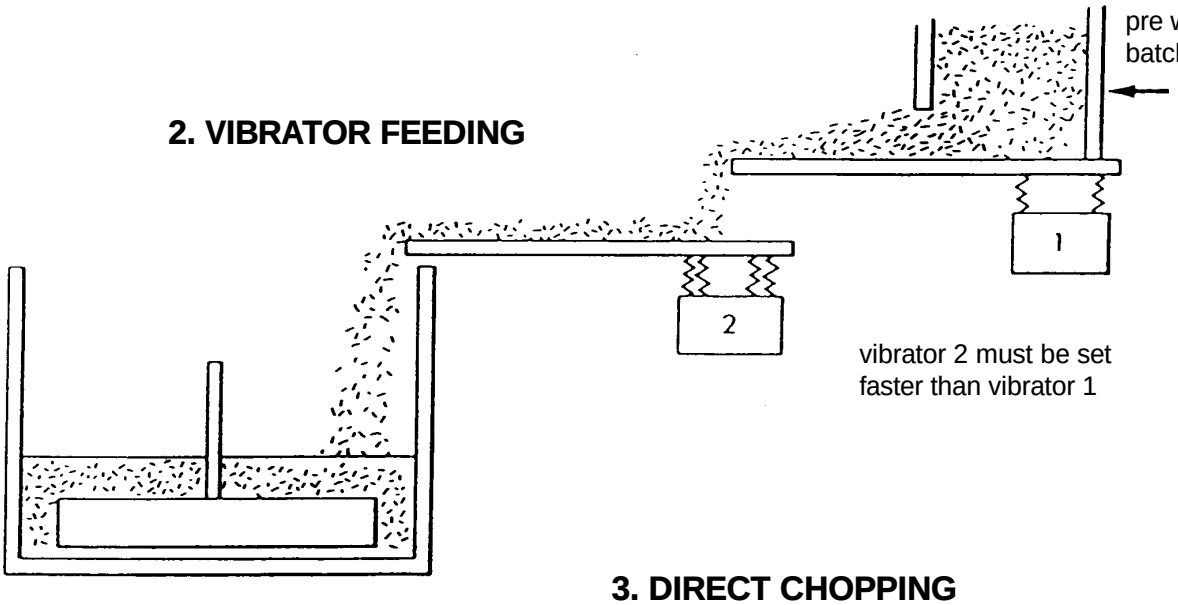


1. HAND FEEDING

Sprinkle fibre into mix
do NOT throw in handfuls

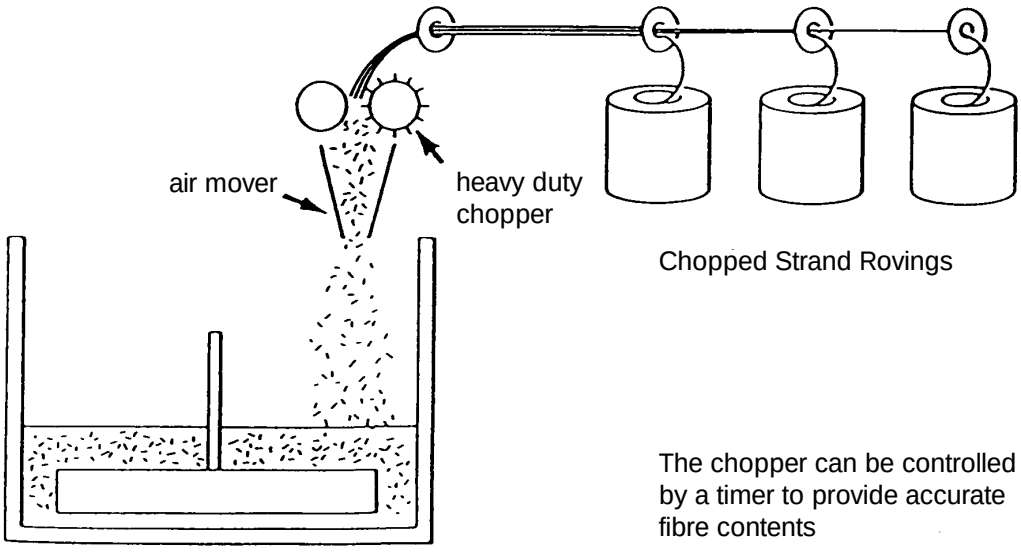
pre weighed
batch of fibre

2. VIBRATOR FEEDING



vibrator 2 must be set
faster than vibrator 1

3. DIRECT CHOPPING



Chopped Strand Rovings

The chopper can be controlled
by a timer to provide accurate
fibre contents

3. VIBRATION CASTING

3.1 Vibration of Mould

In this process the mould is vibrated as the GRC premix is poured into it. The vibration has two functions:

1) It enables the premix to flow and fill the mould.

It releases air trapped in the premix and allows compaction to take place.

There are three parameters which are important on vibration motors; frequency, amplitude and force. Motors are normally available at frequencies from 3,000 rpm to 12,000 rpm. However, at the high frequencies the amplitude is very low, and the amplitude needs to be as high as possible in order to obtain efficient mould filling. High frequency is desirable for consolidating small particles. The force is usually adjustable by varying the position of eccentric weights on the motor shafts.

Most general purpose vibrators and vibrating tables operate at 3,000 rpm.

The output force of the motor is dependent on the construction of the table and the moulds which are to be vibrated. As a general guide, about 500 kg of force per m2 of table should be sufficient for most work

It is necessary to **clamp the mould securely** to the vibrating table to ensure that the vibration is transmitted efficiently to mould and the premix slurry.

3.2 Filling the Mould *(Fig. 2)*

The way in which a mould is filled is very important and will affect the quality of the product.

Wherever possible the mould should be filled from one point only.

This method of filling pushes the air in front of the material and gives consistency of product quality.

If filling is done from two points an interface is likely to be formed between the two flows of material. Fibres will not bridge this interface and a plane of weakness will be formed.

If the premix is introduced rapidly into a deep mould section it will have air trapped within itself which, on vibration, will only migrate to its mould surface, causing surface defects. One method of reducing this is to allow the premix to flow down an inclined plate mounted above the mould. “Degassing” of the premix can take place on this plate to produce a higher density product.

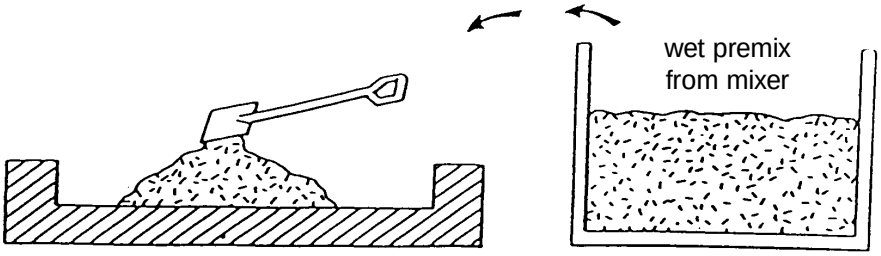
Another mould filling technique is to pump the premix into the mould The type of pump suitable for this technique is a “peristaltic”. Pumping a premix not only reduces the air content of the mix but also presents the opportunity of controlling material usage. For standard products a timed discharge can be used to produce constant product weights. When manufacturing difficult shaped units, such as a sunscreen, the premix can be hosed into the mould reducing the physical effort in moving the wet premix from the mixer to the mould.

When filling deep, narrow moulds, it is often useful to use a secondary hopper above the mould.
This provides a ‘head’ to push the GRC into the mould and reduces spillage over the lip of the mould.

Fig 2 MOULD FILLING

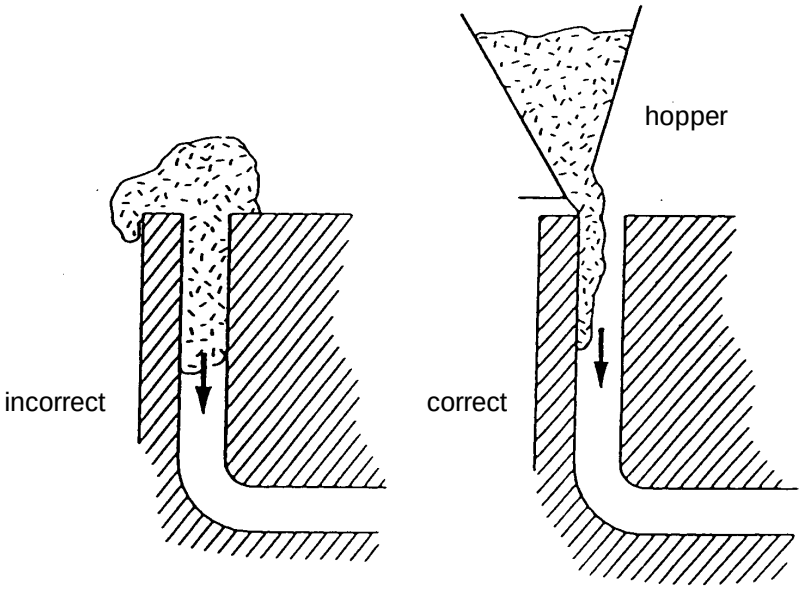
1. TROWEL / SPADE

Simple, suitable for open moulds



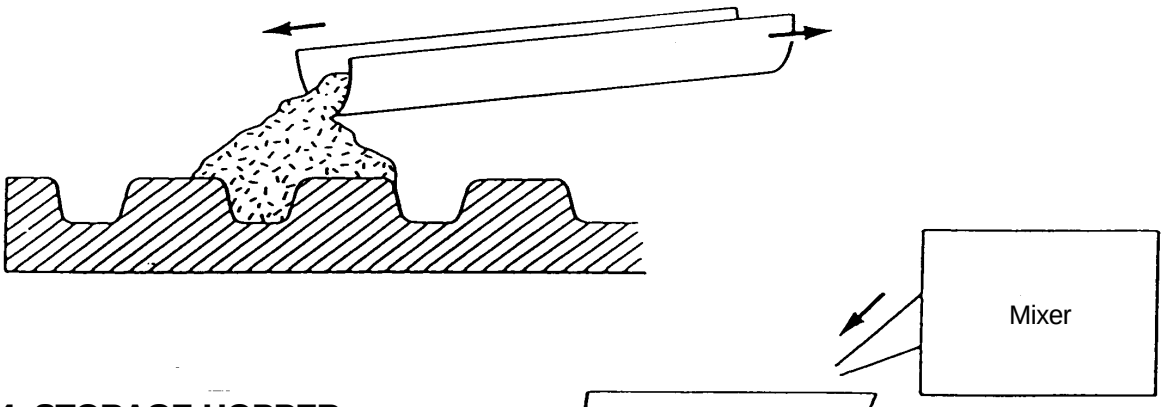
2. HOPPER

Useful for moulds with narrow entries - speeds mould filling and reduces overspill



3. MOVABLE CHUTE

Useful for large surface area moulds such as sunscreens



4. STORAGE HOPPER

Useful for conveyor systems when large quantities of premix are to be cast and for controlling dustribution of premix

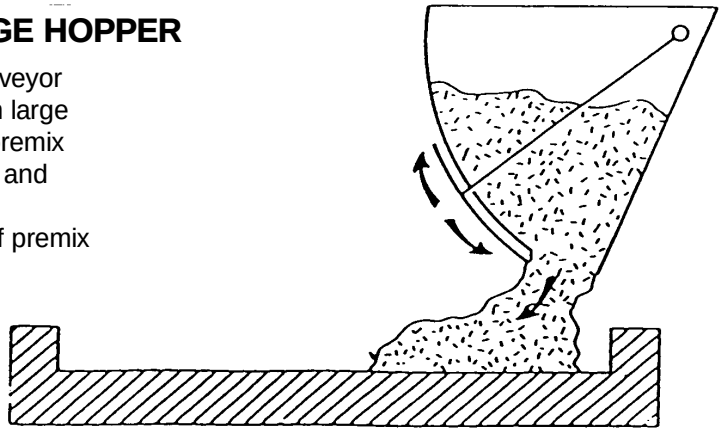
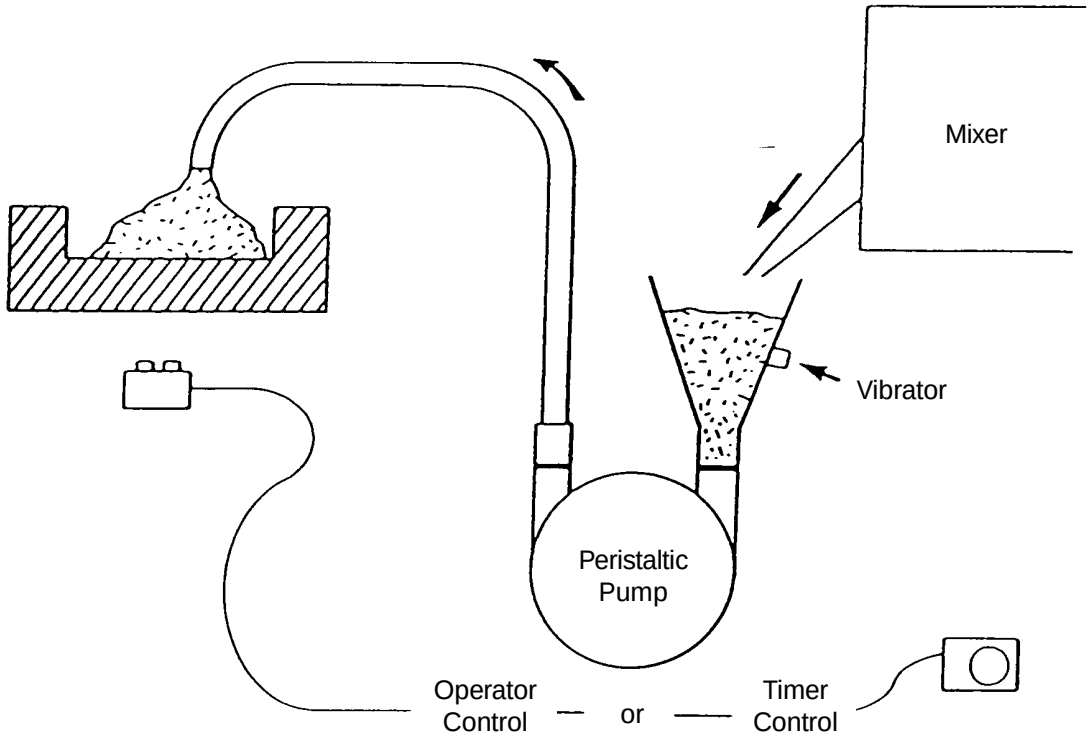


Fig 2 Continued

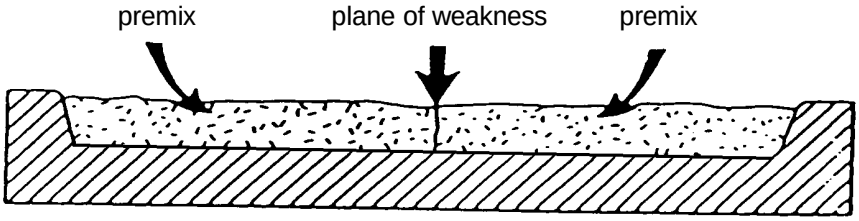
5. PERISTALTIC PUMPING

Useful for filling moulds remote from mixer.
Avoids use of barrows.Can be used to meter quantity of premix into mould if connected to timer.

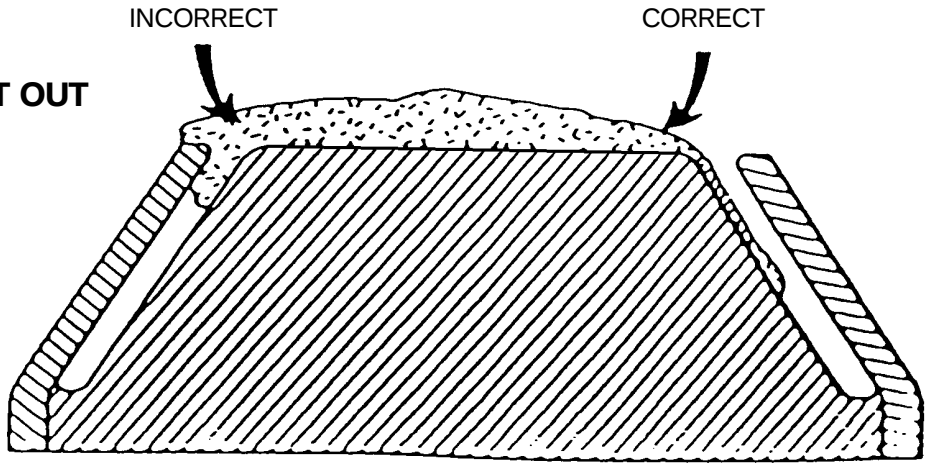


GENERAL POINTS

1. AVOID FILLING FROM MORE THAN ONE POINT



2. LET THE AIR GET OUT



4. MOULD DESIGN

4.1 Mould Requirements

Practical hints on mould design are illustrated in Fig 3. The design of the mould will affect:

a) the ease and speed of filling;
b) the ease and speed of demoulding;
c) the quality of the product;
d) the surface appearance;

A well designed mould made from the correct material will produce good products easily and should have a long life.

Although each product will have specific mould requirements there are basic rules for designing moulds

1) Avoid sharp corners These can interfere with the filling of the mould and are vulnerable in the finished product. A minimum radius of 12 mm should be used whenever possible.

2) Moulds should be tapered to ease demoulding. A minimum of 5˚ is usually satisfactory.

3) Moulds should be strong enough to withstand the vibration and stiff enough to withstand the hydraulic head of the premix. This is very important with deep components. If the mould is too weak the sides will distort and this could make demoulding impossible.

4) The mould must be easy to dismantle, clean and reassemble. This increases the life of the mould and reduces labour and overall cycle time.

5) Attention should be paid to joints to prevent leaking during casting. This produces an unsightly flash mark on the moulded product and may make demoulding very difficult and require costly remedial work on the product.

6) Demoulding can be speeded up by designing in lifting points or location points for hydraulic rams into the mould itself.

7) Where a product has a large surface area demoulding can be made easier by including an air-release valve into the surface of the mould.

8) In components which may be stressed due to restraint imposed by the mould associated with GRC shrinkage, the mould material should be selected to alleviate these stresses. Rubber moulds are extremely useful because they flex to take up the shrinkage, i.e. as in the core members of a gully grid mould.

4.2 Mould Materials

4.2.1 Timber

Very useful for short production runs. This surface must be properly sanded and sealed otherwise demoulding may be difficult.

4.2.2 GRP/FRP

Suitable for long production runs and good for shaped products

Note: The ‘gel coat’ must of an alkali resistant resin. General purpose resins deteriorate rapidly when used with cement causing a poor surface finish and very difficult demoulding.

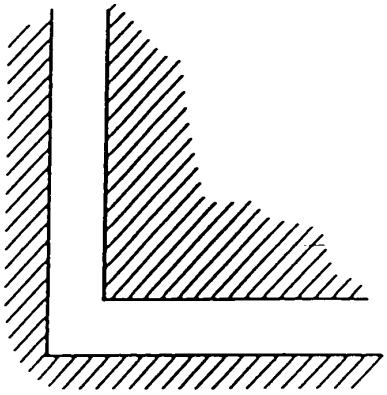
4.2.3 Steel

Very good for standard products and long production runs.

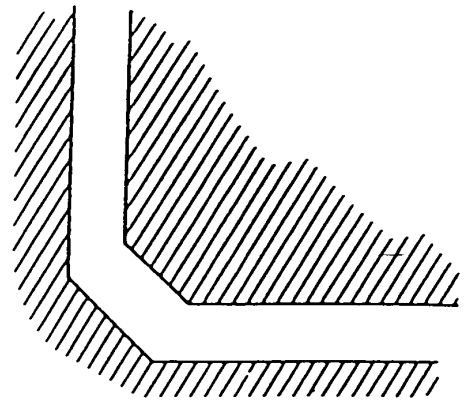
The weight of the mould can cause handling problems and sometimes can damp vibrations on low-powered vibration tables.

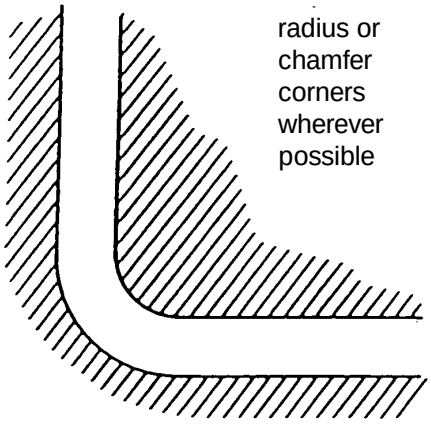
Fig 3 HINTS ON MOULD DESIGN

1. AVOID SHARP CORNERS



INCORRECT

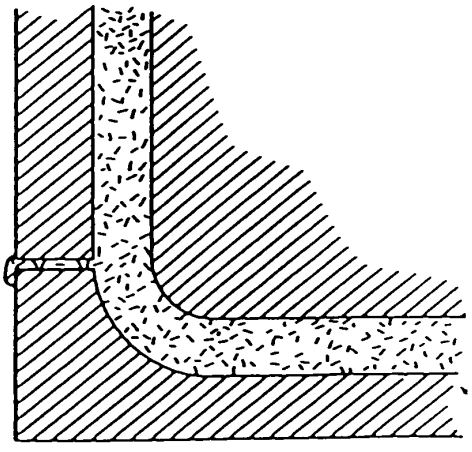




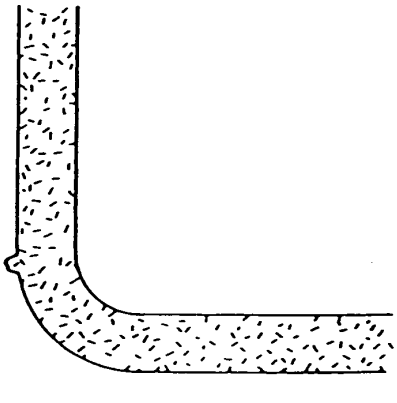
radius or chamfer corners wherever possible

CORRECT

2. MAKE SURE JOINTS ARE LEAK PROOF



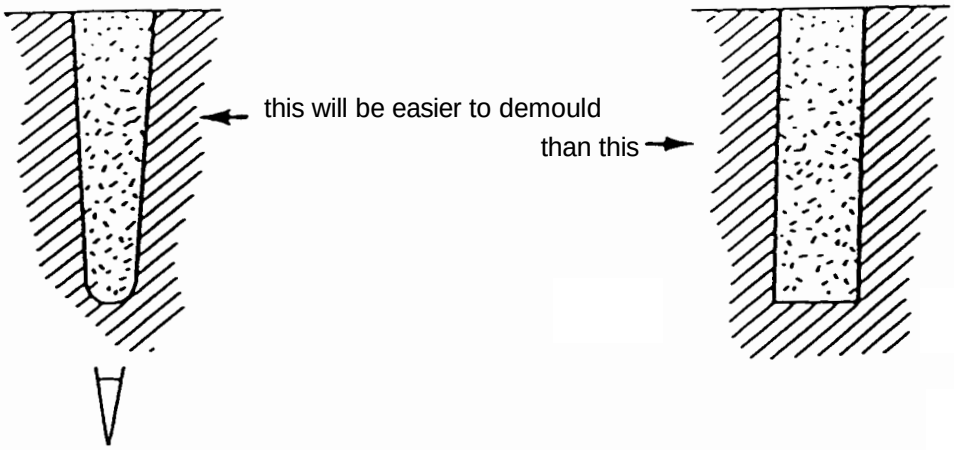
slurry leakage



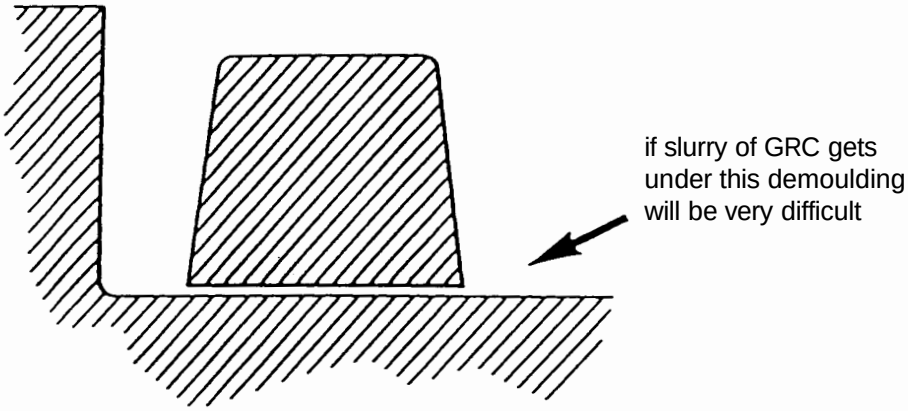
'flash' mark and blow holes in product

Fig 3 Continued

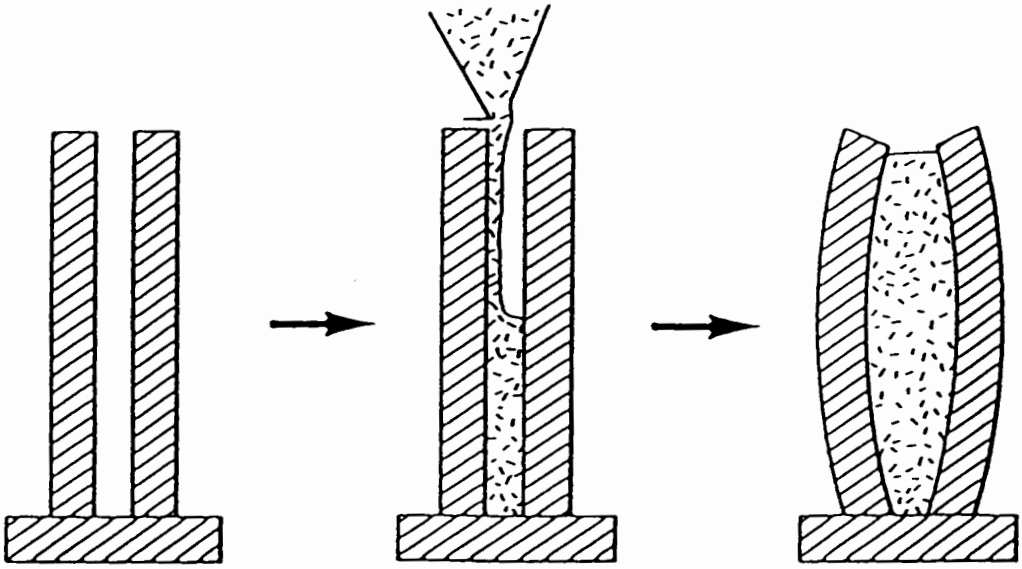
3. ALLOW AT LEAST 5° DRAW ANGLE



4. MAKE SURE INSERTS SEALED



5. MAKE SURE MOULD SIDES ARE STIFF ENOUGH



weak mould

mould distorts as GRC fills mould under vibration

this is impossible to demould, and dimensions and weight are incorrect

4.2.4 Rubber Moulds

Rubber moulds are useful to make demoulding of certain products easier. This is achieved by utilising the flexible properties of the rubber to allow the mould to be peeled from the product. Rubber moulds are essential if there are undercuts in the mould since these could only be demoulded otherwise by extremely complicated interlocking moulds.

The most suitable types of rubber for this application are either polyurethane or silicone. They are two component cold cure systems. They are pourable and readily conform to the patterning they are put in contact with.

The main advantages of using rubber moulds are their ability to reproduce very fine detail, they do not stress the product and demoulding is simply achieved by peeling the mould from the product. Providing that moulds are looked after, rubber moulds should have a life well in excess of 100 castings.

The methods of constructing rubber moulds are detailed in Cem-FIL Information Bulletin No. 46.

5. RELEASE AGENTS

Any release agent suitable for use with precast concrete will work with GRC. In general chemical release agents are preferred.

It is considered best to use as little release agent as possible. Only a thin film is necessary.

Excess release agent collecting in the bottom of the mould will cause discolouration and pin-holing

Release agents can be applied by spray or by impregnated sponges/cloths
(Cem-FIL Information Bulletin No. 52).

6. AFTER MOULD FILLING

l) Remove any excess GRC which may interfere with demoulding when the GRC has set.

2) Carry out any final trowelling when the GRC is still ‘green’ It is easier to do this to achieve a good trowel face than grinding when the GRC has set

3) Cover the filled moulds with polythene to prevent water being lost from the GRC during initial hydration.

7. DEMOULDING

Remember: it takes more time to demould, clean and re-apply release agent than it does to fill the mould.

1) A steady force is quicker and more effective than hammering the mould. It also causes less damage.

2) In the case of a double skin mould it is useful to extract the core as soon as possible after casting. This prevents the GRC from shrinking onto the core and making demoulding difficult.

3) If a produce is overstressed on demoulding it may crack at a later date. Therefore demoulding should be carried out with care.

4) GRC products should not be allowed to dry out after demoulding before being put into cure.

5) **Clean** the mould as soon as possible after demoulding.

8. CURING

Two types of cure system are employed with GRC: moist cure and air cure.

8.1 Moist Cure

Thin section GRC products with low water: cement ratios can rapidly dry out. If this occurs before hydration is complete, the cement never achieves its full strength and the GRC properties are adversely affected.

To ensure complete hydration, it is essential that products are kept moist immediately after manufacture and during the curing period. Several methods of achieving this are currently in use, including storage in a humidity chamber or fog room, sealing in polythene bags, or total immersion in water.

As a guide to practical curing regimes, GRC products will achieve a substantial proportion of their ultimate strength when the main cure is carried out for 7 days, in a humidity of greater than 95% RH and with a minimum temperature of 20°C. A suitable post-curing regime will allow the remainder of the strength to be achieved. *(For more information consult 'Cem-FIL Technical Data' Manual)*.

8.2 Air Cure

The incorporation of acrylic based polymeric materials into the GRC formulations provides the capability for air curing, The polymer formulation used must be capable of forming a film around the mix particles, thus allowing the moisture in the GRC to be retained and hydration to continue. The polymer materials are normally added at rates of between 3% - 10% of polymer solids to cement weight. After initial cure under polythene and demoulding, the GRC product can be allowed to cure in ambient air conditions, but care must be taken to ensure that the air temperature is above the minimum film formation temperature of the polymer. The addition of polymer materials to GRC may affect the fire performance properties.

Further reading - GRCA Guide to the Use of Acrylic Polymers.

9. QUALITY CONTROL

The mechanical properties of premix GRC are highly dependent on density and glass content.

They must be measured regularly. Test methods have been published by Cem-FIL, and European standards (EN 1170-1 to EN 1170-7) are also applicable.

1) Glass Content (Washout Test)
   Use Cem-FIL test method CEM/QC/004 or EN 1170-2.

2) Density
   Use Cem-FIL test method CEM/QC/009 or EN 1170-6.

3) Mechanical Properties
   These may be measured by testing samples in bending* or in the case of products with a performance requirement a direct test may be made by testing the product itself.

* Test methods available *(as applicable)*:

BS 6432 : 1984 *(to be superceded by European standards)*

EN 1170-4 *("simplified Bending Test")*

EN 1170-5 *("complete Bending Test")*

GRCA Methods of Testing GRC Material S0103

ASTM C 947-89 standard test method for flexural properties of thin-section GFRC

10. PROBLEM SOLVING

Mixing Problems

Problem	Cause	Solutions
Poor mix workability	Over-mixing of fibre	Keep fibre mixing time to minimum
	No plasticiser	Check use / type of plasticiser
	Insufficient water	Check water addition
	Sand grading too fine	Use correct grade / remove fines
	Mix left too long before use	As a guide use mix within 20 minutes of mixing
Clumps of fibre in mix	Poor fibre feeding	Use vibratory feeder / heavy duty chopper
Mix segregation	Old cement	Use fresh cement
	Too much water	Control water content
	Bad mixing	Follow mixing recommendations

Product Problems

Problem	Cause	Solutions
Blow-holes *(large)*	Mould filled too quickly	
	Incorrect mould filling technique	See ‘Filling the Mould’
	Inadequate vibration	
Pin-holes	Poor mix workability	See ‘Mix Design’
	Excess release agent	See ‘Mould Design’
	Poor quality release agent	
Cracks on demoulding	Rigid mould	
	Bad mould design	See ‘Mould Design’
	Filling from more than one source	See ‘Filling the Mould’
	Insufficient fibre See ‘Mix Design’	
	Mix too wet	Use superplasticiser
	Too early demould	Longer setting time, heat, accelerators
Non-uniform appearance	Segregation due to poor mixing	May be necessary to use cellulose admixture
	Bad mix formulations	
	Over-vibration	

GRC PREMIX MIX DESIGNS

These formulations are for guidance only and may need to be modified to suit particular product requirements and local raw materials. This will relate mainly to water contents.

	CEMENT KG	SAND KG	PFA KG	WATER KG	POLYMER (1)* KG	ADMIX 2 (2)* KG	ADMIX 3 KG	Cem-FIL FIBRE CONTENT KG	%	LENGTH (mm)
General Purpose	50	33	-	16	-	.5	-	3.61	3.5	(12)
Small Flat Products	50	33	-	16.5	-	.5	-	3	3	(24)
Low Shrink	50	50	-	17.5	-	.5	-	4.17	3.5	(12)
General Sunscreens	50	33	-	16	-	.5	-	3.61	3.5	(12)
Polymer Mix	50	50	-	13	5	.5	-	4.29	3.5	(12)
Accelerated	50	50	-	14.5	-	-	2.25 (3) *	4.23	3.5	(12)
Pumpable Mix	50	33	-	17.5	-	.5	20gms (4)*	3.66	3.5	(12)
Mix Containing PFA	50	-	16.6	18.3	-	.5	-	2.65	3	(12)

NOTES:

(1) Acrylic Polymer

(2) Superplasticiser

(3) Calcium Chloride Accelerating Plasticiser

(4) Hydroxy Propyl Methyl Cellulose

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