HYBRICAST FORTON MG MANUAL

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1. INTRODUCTION

This manual is intended for Forton licensees/clients producing Forton MG (Modified Glass Fiber Reinforced Gypsum). It contains information on properties, planning, specification, production, quality control and safety aspects.

Gypsum is suitable for reinforcement with common E-glass fibers. Unlike cement, gypsum is not high in alkaline and does not generate lime during cure, the main reason why alkaline resistant (AR) fibers are used in glass fiber reinforced cement, GRC. Gypsum therefore has in this respect an enormous advantage compared with unmodified cement matrixes.

However, a disadvantage of gypsum is its poor weather resistance. Because of this, unmodified gypsum is only suitable for indoor applications.

Research programs have shown that Forton MG has very good mechanical and physical properties, which enables the material to be used for a wide range of applications. The material shows improved weather resistance that makes it possible to use the product outdoors. The material has already been used successfully for manufacturing architectural cladding panels, decorative ornamentation, column covers, flowerpots, etc.

Forton B.V. strives to provide the best possible service for its customers by building a base of close cooperation with its client. Through its modern Technicum, its active marketing organization and 14 years of experience Forton has a wealth and depth of technology and experience at its disposal and the dedication to respond quickly and accurately to market needs.

We intend to supplement this manual at regular intervals with new information and news of developments in the international market.

N.B. An explanatory list of symbols has been included in this document, for ease of reference.

2. PROPERTIES OF STANDARD FORTON MG

2.1. Introduction

This chapter relates to the material properties, both mechanical and physical, of Forton MG. In structural design it is essential to have a very good understanding of a materials behavior under various types of loading and climates and to have knowledge of any changes occurring due to environmental influences.
Forton MG is a relatively new material, which continues to be tested. Therefore, the results of continuing test programs will be forwarded to clients as supplements or revisions to this manual, when they are available.

Throughout this manual, the composition of a basic (standard) Forton MG mix is as per table 2.1 below, unless otherwise indicated.

Table 2.1. Compositions of standard Forton MG.

Components	standard composition	
	parts by weight	weight percent
a-hemi hydrate gypsum	10	49.0
Forton compound VF812[1]	7	34.2
Melamine resin	1	4.9
Hardener	0.05	0.2
E-glass fiber	2.4	11.7*

Properties presented refer to this composition and are manufactured by the lay-up method, unless otherwise indicated.
Unless specified otherwise, the strengths stated are average values. For properties of which enough data are available, characteristic values as measured in the Forton Technicum are given, i.e. values with a 5% margin of error.

“Dry material” material is defined as material that has been dried in an oven at 40°C (105°F) for 7 days before testing.

The properties are given for the material tested under specified conditions. Some Forton MG properties are sensitive to moisture content, which will be shown and discussed.
The term "natural weathering" refers to outside exposure of material at Forton Technical Center laboratories in Sittard (in the South of the Netherlands).
The term "accelerated ageing" refers to ageing under the following conditions:
-In water of 20°C (68°F);
-In a wet/dry cycling machine commonly used for the glass fiber reinforced cement material;
-In a weather-o-meter with cycles of rain, UV-and IR-light (temperature).
-Percentage of Glass Fiber is dependent on the thickness and types of fibers used which varies between 10-20 mm. A glass fiber value ratio between 5%-12% is recommended.

2.2. Mechanical properties

Tensile and flexural

The young properties given in table 2.2.1. are for a standard Forton MG material with maximum free moisture content of 1% by weight.
Four-point bending tests have been performed in accordance with the test described in appendix D. The tensile stress-strain tests have been performed as described in BS6432, Rilem technical committee 49TFR or ASTM (C-947) at a crosshead speed of 2 mm/min.

Table 2.2.1. Typical mechanical properties of standard Forton MG conditioned at 20°C(68°F) and 65% R.H.

MECHANICALPROPERTIES	UNIT	AVERAGE	CHARACTERISTIC[1]	UNIT	AVERAGE	CHARACTERISTIC[1]
MOR	N/mm²	70	55	Psi[2]	10150	7977
LOP/yield	N/mm²	20	15	psi	2900	2175
∈MOR	%	2.4	2	%	2.4	2
UTS	N/mm²	34	20	psi	4930	2901
BOP	N/mm²	9	7	psi	1305	1015
∈UTS	%	2	1	%	2	1
Modulus of Elasticity	kN/mm²	6	-	psi	870	-
(in tension)						

[1]) Characteristic value is the value with a 5% margin of error
[2]) N/mm² = MPa = ca. 145 psi

The properties given in table 2.2.1 refer to samples conditioned at 20°C (68°F) and 65% R.H. An increase in moisture content due to water absorption results in a decrease of mechanical properties. The influence of moisture content on MOR (flexural ultimate), LOP (flexural yield and Modulus of Elasticity (in bending) are shown in figures 2.2.1 and 2.2.2.
The mechanical strength recovers completely when the specimen dries.

*   BS: British Standard.
**ASTM: American Society for testing materials in the USA.

Standard Forton composition

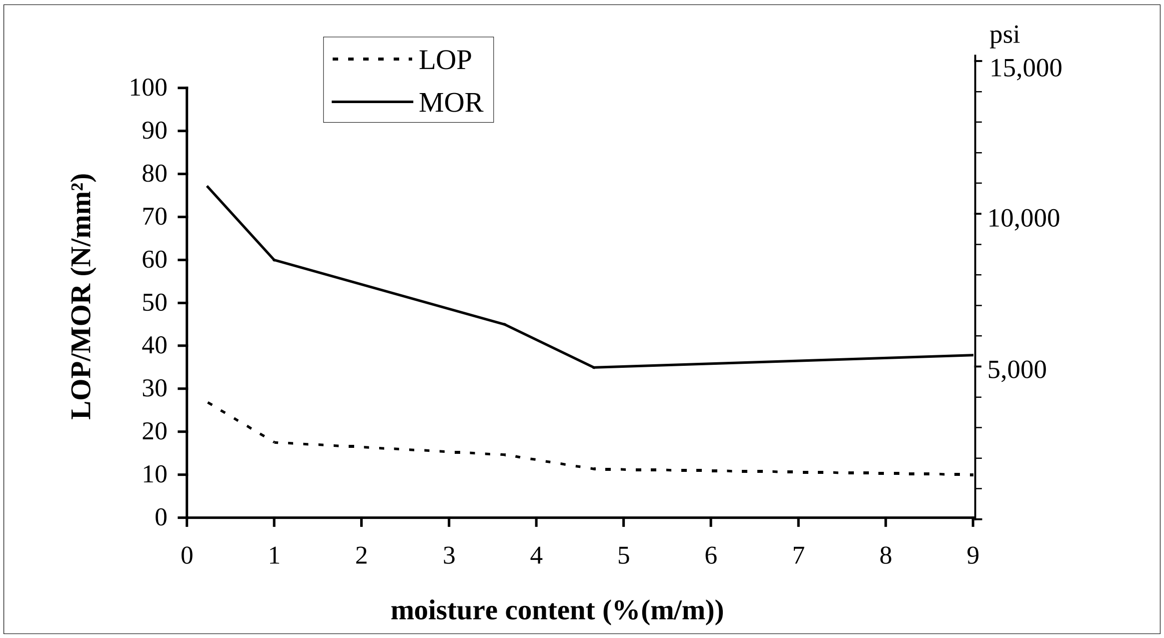

Figure 2.2.1. Influence of the moisture content on the Modulus of Rupture (MOR) and Limit of Proportionality (LOP/yield)

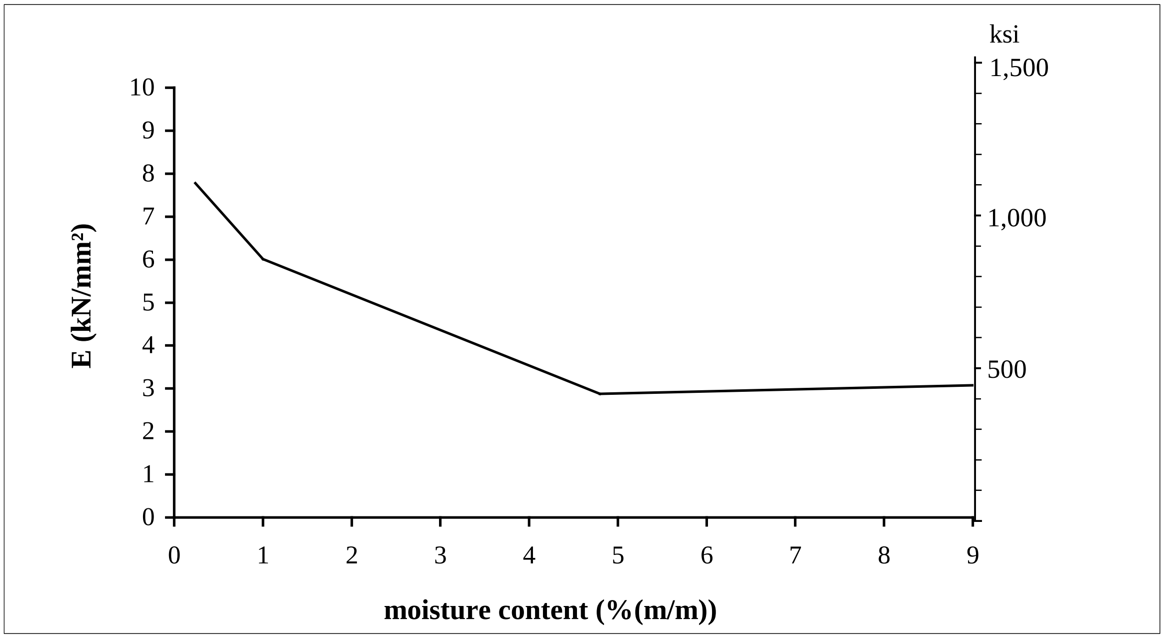

Figure 2.2.2. Influence of the moisture content on the Modulus of Elasticity.

Impact resistance

The impact resistance has been measured with a Charpy impact device for un-notched samples in accordance with RILEM recommendations of technical committee 48TFR. The results are shown in table 2.2.2.

Table 2.2.2. Typical impact resistance properties of standard Forton MG conditioned at 20°C (68°F) and 65% R.H.

Mechanical properties	unit	Average	Characteristic[1]	Unit	Average	Characteristic
Impact strength (Charpy)	KJ/m²	30	16	In lb/in²	170	85

[1]) characteristic value is the value with a 5% margin of error

Creep

Results of creep tests performed on samples manufactured with the standard Forton MG composition tested with four-point bending at 21°C (69°F) and 55% R.H. and at 21°C (69°F) and >95% R.H. gave the results as is shown in figure 2.2.3 and 2.2.4.
The stresses applied are 7,17 and 30 N/mm²(1015, 2465 and 4350 psi) for tests are 21°C (69°F) and 55% R.H. and 4, 10 and 15 N/mm² (580, 1450 and 2175 psi) for tests at 21°C (69°F) and >95% R.H. These stresses are respectively 0.4 LOP, 1.0 LOP and LOP + (MOR-LOP)/4 in which LOP is the

stress at the limit of proportionality (yield stress) and MOR is the stress at rupture. Creep coefficients after one year testing are given in table 2.2.3. It appears that the creep as expected in wet conditions is larger for the high stress levels.

Table 2.2.3 Creep coefficient at t = 1 year.

Stress level			Creep coefficient	
N/MM²	PSI	RELATIVE TO LOP/YIELD (%)	21°C (69°F), 55% R.H.	21°C (69°F), >95% R.H.[2])
4	580	40	-	1.2
7	1015	40	1.1	-
10	1450	100	-	Fractured [1]
15	2175	150	-	Fractured [1])
17	2465	100	1.7	-
30	4351	175	5.2	-

[1]) Fractured due to large displacement

[2]) N.B. For the creep test under the condition with the relative humidity higher than 95%, it has to be mentioned that after finishing the test the samples appeared to have a high moisture content which was much higher than the equilibrium moisture content at 95% R.H. It is most probably that the samples have absorbed condensation water. Because of this the test condition of these samples was more extreme than the test condition of 21°C (69°F) and 95% R.H.

Standard Forton composition

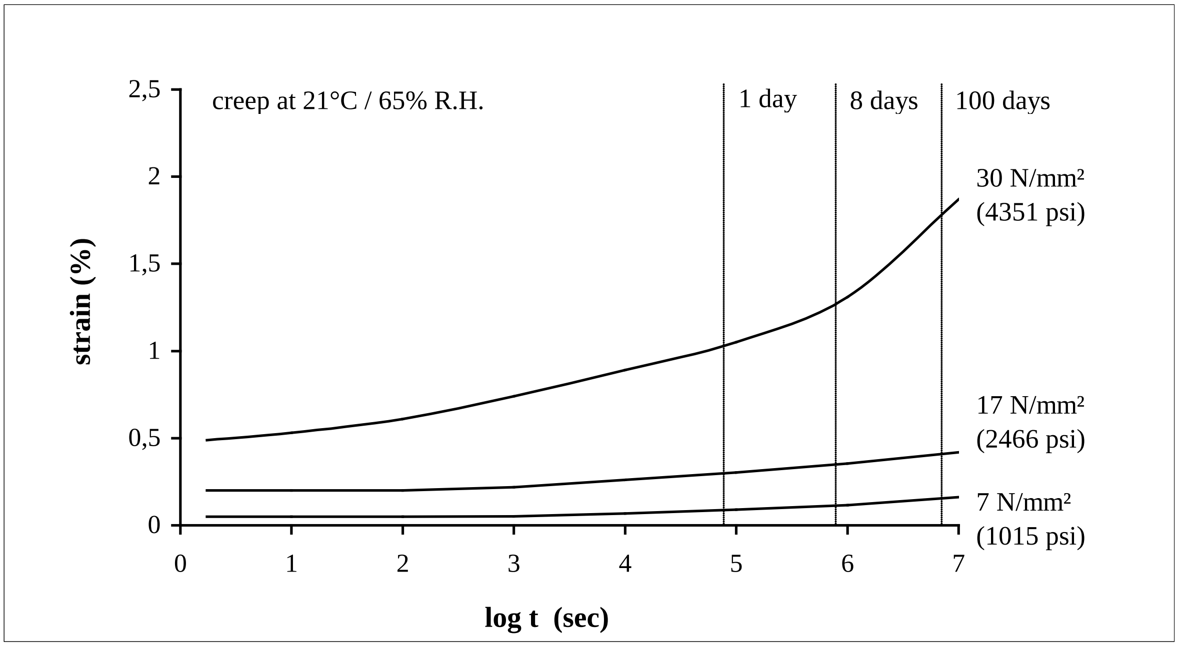

Figure 2.2.3. Creep curves for Forton MG stored at 21°C, 55% R.H.

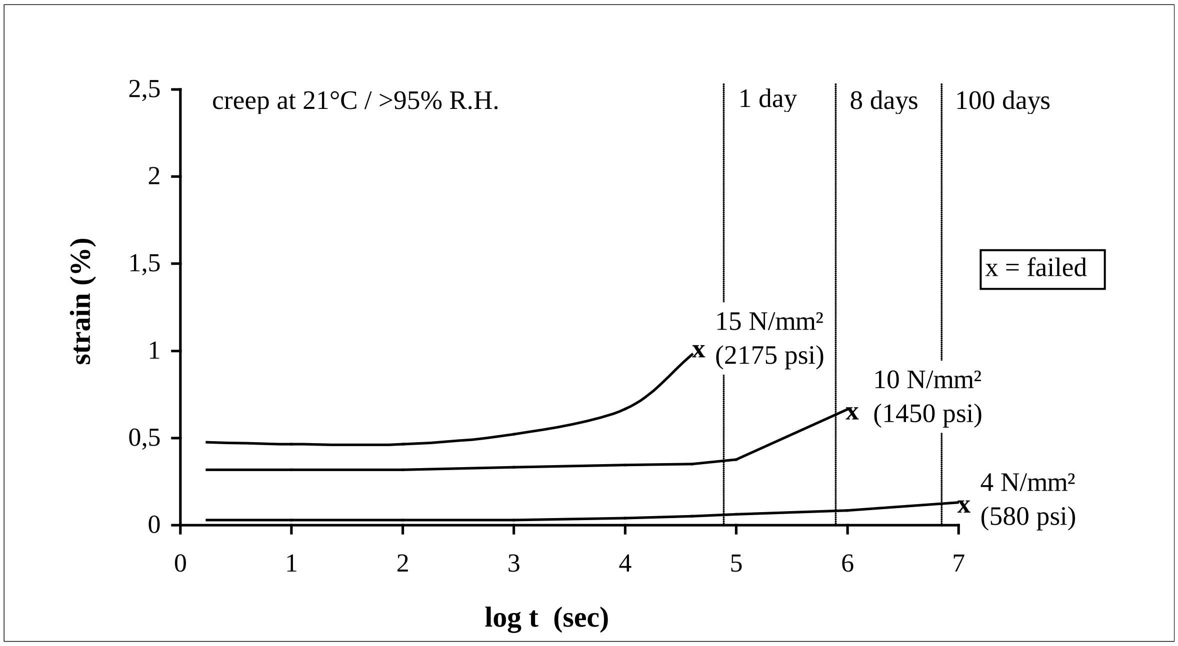

Figure 2.2.4. Creep curves for Forton MG stored at 21°C, >95% R.H. (see N.B.).Fatigue

The fatigue resistance of the standard Forton MG composition is presented in figure 2.2.5. In spite of the relatively low number of tests performed Forton MG can be stated to have a high resistance to fatigue. The tests have been performed at 20°C and 60% R.H.

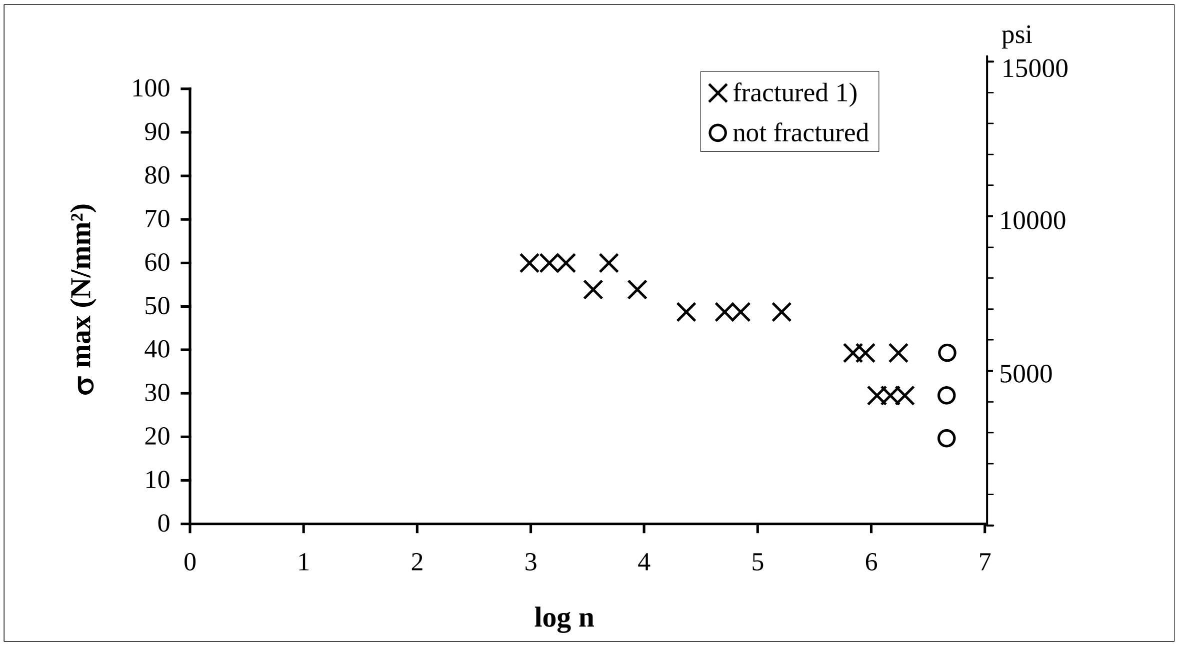

Figure 2.2.5. Fatigue diagrams of Forton MG.

[1]) Failed: Deflection larger than 20 mm.

2.3. Physical properties

Table 2.3.1. Typical physical properties of standard Forton MG.

	UNIT	AVERAGE
Density (dry)	Kg/m^3	1500
	Pcf	94
Equilibrium moisture content at [3)]		
20°C/20% R.H.	% m/m	0.06
20°C/65% R.H.	% m/m	0.5
20°C/85% R.H.	% m/m	1.2
20°C/>95% R.H.	% m/m	11
Maximum expansion due to		
Water absorption [1)]	0/00	0.8
Water absorption after immersing		
in water for 1 day [2)] 28 days	%	3-6
more than 150 days	%	10-11
Coefficient of thermal expansion	%	16
	1/°K	$20 \bullet 10^{-6}$
Water vapor diffusion coefficient	1/°F	$1.1 \bullet 10^{-6}$
	-	250

[1)] already present after 1 day of immersion in water

[2)] dependent largely on curing procedure (see paragraph 6.6)

[3)] see also figure 2.3.1

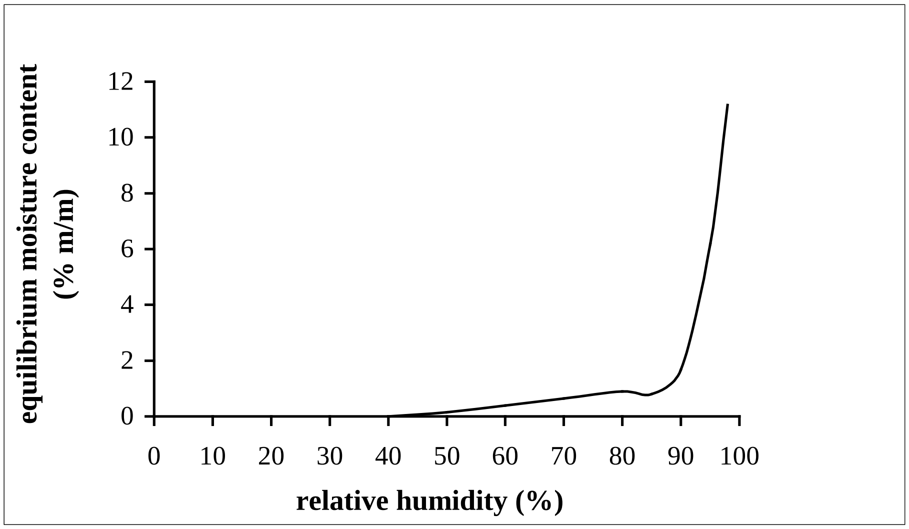

Figure 2.3.1.
Equilibrium moisture content of Forton MG as a function of relative humidity at 20°C.

2.4. Durability

2.4.1. Weather-resistance

Since gypsum cement is not alkaline and after setting and curing will not develop further crystals due to continuing hydration or other processes it is to be expected that there will be no degradation of the E-glass fibers by a chemical or mechanical attack in the gypsum matrix and that the bonding of glass fibers in the gypsum matrix remains constant.
It is known that unmodified gypsum loses strength completely when it absorbs water and is water-soluble. Therefore various test programs have been performed, while others are ongoing to determine that long-term performance of Forton MG, particularly the weather- and water-resistance of the material.

Knowledge of long-term performance of new materials is very important for engineers and designers. The most reliable method to establish the durability of a material is to monitor its behavior in practice. However, this is not feasible for potential manufacturers. Therefore also accelerated ageing tests are also desirable to predict long-term behavior but of course they can never be a 100% guarantee for the actual behavior.

Accelerated ageing tests are performed by:

- Exposure to 400 weather-o-meter cycles (figure 2.4.1);
- Exposure to 50 wet/dry cycles according to a commonly used ageing test for asbestos cement and GRC (immersing for 24 hours in water of 20°C (68°F) followed by 24 hours forced drying at a temperature of 70°C (160°F));
- Immersing in water of 20°C (68°F) for more than 6 months.

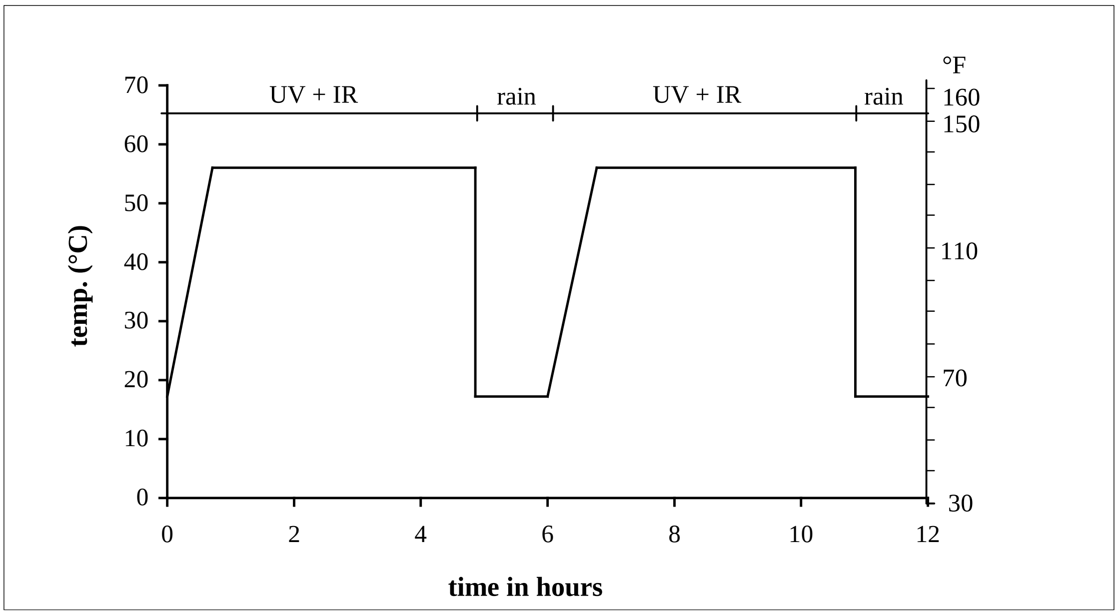

Figure 2.4.1. Cycles weather-o-meter.

Only a minor loss of mechanical strength and density is observed for samples manufactured with the standard Forton MG composition when tested under the same conditions before and after accelerated ageing, independent of ageing procedure. This is shown in table 2.4.1.

Table 2.4.1. Mechanical properties of unprotected standard Forton MG composition after ageing (tested in dry condition).

			AFTER AGEING		
MATERIALS PROPERTIES	UNIT	BEFORE AGEING	WEATHER-O-METER	WET/DRY CYCLES	IMMERSING IN WATER
MOR	N/mm²	75	65	65	68
	Psi	10875	9425	9425	9860
LOP/yield	N/mm²	25	20	27	23
	Psi	3625	2900	3915	3335
∈MOR	%	2.5	-	2.7	2.5
density (dry)	kg/m³	1500	1400	1320	1460
	pcf	95	88	84	92

Forton MG without a face mix, additives or coatings (see section 4), shows some superficial "softening" of the material when the material is in direct contact with water for a long period. Outside weathering exposure shows some superficial erosion of the unsealed surface layer resulting in the exposure of glass fibers at the surface. Also some discoloration is observed.

Table 2.4.2. shows mechanical properties of the standard Forton MG composition after outside exposure for 2 ½ years without any surface protection. The table also gives results with regard to Forton MG with an acrylic paint as surface finish and two years outdoor exposure.

Table 2.4.2. Mechanical properties of Forton MG composition after outdoors exposure.

			AFTER AGEING	
MATERIAL PROPERTIES	UNIT	BEFORE AGEING	2 ½ YEARS WITHOUT SURFACE PROTECTION	2 YEARS WITH AN ACRYLIC PAINT AS SURFACE FINISH
MOR	N/mm²	75	51	73
	Psi	10875	7395	10585
LOP/yield	N/mm²	25	17	23
	Psi	3625	2465	3335
∈MOR	%	2.5	3.0	2.7
density (dry)	kg/m³	1500	1380	1470
	pcf	95	87	93

The results show some degradation of the flexural properties of the standard Forton MG composition when exposed outdoors without any surface protection layer. Also a lower density is found for the exposed samples. Tests have shown that this is not because of dehydration of the gypsum. Most likely some leaching of gypsum material takes place. This also could explain the lower flexural properties. However, this does not correlate with the wet/dry results, where a lower density was measured without a decrease of mechanical properties. Research is continuing on this point.

The above can be limited or avoided by applying special surface treatments like coatings or sealers. This is shown by the material properties of the standard Forton MG composition with the acrylic paint as surface finish after 2 years outside exposure (table 2.4.2). No significant loss of mechanical properties is observed for these specimens.

2.4.2. Freeze/thaw resistance

The freeze/thaw resistance is tested according to RILEM test procedure CDC-1. According to this test procedure Forton MG appears to be freeze/thaw resistant.

2.5. Fire resistance

Gypsum is known for its fire resistant properties and this is certainly one of the reasons why it is very popular in construction. However, polymers are combustible materials.
Tests according to British Standard 476 parts 6 and 7 provide the material with a Class 1 Building Regulation in the U.K. ASTM E-84 tests indicate class 1 results according to U.B.C. code.

3. EFFECTS OF COMPOSITION VARIATIONS ON PROPERTIES OF FORTON MG

3.1. Polymer

Figure 3.1.1. and 3.1.2 show the influence of polymer content on bending strength and water absorption.

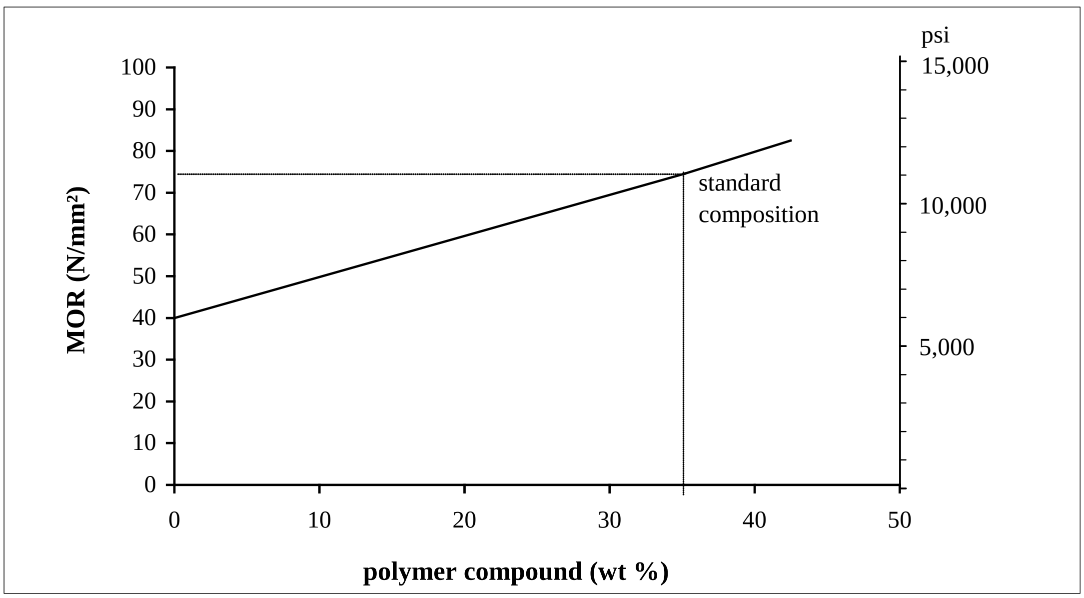

Figure 3.1.1. Influence of polymer content on bending strength (MOR) of Forton MG.

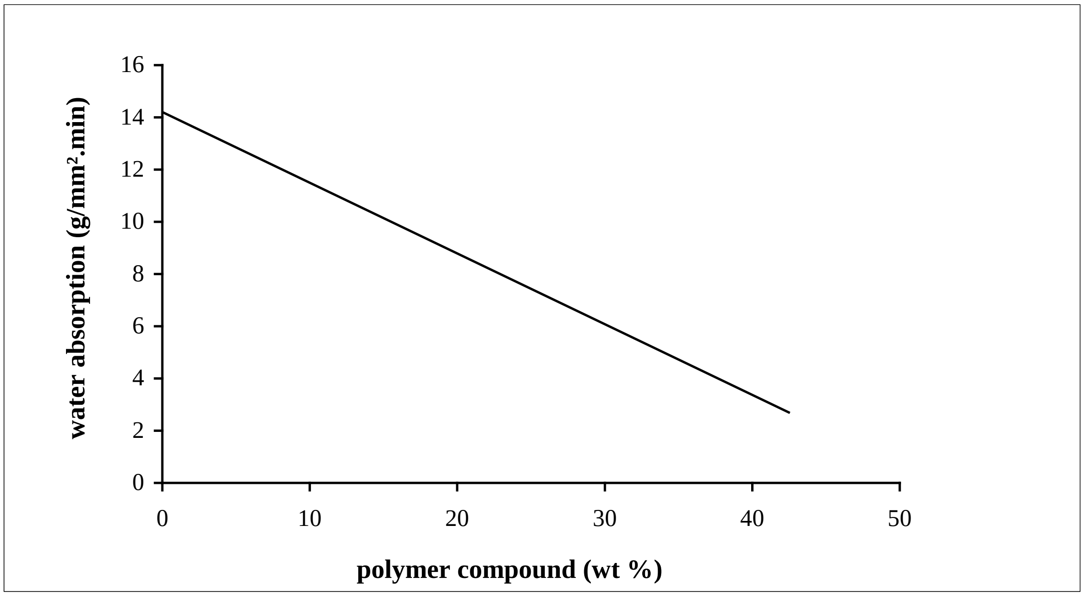

Figure 3.1.2. Influence of polymer content on the water absorption as an average of the absorption in the first day of immersion in water of 20°C (68°F).

Preliminary tests into a more economic MG-composition and a reduced polymer content up to 70% of the standard composition showed that this simplified MG-composition has a somewhat lower bending strength and a some what increased water absorption when compared to the standard MG-composition. Tests are going on to determine the possible applications and limitations of this mix design.

3.2. Gypsum source

All compositions thus far are manufactured using a-hemi hydrate gypsum. Investigations performed into the influence of source (country, industrial or natural) showed that a wide range of a-hemi hydrate gypsum could be used to obtain the properties mentioned in the previous paragraphs. β-Type gypsums should not be used.

3.3. Fillers

The addition of calcium carbonate powder or fine sand (to a maximum of 50% of the weight of gypsum) results in a material with reduced properties; a reduction of bending strength of approximately 20% and an increase in water absorption is observed. For applications that do not demand the high material properties of the standard composition, the use of low cost fillers with the a-hemi hydrate gypsum is possible to reduce the cost of the mix.

3.4. Glass fiber

The influence of glass fiber content as well as glass fiber length on bending strength is shown in figure 3.4.1. The influence on the yield strength is shown in figure 3.4.2

The results are typical of samples manufactured using the spray-up method.
The influence of glass fiber content on bending strength (MOR) and yield strength (LOP) is significant, especially if the fiber length is greater than 30 mm (1.24 in). The influence of glass fiber length is not as pronounced.

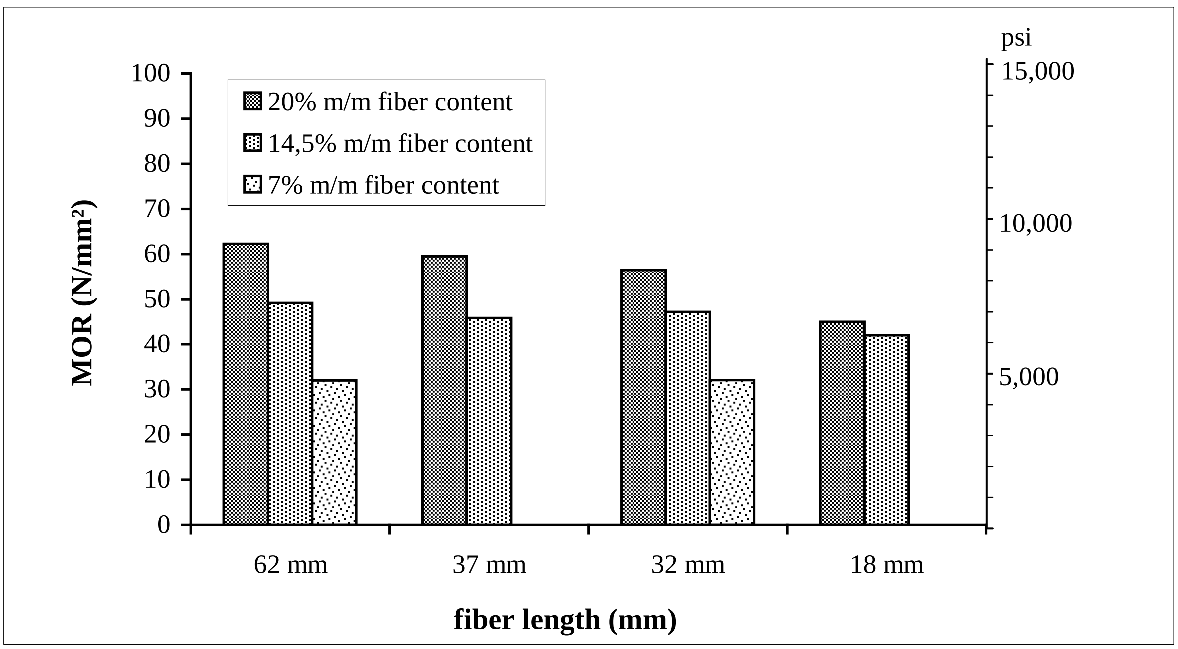

Figure 3.4.1. Influence of glass fiber content and glass fiber type on the bending strength (MOR) of Forton MG.

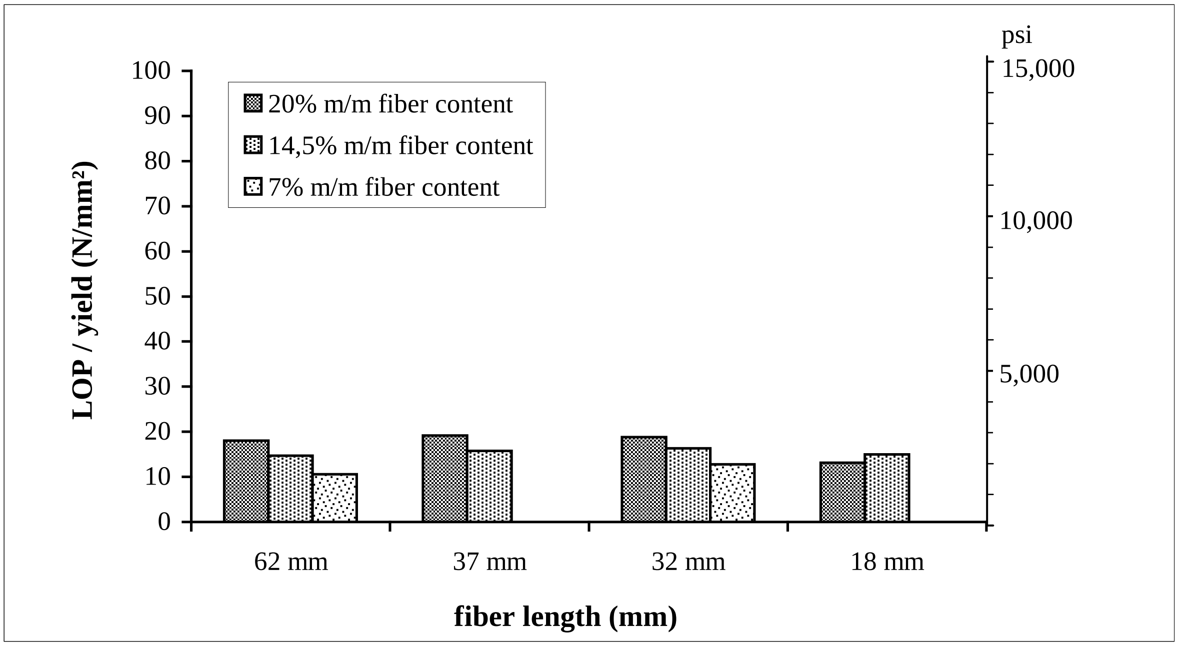

Figure 3.4.2. Influence of glass fiber content and glass fiber type on the yield strength (LOP) of Forton MG.

4. SURFACE FINISHES

4.1. Introduction

There is a wide variety of available surface finishes for Forton MG. Some examples are:
-Smooth and polished;
-Colored with pigments or paints;
-Exposed aggregate surface via sand blasting or grinding;
-Limitations of natural stone, concrete, wood;
-Metal powders: polished or painted.

4.2. MG surface texture

a-hemi hydrate plaster has a very fine particle size and hence can accurately reproduce the characteristics of the surface on the mold.

If Forton MG is produced against very smooth surfaces a smooth, gloss finish can be obtained but this tends to accentuate small surface defects, gives a patchy appearance when used in large surfaces and tends to show the effects of weathering more, These problems can be overcome by making molds of the natural textures, such as plywood, slate, stone, etc., to give smooth but matt finish textures of varying depths.

Some face coats may suffer from micro crazing. Microscopic examination has shown that such micro cracks normally travel no further than the nearest “E” glass fiber and hence do not significantly influence the long term performance of the composite. Crazing can be eliminated or reduced considerably by:

- i) Minimizing the thickness of any un-reinforced Forton MG facing mix on the component surface.
- ii) By the addition of sand fillers and/or “E” glass fibers to the facing mix.
- iii) Increase the polymer content in the face mix.

Using a coarse surface texture in the mold can reduce the visual effect of crazing.

4.3. Pigments

Water dispersible paste pigments may be used to color the Forton MG material. The most successful are the paler shades containing natural oxide and carbon based pigments. Stronger colors are to be avoided if possible as these may cause a patchy appearance in the product after demolding unless an appropriate dispersing aid is used. Also Copper, brass and bronze powder pigments can be used in the mix to give the Forton MG material a metallic appearance.

Metal powders with a particle size of 325 meshes are recommended. Surface textures and sand- or grit blasting of the face mix reduces the visual effect of any patchy appearance. Preferably pigments are added to the bulk ingredients to ensure maximum of color uniformity in the product. The best results are obtained when the pigment in a pre-dispersed form is added to the VF812 compound and mixed in before the dry materials are added.

4.4. Post treatment processes

The mold surface of Forton MG can be textured by:

- i) Light sand blasting of the face mix similar to concrete façade panels. It is important to establish a regular curing program if the product has to be sand blasted, in order to uniformly harden the Forton MG material. Otherwise sand blasting can create an uneven surface texture.

ii) Coarse or fine grinding of the Forton MG, surface. This provides a smooth surface but exposes the stone dust and sand fillers added to the facing mix.

iii) Wet polishing of sanding of the freshly demolded surfaces using the appropriate abrasive materials.

The finishing treatments should not be so aggressive as to expose fibers on the surface.

These techniques are also particularly valuable in removing the fine surface layer on the piece and thereby reducing the tendency to craze.

4.5. Exposed aggregate finish

Exposed aggregate finishes are widely used in the architectural precast concrete and GFRC fields. The aggregate is added to the regular Forton MG gypsum mortar at the mixing stage and applied as a thin layer to the mold surface prior to spray-up (face down technique). The aggregate mix can be applied to the top surface after spray-up (face-up technique). The aggregate is exposed after demolding by sand blasting. The sand blasted surface must be sealed with a clear acrylic sealer after sand blasting. Acid washing will not work with Forton MG.

4.6. Applied finishes

Applied finishes, which are essentially organic based, cover a wide range of chemical types. It is recommended that any applied finish sealer or paint used on the Forton MG material should allow water vapor to pass (breathable-system). Coatings based on water based synthetic latex emulsions such as polyvinyl acetate co-polymers, (styrene) acrylic co-polymers and styrene butadiene rubbers (SBR) are appropriate.
Non-breathable systems such as epoxies or urethanes can be used if water vapor transport is limited.
Care must be taken in preparing the Forton MG surface before coating, including removal of friable material (laitance) and any residual mold release agent. Installations using this coating system must be property vented to prevent hydrostatic pressure from building up behind the piece.

4.7. In mold facing/coating

The addition of an epoxy resin with catalyst to the standard Forton MG gypsum slurry creates a face mix with high weather resistance. The face mix is applied to the mold surface with a layer thickness of approximately 2 mm (0.08 in) by pouring, brushing, using a hopper gun or a cup gun. No later than 90 minutes, the Forton MG mortar mix should be applied. The addition of pigments or aggregates also allows the previously (paragraph 4.5 and 4.6) discussed finishes.

All mix formulations are obtainable at Forton Technical Service on request. However, each producer should prepare their own testing program with the available raw materials and admixtures.

5. RAW AND AUXILIARY MATERIALS

5.1. Introduction

This chapter covers the specific raw materials for the production of Forton MG. In addition, materials used for finishing, attachment, etc. will be covered.

5.2. Gypsum

The gypsum used in Forton MG is a-hemi hydrate plaster. Results indicate that physical and mechanical properties of Forton MG's manufactured with a-hemi hydrate plasters of various sources can be identical.
However, since the plaster also influences workability setting time, expansion, etc. tests have to be performed in the production plant to check the usability of the specific plaster used. Tests on the plaster need to be performed before production begins. Reference is made to chapter 7.
Some suitable ranges of a-hemi hydrate gypsum properties are shown in table 5.2.1.

Table 5.2.1. Suitable ranges of a-hemi hydrate gypsum properties.

PROPERTY	RANGE
Water-gypsum range at standard consistency according to DIN 51020	0.2 – 0.4
Wet density of gypsum slurry at standard consistency	1600 – 1900 kg/m³ 95 – 120 pcf
Expansion due to hydration	0 – 5 ‰

Unlike cement, gypsum has the tendency to expand due to hydration. The degree of expansion depends on the plaster type used.
Some non-expansive or low expansion gypsum plasters are commercially available to deal with dimensional tolerances and demolding problems.

Measures should be taken to protect the gypsum against high humidity when stored.

5.3. Polymer / resins

5.3.1. Forton compound VF 812

The Forton compound VF 812 is a cross-linkable acrylic co-polymer emulsion specifically developed for polymer modified gypsum (MG).

The Forton compound VF812 consists of an aqueous co-polymer dispersion including additives. This co-polymer dispersion contains small polymer particles, with an average particle size of 225 nm that are held buoyant in the water by emulsifiers. It also includes a defoamer.

The emulsion remains stable for several months at normal room temperatures.

Measures should be taken to protect against freezing and to avoid strong direct sunlight or storing close to heaters.

In table 5.3.1 some specific data of the Forton VF812 are given.

Table 5.3.1. Properties of Forton compound VF812

SOLUBILITY IN WATER 20°C, % BY WEIGHT	DILUTABLE
ACIDITY (PH)	4.5 – 5.0
APPEARANCE, COLOUR INDEX ASTM D1544-68	MILKY-WHITE
BOILING POINT AT 101.3 KPA °C	APPROX. 100
VOLATILES, % BY WEIGHT	50 ± 1
POLYMER SOLIDS, & BY WEIGHT	50 ± 1
PARTICLE SIZE NM	200-300
VISCOSITY AT 23°C, MPA•S[1)]	200-450
AT 70°F, CPS [2)]	100-400
DENSITY AT 20°C, KG/M^3	APPROX. 1070
68°F, PCF	APPROX. 67
ODOUR	MILD ODOUR

[1)] Haake VT 180, spindle E30, 187.5 rpm

[º)] Brookfield LVT, spindle 3, 60 RPM 70°F (21°C)

5.3.2. Melamine resin/hardener

A melamine-formaldehyde (MF) powder resin is used in the system to cross-link with the acrylic co-polymer. The reaction is improved by the addition of e.g. $(NH_4)_2SO_4$ or NH_4CL as a catalyst. In table 5.3.2 data of the melamine formaldehyde powder are given.

Table 5.3.2. Properties of melamine formaldehyde powder.

APPEARANCE	WHITE POWDER, FREE FLOWING
MOISTURE, % BY WEIGHT	<2.7
MF 50% SOLUTION IN WATER	
DENSITY, IN KG/M³	APPROX. 1200
IN PCF	75
ACIDITY (PH)	APPROX. 10

The MF powder is extremely moisture sensitive (hydroscopic).

The storage of the MF powder resin should be in dry conditions. Moisture can cause lumping of the powder. Dry blending the materials before mixing can minimize lumping in the mix.

5.4. Glass fibers

Glass fibers can be manufactured from various glass compositions. By far the most commonly used is E-glass, which is supplied in large quantities for the reinforcement of both thermosetting and thermoplastic plastics. E-glass composition is as follows:

55% SiO_2
9% B_2O_3
14% Al_2O_3
1% Na_2O-K_2O (max.)
21% CaO-MgO

Roving consists of a series of parallel strands without intentional twist, wound in to a cylindrical package. For the application in the gypsum mortar special sizing are necessary. Forton roving is supplied in packages weighing 19-20 kg (42-44 lb).
Forton chopped fiber strand has a special finish to keep the filaments tightly together, to reduce defilamentizing during mixing. Chopped fiber is supplied in various lengths.
12 mm (0.5 in) is the standard. Other fiber lengths are available on request. All chopped fiber strands are package in cardboard cartons. Sometimes it is advisable to chop soft spray-up roving into chopped stands of 25 mm (1 inch) or longer to make a pre-mix which has good mould conformability properties.

Glass fiber mats are available in a variety of thickness, weights and fiber lengths. The mat weight most commonly used varies from 150 to 450 g/m² (1/2 to 1 oz per sq. yd.), and the usual fiber length of 50 mm (2 in). However, continuous strand mats or combinations are also available and can be used.
Glass fibers should be handled with due care. Roving packages should always be stacked vertically.
Glass fibers should not stand in direct contact with damp floors, and should be protected from dust.
Glass fibers should be stored between 0°C (33°F) and 30°C (87°F).
The shape of the mold has a significant influence on which type of reinforcement (roving, mat or chopped strand) and production techniques (lay-up, spray-up of casting) is most practical. All types of E-glass fiber reinforcements and manufacturing processes can be used with Forton MG.

5.5 Water

Normal tap water, clean and free from deleterious matter can be used.

5.6 Admixtures

Sodium citrate can be used in Forton MG to control (retard) the setting time of the material. The amount necessary depends on the plaster used. Commonly an amount of 1 0/00 by mass to the plaster is enough to maintain good workability for about 1 hour. A plasticizer (for example Melment F powder up to 0.5% by mass on gypsum) can be used to increase workability at low water/gypsum ratios. Aluminum sulfate in 10 parts water to 1 part solution is a good accelerator. Also potassium sulfate and terra alba can be used.

With the spray-up method, it is often difficult to achieve good results on vertical sections: the sprayed material tends to sag. This problem can be overcome by the addition of thixotropic agents. These agents make the sprayed-on MG fairly sticky when it is subject to the force of gravity only. When greater forces are applied, however, as is the case with compacting or pumping. The workability is not much different from the un-thickened mix.

For advice on the use of retarders, accelerators, thixotropic agents, plasticizer agents, etc., consult Forton's Technical Service Department.

5.7 Fillers

Silica sand with a maximum diameter of 0.5 mm washed, graded and dried can be added to Forton MG facing mixes, to improve durability, and also to obtain textures by the sand- of grit blasting of the cured product. For specific faces mixes, ratios up to equal parts of gypsum and sand can be used.
Silica sand can also be added to Forton MG premix products. The usual addition of and added to the total composite is between 10-20% to the weight of gypsum.

5.8 Pigments

Preferably pre-dispersed pigments, together with titanium dioxide, should be used in Forton MG to obtain a variety of colors. Oxide and carbon based colors are the most reliable and resistant to fading due to U.V. exposure.

5.9 Release agents

Not all regular concrete release agents are appropriate for Forton MG. Some agents may interact with Forton compound to form air pockets or stains, weaken the MG skin or may not permit proper release. In general release agents based on mineral oil are not advised. Release agents should also be checked for compatibility to the mold material. When the Forton MG product has to be painted, the release agent must be easily removable from the surface of the part. If the piece is to be painted, silicone releases should not be used.

The procedures recommended by the supplier should be strictly followed. Excessive use of release agents may give rise to problems when applying subsequent coatings to the product.

5.10. Cleaning agents for equipments

Equipment such as mixers, pumps, rollers, etc. can be cleaned with water. To prevent caking and material build up, release agents can also be applied to the mixer, pump hopper, etc. before use. This facilitates cleaning.

6. PRODUCTION PROCESS AND PRODUCT ASSEMBLY

6.1. Introduction

Choice of an appropriate production method is of vital importance in determining investment and production costs (labor and molds) and is, consequently a major factor determining the success of a project. A number of production processes will be discussed, with special attention being paid to those most widely used at the present time.
This may appear to suggest that techniques such as casting and extrusion are of minor interest, but the opposite may prove to be true in the future.

6.2. Production facilities

The size of the facilities required depends on the method and volume of production. In general, however, the following provisions are essential:

a. Dry storage facilities for raw materials. Materials should be kept above freezing and no direct sunlight is allowed;
b. A dry, draught-free area of at least 15°C (60°F) for production;
c. Mixing and processing equipment;
d. A product curing area of at least 15°C (60°F) preferably with a minimum of 20°C (68°F) and with a maximum of 50°C (122°F); a relative humidity at a maximum of 80%;
e. Facilities to hoist and transport freshly demolded or young products without overstressing;
f. An area of at least 15°C (60°F), preferably >20°C (68°F), to store finished products for at least one week, or a hot tool maintained at 30°C (110°F) and dehumidified to cure the product overnight;
g. An area to finish products: patching, coating, packaging, etc.;
h. Water-treatment system: clean up water and production water should be purified in a system of settling tanks before being discharged.

6.3 Weighing and mixing

The weighing equipment must have accuracy of 0.1% or less. Depending on the quantity of material used a balance of 100 kg (200 lb) and a balance of 1000 g (2lb) (with 0.05 g = 10^{-4} lb accuracy) is the minimum that is necessary for production.

In order to get a homogeneous Forton MG mix the following mix procedure is essential:
-Mix dry components thoroughly (a dry blend of all dry components can be supplied by Forton B.V.);
-Add admixtures (wet compounds such as anti foaming agent, retarder, plasticizer) and if necessary additional water to the Forton VF812 compound using e.g. a high-shear mixer at low speed;

-Add the premixed dry blend to the wet premixed compound with increasing mixing speed. After mixing, the slurry should be free of lumps. The slurry can be strained to prevent lumps in the face mix.
Before each mixing cycle, equipment should be checked to be sure that it is clean and free from any material caking or build up, for this could loosen and cause blockages during the spray-up process. It is recommended to coat the high-shear mixer with a release agent, as mentioned in section 5.9.

The high-shear mixer consists of a large plastic drum into which a shaft with a circular mixing disc with raised teeth is pneumatically lowered. The mixer has a maximum speed of 1450 rpm; this high speed insures that very short mixing times are necessary.

6.4 Manufacturing methods

6.4.1. Spray-up

Forton B.V. can advise or supply specially designed spray-up equipment. The following process description is based on the use of a manual spray unit, but automatic equipment is also available. Forton Technical Service may be consulted for advice on the purchase and design of processing equipment.

The pump unit consists of a slurry pump (mono pump of peristaltic pump) with a hopper, a hose system for air and slurry feed and spray gun. The output of the pump can be adjusted with a variable-speed control. The spray gun is constructed with a concentric spray head, so that the slurry is sprayed onto the mold around a stream of pneumatically directed chopped glass fiber. The slurry is atomized with air. The gun contains a glass chopper with an air motor to chop the glass fiber roving, with potential for adjusting the fiber length. The pump unit has a variable capacity of 0-20 1 slurry/min. Outputs of 3-6 1/min are practical.

So that the operator is not loaded down with the weight of the hoses and the spray gun itself, a movable boom supports the equipment with balancer for the gun. At the same time, the glass roving is transported along the boom to the chopper of the spray gun. A compressor, with a capacity of 2000 liters/min at 7 bars, is required for the airflow to drive the glass chopper and atomize the slurry. Depending on the requested finish, a thin “mist coat” without glass fiber can be sprayed first into the mold to obtain a smooth surface and to form a covering layer for the fiber. The operator should spray the material perpendicularly across the mold. Next, a thin glass fiber layer is applied over the mist coat and rolled in to ensure that the fiber remains as close to the surface as possible.

Next the build up of the backing Forton MG layer can be started. Depending on the mold shape, complexity and the required element thickness, 1 to 4 mm Forton slurry mixed with glass fiber is sprayed on. A regular spraying pattern will help to obtain a uniform product thickness.

The freshly sprayed Forton MG is compacted by rolling, the most important function of which is to force out air voids between the mold and the MG and in the composition itself. Roller-compaction ensures conformity with the mold face, impregnation of the glass fiber by the slurry, removal of entrapped air and development of adequate density. The rolled surface may be trowel led smooth after the piece is checked for thickness.

Rollers should be regularly rinsed in water. Spraying and rolling is repeated until the required thickness is achieved. Equipment should be cleaned regularly and free of material build up. Dirty tools should not be left in water, as Forton MG will harden under water.

Thickness control is achieved by the use of depth screeds, pin gauges and profile forms. The properties obtained can be equal to those obtained using the lay-up method, depending on the craftsmanship of the laborer.

6.4.2. Lay-up

With the lay-up method, layers of glass fiber mats are embedded in the matrix. The general procedure is to first apply a thin matrix layer to the mold, lay the mat in and impregnate it with matrix by means of a roller, then apply another matrix layer, and so forth.

Roller compaction is employed after each layer to ensure wet through of the fiber by the slurry, removal of entrapped air and development of adequate density.

To obtain a homogeneous laminate the slurry is not applied in 4-6 equal parts, but in a decreasing amount. For instance, a 4 layer panel is manufactured by adding 40% of the total slurry in the first layer, 30% in the second, 20% in the third and 10% in the fourth layer.

6.4.3. Premix

All premix processes involve the blending together of the Forton MG plaster slurry and chopped strands of "E" glass fiber in a mixer prior to casting.
To produce a premix of the correct quality it is necessary to mix in two steps. The first step is designed to produce high quality slurry to achieve the necessary fluidity and to allow for uniform incorporation of glass fiber. The second step is blending of fibers into the slurry (with low mixing energy). It is more convenient to carry out both steps in the same piece of equipment, but

separate mixers can be used for each step. For perfect void free parts an accelerated face mix should be applied to the mould. When the face mix is firm to the touch the back up mix with glass fibers can be applied.

6.5 Molds

There is a very wide range of materials suitable for molds. The choice will depend on the shape and nature of the Forton MG product required, rigidity, the number of times the mold has to be used, cost, and other factors. The following materials are suitable:

-Glass Fiber Reinforced Cement
-Modified Glass Fiber Reinforced Gypsum
-Steel
-Phenol resin laminated plywood
-Coated plywood
-Glass fiber reinforced polyester
-Elastomeric mold materials, such as latex, silicone, urethane.

Molds should be rigid under their own weight but also together with the weight of the product. They should have round corners with a minimum radius of 1 cm (0.4 in). Raised edges should form an angle of 95° with the horizontal to enable removal. If vertical surfaces are required, it should be possible to take out parts of the mold.

Incorporation of vent holes and pressure points facilitate removal and increase mold service life. Unlike cement based materials, gypsum based materials tend to expand due to hydration. The amount of expansion depends on gypsum type used, the amount of glass fibers, the use of aggregates, etc. Care should be taken when complex forms are used. In this case the use of non-expanding gypsum is advised.

6.6 Curing

The hydration of a-hemi hydrate plasters proceeds relatively fast and generally is not much affected by the ambient temperature.
After hydration the MG product needs further drying to obtain the required properties. Indeed of drying strongly depends on the drying temperature. Good water-absorption characteristics are obtained, when the product is cured for 1 day at 30°C (87°F) within 2 days after fabrication. This improves the weather resistance of the Forton MG significantly.

The plaster setting and resin cross-linking process takes place within the first 60 minutes of mixing the materials. During this period the slight expansion of the setting material takes place (depending on gypsum type) and the majority of the water in the mix is taken up. The setting resins form a skin on the surface hindering moisture loss from the wet mix, ensuring that sufficient water is retained to fully hydrate the plaster. Usually, demolding of the product can be carried out within 120 minutes after mixing. The use of accelerators can reduce this time.

Forton MG products should be stored inside to allow thorough drying before being taken to open yard storage. The drying time will depend on the ambient temperature and relative humidity of the inside storage phase. It is essential to allow the fresh panels to dry for at least one week (this depends on the drying temperature). No further curing or protection for the Forton MG product is necessary.

6.7. Transport

Lifting equipment may be necessary for the removal of larger-size panels from the mold. Also, after demolding in-plant transport facilities may be required (trucks, etc.). When loading for transport to the building site, direct contact of the MG with iron chains, etc., should be avoided. Forton MG products should be kept free of one another during transport; this can be done using rubber or plastic sheeting. The same applies to unloading on the site and to erection. Forton MG products should be stored properly on the jobsite, for instance under cover, protected and out of standing water until erected.

7. QUALITY CONTROL

7.1. Introduction

As with all production, quality control is of vital importance for Forton MG products. If production methods are employed in which operator skill is of major importance, as in spray-up and to a lesser extent in lay-up, quality control should receive extra emphasis.

The methods described for determining the properties of Forton MG as a material in both its uncured and cured stages are primarily for quality control purposes.
Quality control should cover raw materials, matrix workability, demolded product and finished product. All data and other specific information should be carefully recorded.
The recommended testing and controlling procedures described follow closely the accepted practice for determining properties of glass fiber reinforced cement material and are for a large part supported by a Dutch Stupre’ committee. However, also other test methods are useful as long as a quality MG product is obtained.

7.2. Documentation

Every spray-up or lay-up product should be provided with its date of production, the name of the operator and reference to test data.
All the information collected should be kept for the length of the guarantee period, with a minimum of 2 years.

A daily report must be drawn up with a statement of the quality control elements, the noted deviations or remarks and the executed and quality control adjustments or repairs. These reports must be kept in a special register.

7.3. Raw materials

7.3.1. Gypsum

Supplier's specifications are adequate, accompanied by written conformation form Forton that the material concerned may be used for Forton MG.

7.3.2. Forton VF812 compound

The specifications supplied by Forton are adequate.

7.3.3. Hardener and catalyst

Supplier's specifications are adequate, accompanied by written conformation from Forton that the material concerned may be used for Forton MG.

7.3.4. Glass fiber

Supplier's specifications are adequate, accompanied by written conformation from Forton that the material concerned may be used for Forton MG.

7.3.5. Admixtures, fillers, pigments, release agents

Suppliers' specifications are adequate, accompanied by written conformation from Forton that the material concerned may be used for Forton MG.

7.4. Control of the basic properties of the material before production

7.4.1. General

The following control tests are to be carried out before actual production-starts.

-Workability	(appendix A)
-Density of the slurry	(appendix B)
-Setting time	(appendix C)
-Bending strength	(appendix D)
-Expansion (optional)	(rate of expansion of gypsum can be supplied by the gypsum supplier)

If it is the first time that Forton MG products are to be made, test production should be started at least 2 weeks before the actual production starts, while a quality control program can start immediately. If material testing starts only with the beginning of the production run, several weeks production loss could possibly result. The test production should include a testing program in order to check if the MG meets the requirements. MG cured for at least 1 week as is indicated in section 6.6 can be regarded as giving a good indication of its bending strength.

7.4.2. Spray-up

It is of major importance to quantify the slurry output and to adjust the glass fiber output to this (appendix E, respectively F).
In addition to the glass fiber output, the glass fiber length must also be checked.

These tests should be carried out at the start of every production shift and also before work is restarted after major cleaning sessions.

7.4.3. Lay-up

For the lay-up method it is essentially to determine the amount of layers, which must be used to give the required thickness of the total MG-layer. The total slurry can be calculated using the amount of layers, the glass fiber mat type (gr/m²) and the glass fiber percentage required. The homogeneity of the glass fiber distribution over the total thickness of the MG-layer has to be checked before production.

7.5. Quality control during manufacturing

During the production process, the following quality control tests are to be systematically carried out.
If, because of a defect readjustments have to be made, an additional testing program must be carried out.
Tests to be carried out on the green product:
-Determination of the glass fiber content (of test board, see appendix G)
-Determination of the glass fiber distribution (of test board, see appendix G)
-Thickness (of product).

When producing by the spray-up and lay-up methods, special attention must be paid to achieve the proper thickness. It is absolutely essential that the thickness produced be accurately measured. It can easily be checked with a pair of calipers or a penetration thickness meter. Since the MG layer produced is relatively thin; i.e. 5 to 7 mm, an accurate measurement of the thickness of the MG layer applied is essential; 6 measurements per m², with a minimum of 8 per product are sufficient. The minimum measured thickness should correspond with the specified value at each point. Special attention should be paid to corners, anchoring points, etc.

7.6. Quality control of the properties of the cured product

7.6.1. Test board

Simultaneously with the production process test boards with minimum dimensions of 0.8 x 0.8 m² (30 x 30 in²) are to be manufactured, with a minimum frequency of 1-test boards per production team per day. Because of edge effects material from 50 mm from the edge of the test boards should not be used for quality control measurements. If because of a defect readjustments have to be made, an additional test board must be manufactured.

This test board is used to determine the bending characteristics of the product, together with the properties mentioned in paragraph 7.4. with a minimum frequency of
-1 test series (6 samples) per 500 m² (50 sq. ft.) sheet production
-3 test series per week

The quality control tests after curing include the bending test at 7 days age (optional), bending tests at 14 days age (obligatory) and the mass by volume. Appendix D gives a complete bending test procedure.

7.6.2. Finished end product

The first production element must be completely re-measured for dimensional deviations, flatness and warp; random testing controls the following elements.

All elements must be visually inspected for:
-Damage
-Surface quality
-Color and texture deviations

Finally all elements must be marked with the following data:
-Works and/or purpose of the element (via code)
-Mark number of panel
-Date of manufacture
-Weight

7.7. Quality control of the mold

When a new mold is put into production, measurements must be carried out on the dimensions, warp, square ness, flatness and quality of the finish. Tolerances should be established in the projects specifications.

A quality control report must be kept in a separate register.

During production a daily visual inspection must be carried out on the condition of the mold.

8. HEALTH SAFETY DATA

Forton MG composition when compared with reinforced plastics and asbestos cement can be regarded as non-hazardous for human health. However, certain precautions have to be taken into account when the Forton MG composition is used.

Forton therefore advises with respect to health and environmental considerations to take cognizance of the specific safety date sheet of the Forton MG raw materials as supplied by the manufactured of distributor.

The safety data sheet of Forton Compound VF812 is provided in annex H.

Annex A. WORKABILITY

The method described below can be used to test mixes for their suitability for spray-up or lay-up. The method is derived from the slump test applied in concrete technology. The required apparatus consists of a flat Perspex plate and an open Perspex cylinder (for dimensions, see table A1). The Perspex plate is provided with 9 circles numbered 0-8.

The cylinder is positioned on the base plate, with the outside diameter coinciding with the smallest circle. The apparatus should be clean and dry, and should be set up on a stable, horizontal surface.

The cylinder is carefully filled with the matrix using a trowel, with which entrained air voids are also carefully stirred out. The upper surface of the matrix should be smoothed off.

In a slow, uniform motion, the cylinder is then raised from the plate, and the matrix allowed slumping. After about 30 sec., the number of the circle reached by the front edge of the flow is noted. The matrix can be returned to the mixer or hopper.

The test is repeated three times in 15 minutes. Results may not deviate by more than one circle. Mixes with a plasticity of between 6 and 8 (scale circles) are in general workable. Optimum workability is determined by the mixing and pumping equipment and also by the operator. The slump test needs only be carried out once for each mix.

Table A1. Equipment slump test.

Flat Perspex base plate: 300 x 300 x 10mm	
Circles: No	Diameter (mm)
0	65
1	85

2	105
3	125
4	145
5	165
6	185
7	205
8	225

Perspex cylinder	inside diameter	: 57 mm
	outside diameter	: 65 mm
	height	: 55 mm

Annex B. DENSITY OF THE SLURRY

Fill a measuring glass with content of 100 cc with mortar until it is completely filled. Smooth of the upper surface of the slurry. Weigh the measuring glass with content (m^2) with an accuracy of 0.1 gram.

The weight of the empty glass is m_1, and the weight of the glass entirely filled with water is m_3.

The density p, of the slurry is calculated as follows:

$$P\ slurry = \frac{m_2 - m_1}{m_3 - m_1}$$

Annex C. SETTING TIME

A relatively simple test to determine the setting time of the slurry can be performed directly after the workability test using the slurry slice formed by the slump test. The setting time is reached when a cut made by a knife with a blade length of approximately 100 mm, a blade height of approximately 16 mm and a blade thickness of 1 to 1,5 mm, no longer unite at the edges. The knife has to be cleaned and dried after each cut.

This tests need only be carried out once for each mix, except when plant conditions, especially temperature, changes significantly (i.e. more than 5°C)

Annex D. BENDING STRENGTH

D.1. GENERAL

Although direct tensile street-strain curves provide a better means of studying the behaviors of the loaded material than bending stress-deflection curves, the latter is advised for its practicability. A 4-point-loading bending test has been chosen.

The test method is described for the execution of bending tests on test pieces made of MG and it is indicated how they are determined from the measurement results of the following properties:
- Bending strength (MOR)
- Fracture strain ($\in_{fracture}$)
- Limit of proportionality (LOP/yield)
- Modulus of Elasticity (E-modulus)

The purpose of the bending test is to investigate whether the material produced satisfies design specifications. The ultimate bending strength (MOR) is employed in the design calculations. If the measured bending strength is below the design value, either the design will have to be adapted to these values or production critically followed. In the first case, the production thickness will often have to be increased.

D.2. PRINCIPLE OF THE TEST

A prismatic test piece is subjected to a four-point bending test with uniformly increasing deformation in time. By measurement of the force necessary for this, a diagram is established between deflection and force.

D.3. TEST PIECES

D.3.1. Number of test pieces

The bending test is carried out on series of at lease 6 test pieces, 3 with the molding side in the tensile zone and 3 with the molding side in the compression zone.

D.3.2. Dimensions of the test pieces

The dimensions of the test pieces are stated below (length x width x thickness).

- 160 mm x 50 mm (tolerance $\pm$ 1 mm) x $\leq$ 6.7 mm.

D.3.3. Manufacture and storage of the test pieces

The manufacture and storage of the test pieces takes place under the same conditions as the normal product. When reproducing the test results the age and the storage method must always be indicated. Also has to be indicated the moisture content of the test pieces when tested (drying at 40°C until constant weight).

D.4 APPARATUS

The bending test must be carried out on a universal test machine with the following characteristics:

- Constant deformation speed: 2.0 mm/min
- Measurement accuracy: 2.0 N
- Paper speed: the paper speed for measurement of the diagram must be adjustable to the deformation speed of the test machine
- Dimensions and support distances for the bending test: see figure D1

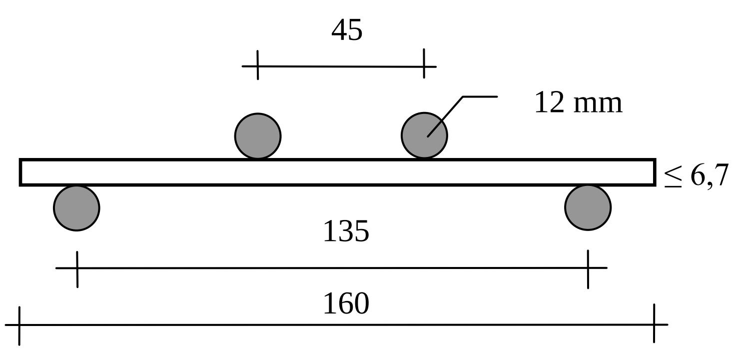

Figure D1. Dimensions and support distances for the bending test.
-sliding gauge with an accuracy of 0.05 mm

D.5. EXECUTION OF THE TEST

The bending test is carried out for three samples with the molding side of the test piece in the tensition and for three samples with the molding side in the compression. The deformation speed is constant during the complete test:
2.0 mm/min ± 10%

At the location of the support rollers the test piece must be completely flat. The increase in the load is measured on an x-y writer whose paper speed is set at a value such that an easily readable diagram is obtained.

The inclination ø in respect to this time-axis (= deflection registration) must lay between 55° and 75°(Rilem 49 TFR, 1984).

It is clear that the smaller inclination (greater speed of the paper) a better accuracy for reading is, but a lot of paper is expensive. Higher that 70° seems that the reading of the LOP value is not sufficient. Although the survey of the result is limited, after measurement of the LOP, to economize paper in width and length the load-scale and the time-scale can be reduced.

The thickness and the width of the broken test pieces are measured in the fracture surface to 0.05 mm. For the thickness the average of 3 measurements is retained, attention must be paid to local bulges of the material which can falsify the measurements.

D.6. REPRODUCTION OF THE TEST RESULTS

On the basis of the bending stress-deflection curve reproduced in figure D2 the symbols used are explained.

Bending stress at the limit of proportionality, Lop/yield

$$oLOP = \frac{PeL}{bd^2}$$ (N/mm², express up to 0.1 N/mm accurately)

in which: Pe = the stress at the point after which the curve no longer runs linearly (N)
L = support distance = 135 mm
b = the width (mm) of the test piece
d = the average thickness (mm) of the test piece in the fracture surface

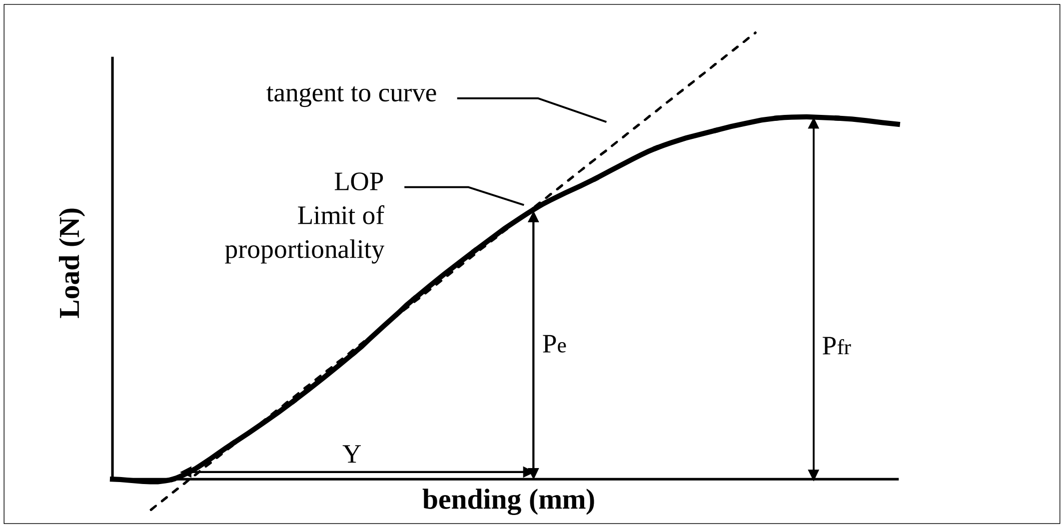

Figure D2. Bending stress – deflection curve.

The bending strength, MOR

$$oMOR = \frac{P_{fr} \bullet L}{b \bullet d^2}$$ (N/mm², express up to 0.1 N/mm² accurately)

in which: P_{fr} = the maximum load at fracture (N)

The modulus of elasticity, E-modulus

$$E\ modulus = \frac{0.185 \bullet P_e \bullet L^3}{b \bullet d^3 \bullet Y} \times \frac{V_{paper}}{V_{machine}}$$

The ultimate strain ε fracture

$$\varepsilon\ \text{fracture} = \frac{Y\ \text{fracture} \bullet d}{0.185 \bullet L^2} \times \frac{V\text{machine}}{V\text{paper}}$$

(%, express up to 0.1% accurately)

Annex E. SLURRY OUTPUT

Determination of the slurry output is of importance in application of such production method as spray-up and, in some cases, premixing. A slurry output test forms a central part of quality control, since the date are required to determine the right quantity of glass fiber to work with.

The test should be carried out at the start of every production shift, and also before work is restarted after major cleaning sessions.

When the pump discharge has assumed a uniform consistency, to be visually assessed, a weighed plastic bucket (W_1) is held under the discharge nozzle (turn off glass chopper). The slurry is collected in the bucket for exactly 15 seconds, and the bucket is then weighed with its contents (W_2). The slurry used can be returned to the pump hopper.

The output is calculated as follows:

Slurry output (g/min) = $4 (W_2 - W_1)$
The test measurement is repeated 3 times, and the average output this calculated.

Annex F. GLASS FIBRE OUTPUT AND FRACTION

The glass fiber output should be determined if the spray-up method is used. The test can be carried out jointly with slurry output determination (Appendix F). A weighed plastic sack (W_1) is held over the glass fiber pistol nozzle for 15 seconds and the fiber collected. A vent opening should be made to allow the air to escape. The sack plus contents is then weighed (W_2) and the glass fiber output determined from the following expression:

Glass Fiber output (g/min) = $4 (W_2 – W_1)$

The measurement is repeated three times and the average output thus determined. The required glass fiber fraction is calculated from the following expression:

$$\text{Glass fiber fraction (\% m/m)} = \frac{\text{Glass fiber output}}{\text{Slurry output} + \text{glass fiber output}}$$

If the measured fiber fraction deviates from that required, appropriate adjustments should of course be made.

Annex G. GLASS FIBRE FRACTION AND DISTRIBUTION

Even if the output of slurry and glass fiber have been properly set before starting spray-up, the glass fiber fraction may still be locally lower than the specified value, and there will thus be a spread in the glass fiber over the surface. Even with well-trained operators, such spread should be reckoned with. To obtain an impression of whether the specified quantity of fiber is present and how the fiber is distributed over the product, the panels should be made during production. These panels should measure approx. 800 mm x 800 mm and be produced in an identical manner to the main product run. The thickness should be the same as the thickness of the actual product. (without surface layer).

At least one test panel should be prepared for each spray unit, shift, operator and mix, preferable at the start of a production run.

If the matrix composition or the glass fiber fractions are altered, the test should be repeated.

From the fresh test panels, three test specimens measuring 150 x 50 mm are cut, using a Stanley knife, roughly as indicated in Fig. F1.

The glass fiber fraction of these specimens is then determined by the following “rinse-out” method. The specimen is placed in a dried and weighed screen tray (W_1). This tray should be made of perforated stainless steel with a mesh width of 3 mm, and should measure 175 mm long, 100 mm wide and 25 mm deep.

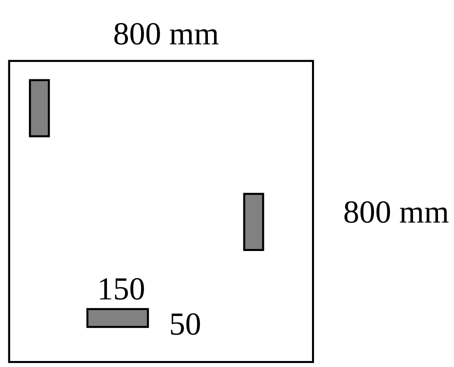

Fig. G1. Test panel, showing specimens.

The screen tray with specimen is weighed (W_2). The slurry is then washed with running water, the material being carefully crumbled by hand to accelerate the rinsing process. Special care should be taken to avoid loss of glass fiber (as a result of breakage, for instance).

After rinsing, the screen plus contents are dried in a drying chamber at 100°C for 4 hours. The screen is then removed and weighed again after it has cooled down to room temperature (W_3).

The glass fiber fraction is then calculated as follows:

$$\text{Glass fiber fraction (\% m/m)} = \frac{W_3 - W_1}{W_2 - W_1} \times 100\%$$

From the three measured values, the variation coefficient is determined. All measured glass fiber fraction should be greater then the specified value. A variation coefficient of between 0 and 10% indicates an acceptable distribution.

This rinsing method can also be used to assess the glass fiber fraction for the premix method.

With glass mat lay-up, where distribution is much less operator-dependent, it is sufficient to take a single test panel at the beginning of the working week. In this case, proper distribution of the glass mats through the thickness of the product is of particular importance.

Annex H. SAFETY DATA SHEET

MATERIAL SAFETY DATA SHEET
(including EEC-directives)

PRODUCT DATE

Trade name	Forton VF 812	
Chemical name		% WT
Of solid	Self-cross linking acrylic copolymer dispersion	50
Chemical name		
Of solvent (s)		
Other(s)	Water	5

HAZARDOUS INGREDIENTS

Chemical name	Cas No.	EEC 67/548 No.	82/473 Class p.p.m.	TLV (ACGIH) mg/m³	% WT

TRANSPORT CLASSIFICATION

ADR	class	figure	N.A.
IMCO	class	page	
UN No.			

LABELING-REGULATIONS OF THE PRODUCT

Classif. Content	R-phrases:	
	S-phrases:	
Symbol:	P-phrases:	N.A.

REACTIVITY DATA

Hazardous reactions:

None

FIRE AND EXPLOSION HAZARD DATA

Flashpoint, °C (ISO 1523): N.A.

Explosive limits in air: lower level upper level

Material % vol %vol

Auto ignition temperature: N.A.

Extinguishing media: x sand x non-combustible

Protective equipment: x self-contained breathing apparatus

-other

Hazardous thermal
Decomposition products: Noxious fumes

HEALTH HAZARD DATA

Effects of overexposure:

- Inhalation headache, dizziness
- Ingestion irritation of alimentary canal
- Eyes irritation
- Skin irritation

First aid procedures:

- Inhalation remove to fresh air
- Ingestion give plenty of water to drink, get medical attention

- Eyes	immediately wash with plenty of water, at least 15 min. get medical attention
- Skin	wash thoroughly with water and soap
Contaminated Clothing:	Remove and launder before re-use

SPILL OR LEAK PROCEDURES

Corrective actions to be taken:	Confine area of spill – absorb with dry sand or other inert material – transfer to suitable container for disposal
Waste disposal method:	Controlled incineration
Empty drums disposal method:	Empty drums retain solvent vapors, hazardous in respect of fire, explosion and noxiousness - N.A. disposal only by reputated drum reconditioners

PERSONAL PROTECTION PRECAUTIONS

Respiratory protection:	Avoid inhalation of vapors, use adequate respiratory equipment
Eye/face protection:	Safety eye wear against: splash
Skin protection:	Wear rubber or synthetic gloves. Prevent contact with contaminated clothing
Other protection:	

STORAGE AND HANDLING PRECAUTIONS

Area:	Indoor/outdoor, preferably between 5-25°C. Direct sunshine should be avoided. Keep from freezing.
Ventilation and Exhaust systems:	Have sufficient ventilation
Washing facilities:	Adequate washing facilities and emergency eye washing Equipment – skin cleansers available
Dust:	Dust/air mixtures constitute a fire and explosion hazard N.A. Prevent accumulation of dust
Empty drums:	See section 7

PHYSICAL DATA

Product Name	Forton VF 812
Solubility in water 20°C, % by WT	dilutable
Acidity (pH)	4.5 – 5.0
Appearance, color index ASTM D 1544-68	milky-white
Boiling point at 101.3 kPa, °C	approx. 100

Volatiles, % by WT	50
Viscosity at 23°C, mPa.s	200-450
Density at 20°C, kg/m³	approx. 1070
Odor	mild odor
Vapor pressure at 20°C, kPa	--
Melting range, °C	--
Glass transition temp., °C	--

DC = 001
Date December 19, 1988
N.A. = Not Applicable

Information provided by:

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