Pultruded glass fibre reinforced plastic profiles

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Pultruded Glass Fibre Reinforced Plastic Profiles

Profils pultrudés en composites fibres de verres

Glasfaserbewehrte Plastikprofile

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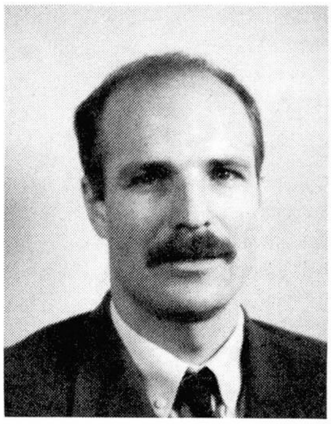

SUMMARY

In an electrolysis hall, the atmosphere is heavily loaded with sulphuric acid vapours. For that reason, the roof supporting structure consists of pultruded glass fibre reinforced plastic profiles. A three-dimensional framework, of which the profiles are glued together, is constructed. Composites have advantages over conventional materials, such as their high chemical resistance, their high specific stiffness and their high specific strength.

RÉSUMÉ

Dans un atelier où l'on pratique l'électrolyse, l'atmosphère est fort chargée par des vapeurs sulfuriques. Dès lors, la charpente est réalisée au moyen de profilés en matière plastique pultrudés et renforcés de fibres de verre. Les profilés sont collés les uns contre les autres dans un treillis spatial. Par rapport aux matériaux conventionnels, les composites offrent l'avantage d'une bonne résistance chimique, d'une grande rigidité spécifique et d'une parfaite solidité spécifique.

ZUSAMMENFASSUNG

Die Tragstruktur des Daches einer Elektrolysenhalle, deren Atmosphäre stark mit Schwefelsäuredämpfen angereichert ist, wird aus glasfaserverstärkten Kunststoffprofilen hergestellt. Ein räumliches Fachwerk, dessen Profile aneinandergeklebt sind, wurde entworfen. Verbundstoffe haben Vorteile gegenüber herkömmlichen Werkstoffen dank ihres guten chemischen Widerstandes, ihrer hohen spezifischen Steifigkeit und ihrer hohen spezifischen Festigkeit.

1. INTRODUCTION

To renovate the roof supporting structure of the electrolysis hall wind tunnel of an important zinc-works, the authorized departments opted for a supporting structure made of pultruded glass fibre reinforced plastic profiles.

The atmosphere in these electrolysis halls is heavily loaded with sulphuric acid vapours. That is why the existing reinforced concrete structure resulted inappropriate. The formation of etringite caused the reinforced concrete structure to crumble quite rapidly, so that a new structure was required.

In order to withstand this highly corrosive atmosphere, we have designed a GRP profile braced frame structure.

2. MATERIALS

2.1. Reinforcement

Glass fibres are used in a variety of forms as reinforcement in plastics. The forms of reinforcement and their positions are defined by the method of production of the final product, the properties required and the cost.
Compared to steel, glass fibres have a low stiffness modulus and a high tensile strength (see Table 1).

material	specific gravity	ultimate tensile strength (MPa)	ultimate compressive strength (MPa)	modulus of elasticity (GPa)	Poisson's ratio
polyester resin matrix	1.1-1.4	45-65	90-130	2.5-4.0	0.3-0.4
E-glass reinforcement	2.58	3450	-	72	0.2
structural steel	7.8	400-550	-	210	0.3
struct. aluminium alloy	2.8	200-450	-	70	0.3
concrete	2.4	3	40	15-35	0.1-0.3

Table 1 Comparison of the mechanical properties of various materials

After formation of E-glass into rovings or textile fabrics and after processing these into composites, the ultimate tensile strength of the E-glass is considerably reduced. The magnitude of the reduction, which varies from fibre to fibre, depends on the voids content, the nature and degree of handling, the amount of fibre misalignment,... For the determination of the working stress, see 3.2.

In order to minimize the size of the profiles and the deflections of the structure, the frame, the roof truss and the joints are made into braced structures. Hence, the profiles are not subjected to flexural strength, but only to tensile or compressive strength. Therefore special attention has been paid to buckling and the realization of the joints.

2.2. Matrix

In order to withstand the chemical corrosion of the sulphuric acid atmosphere, all GRP profiles have a vinylester matrix.

2.3. Production technique

The profiles are fabricated by means of pultrusion. The pultrusion process is one of the techniques designed for the production of a continuous product. The process consists of impregnating continuous glass strands and glass cloth in a resin bath before drawing them through a die to obtain the desired shape of the section. Due to the continuity of the reinforcement the final products possess an exceptionally high strength in the direction of the reinforcement.

2.4. Profiles

To realize the braced structures, two different profiles are used, i.e. a boxbeam 80/43/3 and a ⊔-profile 90/30/3/5. The properties of the profiles will depend on the properties and the proportions of fibres and matrix (rule of mixture) :

$$C = C\,(E_f,\ \nu_f,\ G_f,\ V_f,\ E_m,\ \nu_m,\ G_m,\ Vm)$$

where the subscripts f and m refer to the fibres and matrix, respectively, E is Young's modulus, is Poisson's ratio, G is modulus of rigidity and V is proportion by volume in the composite. The properties of the profiles (in the longitudinal direction) are :

- Profile 80/43/3 : $E = 24$ GPa
  $\nu = 0{,}3$
  $G = 5$ GPa
- Profile 90/30/3/5 : $E = 28$ GPa
  $\nu = 0{,}3$
  $G = 5$ GPa

3. STRUCTURE

3.1. Description of the structure

The final structure has a total length of 43.40 m, a height of 5.15 m and a span of 5.65 m (see fig. 1 and fig. 2).

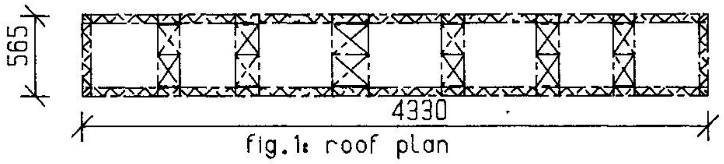

fig.1: roof plan

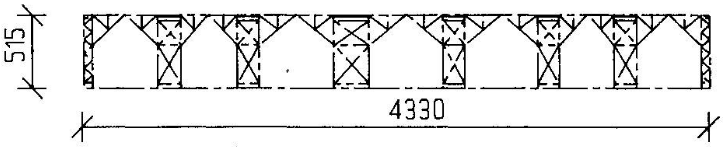

fig.2: longitudinal wall

In fact, a three dimensional trussed system is formed by two adjacent frames joined together, both in the vertical plane of the wall and the horizontal plane of the roof (see fig. 3 and fig. 4).

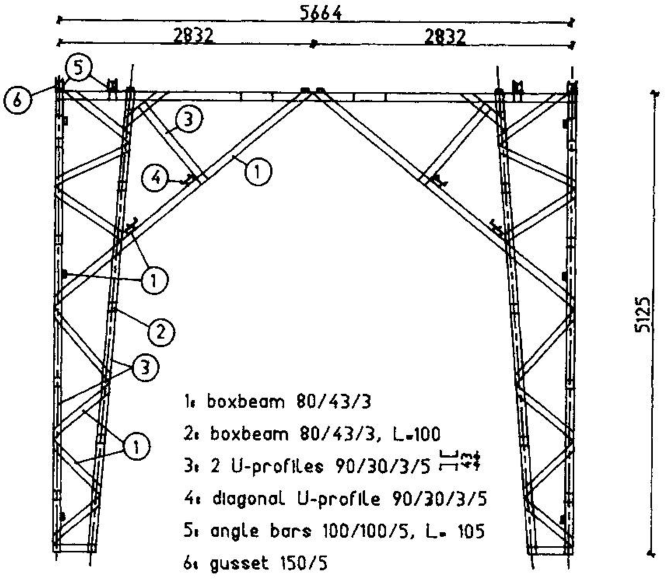

fig. 3: cross-section

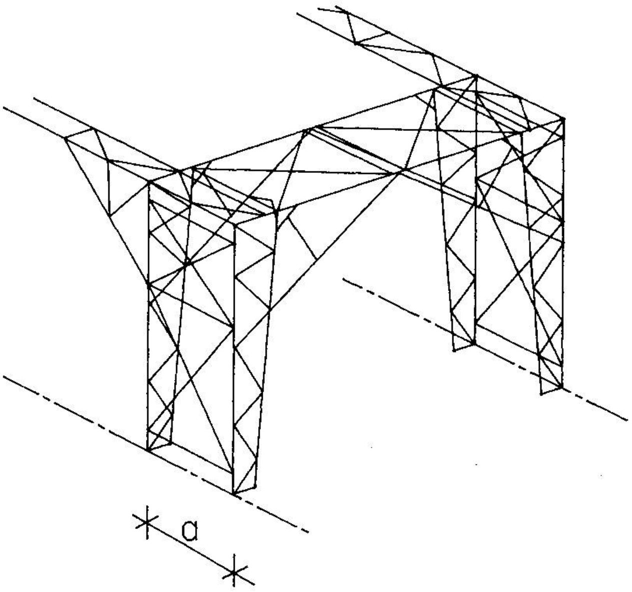

fig. 4: perspective truss

The two frames are placed at a distance "a", varying between 0.60 and 2.46 m. The frame units are placed at 6.50 m from each other. The frames are joined together in the roof plane by means of a roof truss, also braced. The frames are joined at the bottom to the existing structure by means of stainless steel elements.

3.2. Calculation of the frames

The loads working on the frames include the self-weight, the fixed loads of wall and roof covering, the snow loads and wind loads. All affecting loads were increased with a "load factor" of 1.5. With respect to GRP profiles, the average strain at rupture is assumed to be 1.5 % (short-term properties).

When a unidirectional glass fibre reinforced composite is subjected to compression in the direction of the reinforcement, the failure load appears to be controlled by buckling of the fibres. From the theoretical point of view, the ultimate compressive strength X_c is given by

$$X_c = \frac{G_m}{1 - V_f}$$

for values of $V_f > 0.2$
where G_m is the modulus of rigidity of the matrix and V_f is the proportion of the fibres by volume in the composite.
The experimental values of X_c tend to be much lower than those predicted by the analysis described in theoretical works. Failure occurs at a strain of approximately 1.2 %.

This failure strain value for tensile and compression leads to a varying ultimate stress according to the properties (E moduli) of the profiles concerned. In order to determine the working stress, a safety coefficient = 4 on this ultimate stress is taken into account. This safety coefficient covers the long-term failure behaviour.

Results from literature suggest that over a period of 50 years a unidirectionally continuously reinforced composite containing a reasonably high percentage of fibres may lose approximately 40 % of its short term stiffness. After a period of 30 years, the strength of glass-reinforced composites will be reduced to about 50 % of the short term strength. However, composites containing a high percentage of UD (= unidirectional) continuous reinforcement and loaded in the direction of the fibres may show rather more favourable characteristics.

3.3. Assembly of the structure

For GRP, adhesive joints are normally used because bolted joints can shear out under load.

The profiles are joined together by means of epoxy adhesive and stainless steel rivets. These rivets are mainly used to obtain a certain pressure during glueing; this results in a perfect adhesive joint.

Several kinds of joints are applied (see fig. 5). In order to resist great tensile forces, the area of adhesion can be considerably increased as in fig. 5b en c.

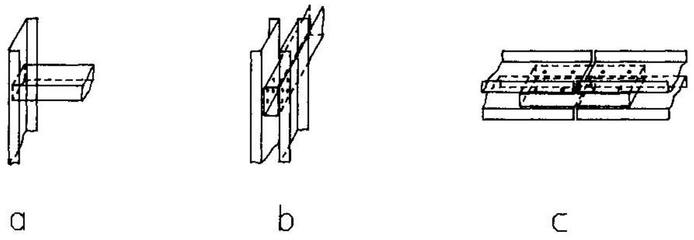

fig. 5: joints

The length of the joints is calculated assuming that the adhesive has a shear strength τ_{au}. Thus, for sheets of thickness t, and a joint length of L_j, the single lap joint can transmit a stress σ_{ju} where

$$\sigma_{ju} = L_j \cdot \tau_{au} / t$$

Most of the joints are factory made. So, we can immediately reckon upon its strength and we have a better quality control of the joints. A few of them are site made.

4. CONCLUSION

This realization opens new perspectives for the application of GRP structures in chemical industry; especially, in structures with considerable spans at little loads.

These profiles have some major advantages, thanks to their high chemical resistance, their high specific stiffness (EI/γ) and their high specific strength (σ_{fr}/γ), with a very low specific gravity γ.

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