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Autor: Gerritse, Arie / Werner, Jürgen / Groenewegen, Leon
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Long-Term Properties of Arapree

Comportement à long terme du matériau composite arapree

Langzeiteigenschaften des Verbundwerkstoffes Arapree

Arie GERRITSE
Civil Engineer
Hollandsche Beton Groep nv.
Rijswijk, The Netherlands

Jürgen WERNER
Civil Engineer
Akzo nv.
Wuppertal, F. Rep. of Germany

Leon GROENEWEGEN
Civil Engineer
Hollandsche Beton Groep nv.
Rijswijk, The Netherlands

Arie Gerritse, born in 1929, graduated in Civil Engineering at Rotterdam Technical College, the Netherlands. He is a staff member of the R&D department of Hollandsche Beton Groep (HBG), an international contractor based in the Netherlands, supervising since 1984 the Akzo/HBG development project on the practical use of aramides in concrete.

Jürgen Werner, born in 1939, obtained his Civil Engineering degree at the Technical University of Braunschweig (Fed. Rep. of Germany) in 1966. He is an Akzo project manager in the field of application of fibre reinforced materials in civil engineering.

Leon Groenewegen, born in 1961, obtained his Civil Engineering degree at the Technical University of Delft (the Netherlands) in 1986. He is currently a research engineer at the R&D department of HBG.

SUMMARY

Arapree is a composite made up of aramide fibres and an epoxy resin. It is used as a prestressing material in concrete structures. Apart from some general information on Arapree and its short term properties, the durability aspects are discussed. The paper ends with some impressions of two projects in which Arapree has been applied.

RÉSUMÉ

L'arapree est composé de fibres d'aramide et de résine époxy. Il est utilisé comme matériau de précontrainte dans des structures en béton. Après une information générale sur l'arapree, son comportement à court el long terme est discuté. Enfin deux projets sont décrits, au cours desquels l'arapree a été employé.

ZUSAMMENFASSUNG

Arapree ist ein Verbundmaterial aus Aramidfasern und einem Epoxyharz. Es wird als Vorspannmaterial in Betonkonstruktionen gebraucht. Neben einigen allgemeinen Informationen über Arapree und seine Kurzzeiteigenschaften werden die Langzeitaspekte diskutiert. Am Schluss werden zwei Projekte besprochen, in denen Arapree angewandt wurde.

1. Introduction

In the past few years interesting developments have emerged in the field of non-metallic tensile elements. More and more successful applications of such new materials are reported [1], [2], [3], [4].
The use of these materials will become common practice to structural engineers in the near future. This development necessitates the need for reliable data for these non-metallic elements especially with respect to their long-term behaviour.
In this paper the main long-term properties of Arapree, one of these new materials, will be discussed. The phenomena associated with these properties are well known since they must also be taken into consideration for materials like steel and concrete. However, other -less familiar- characteristics, such as stress-rupture behaviour can be decisive in designing constructions with these new materials. A thorough understanding of the characteristics will be needed for structural engineers who are faced with the problem of assessing constructions in which such new materials are applied.
The products belonging to this new generation of non-metallic tensile elements are based on high strength fibres like glass, carbon and aramid. In this paper the discussion on long-term properties is limited to an overview of the most important characteristics of Arapree, a composite made up of an epoxy resin and Twaron, the aramid fibre produced by Akzo.

2. General information Arapree

Arapree is the result of an ongoing research program of the Dutch/German chemical company Akzo and the Dutch contractor HBG. Arapree is produced as endless elements composed of bundles of non-twisted Twaron-fibres.
The elements are produced by passing the fibres through eyelets and combs and subsequently impregnating the bundles with an epoxy resin. To ensure a good bond of the elements with concrete the surface of the elements is provided with a pattern of nobs.
An essential step in the production process is the impregnation of the Twaron bundles. A number of reasons have lead to the decision to impregnate the bundles with resin:

- By impregnating the bundles with an epoxy resin shear stresses fibre to fibre can and will be transmitted in the anchorage zone and in the vicinity of an incidental fibre rupture.

- Transmission of shear stresses of the bundle to the concrete regulated by tuning the surface structure.

- Handling of the elements

- Improvement of the resistance to extreme alkaline and acid environments.

- UV-protection. If applied in concrete this aspect can be neglected. Only in case of external prestressing this might be significant, but can be prevented by the use of additives to the resin deterioration.

- Optimal use of fibre strength. Thanks to the ability of the resin to transfer shear stresses the effect of fibre rupture is limited to a small area.

In table 1 the presently available types of Arapree are summarised.

TABLE 1: Available types of Arapree

Shape rectangular round	Cross-section [mm²] [mm]	Number of filaments	Fibre-cross-section [Twaron HM] [mm²]
rectangular	0,5*20	30 000	3,3
	1,4*20	100 000	11,1
	2,8*20	200 000	22,2
	5,6*20	400 000	44,4
round	2,5	20 000	2,2
	5	100 000	11,1
	7	200 000	22,2

Figure 1 shows a picture of a rectangular Arapree-strip and an Arapree-wedge anchor that is used as a temporary anchorage device. In concrete elements the prestressing force in the elements is transmitted to the concrete by bond.
In figure 2 the stress strain relation of Arapree is compared with common reinforcing and prestressing steel.

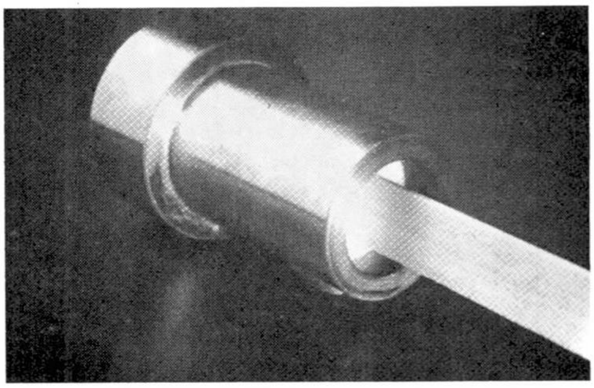

figure 1

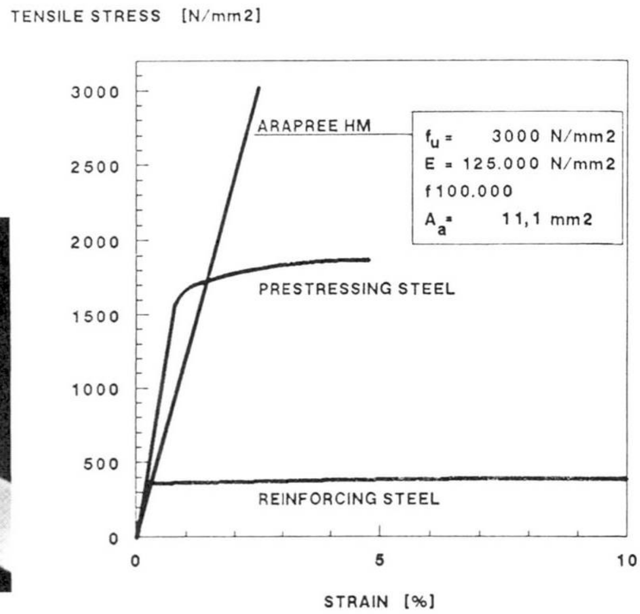

figure 2

The most significant short term mechanical properties of Arapree are given in table 2.

TABLE 2: Short-term properties of Arapree

Properties	Values	Dimension
Arapree bar-strip		
axial tensile strength	3000 (**)	N/mm² (*)
modulus of elasticity	125-130 (***)	kN/mm² (*)
failure strain	2.4	%
density	1250	kg/m³
transverse compressive strength	ca. 150	N/mm²
interlaminar shear strength	ca. 45	N/mm²
poisson ratio	0.38	-

*) Values related to the effective fibre cross-section.
**) Characteristic value: 2800 N/mm².
***) Modulus based on measurements in the range between 10 % to 50 % of the ultimate strength.

3. Durability

Apart from properties like an extremely high strength and considerably high stiffness of these new materials, the most interesting characteristics generating the interest of structural engineers have reference to the long-term behaviour.
Tensile elements based on aramid are non-corrosive, exhibit an excellent resistance to chlorides, are insensitive to electromagnetic currents and prove to have an outstanding fatigue behaviour. In case of reinforcing or prestressing steel all of these characteristics generally lead to requirements to ensure the durability. If aramid is applied there will be no need for such measures.
However, the stress-rupture behaviour and the sensitivity of glass- and - to a lesser degree - aramid fibres to an alkaline environment will give rise to new requirements. This is illustrated in figure 3.
The stress-rupture line given in figure 3 represents the relation between the stress in a tensile element and the time that passes before the material fails under a specific sustained stress-level. It is therefore a different property than the 'long-term-strength', which can be defined by the maximum constant load which can be present over a (very) long period. The long-term strength is also presented in figure 3. It can be seen that the residual strength of an unloaded strip after 100 years exposition in an alkaline environment like concrete is about 85 % of the short term strength. This value has been obtained by means of an extrapolation using the Arrhenius principle, that decribes a relation between the residual strength, temperature and time. Tests at elevated tempatures thus give indications about the residual strength level under normal circumstances.

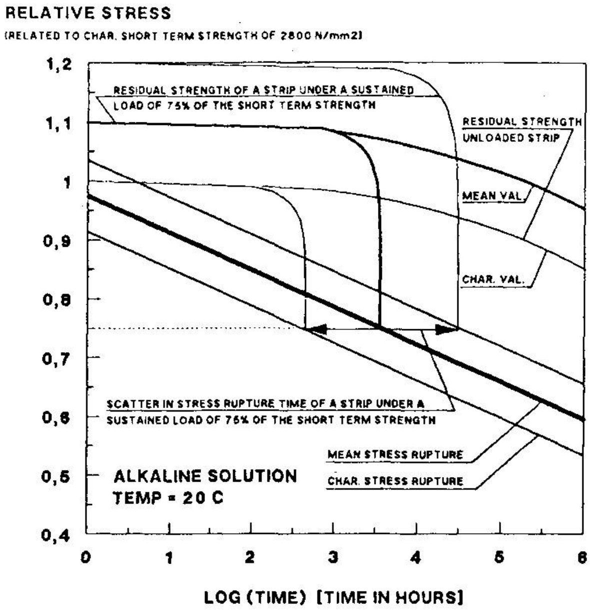

figure 3

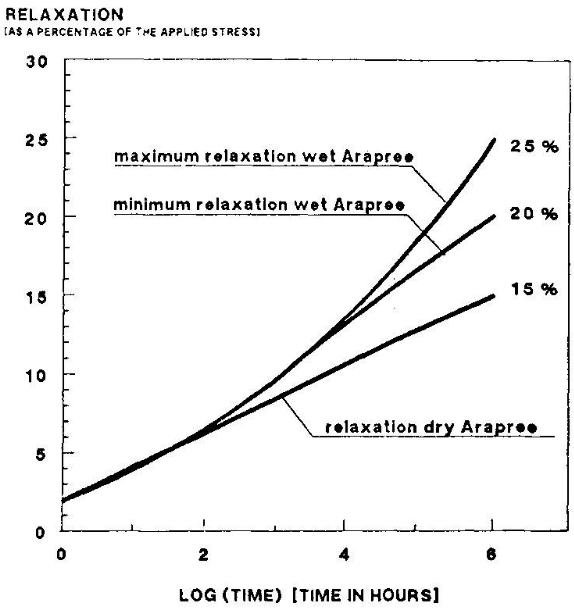

figure 4

The residual strength of a loaded strip hardly depreciates until just before stress rupture. This is illustrated in figure 3 by the residual strength of a strip to which a sustained load of 75 % of its short term strength was applied.

In assessing the structural safety one should estimate the final prestressing level, taking into account all losses caused by concrete deformations and relaxation of Arapree (figure 4). This value must be compared with the characteristic stress-rupture curve taking into consideration a partial factor for Arapree that has been set at 1.15 .
More information about Arapree is given in [5],[6].

4. Arapree in practice

Two projects have already realised in which Arapree was used as prestressing material. An impression of these projects is given in figure 5 and 6. In both cases relatively small prestressed (pretensioned) concrete elements have been produced. This first application of Arapree (1988) concerns concrete posts in a traffic noise barrier along a motorway near Rotterdam (figure 5). Ninety elements of about 4.5 m were prestressed with Arapree.
The second application of Arapree is illustrated in figure 5. Ten concrete hollow core floor slabs with a span of ca. 6 m were prestressed with Arapree (1988/1989). In both cases no additional steel reinforcement was used. The aim was to produce non-magnetic durable pretensioned elements without any steel.

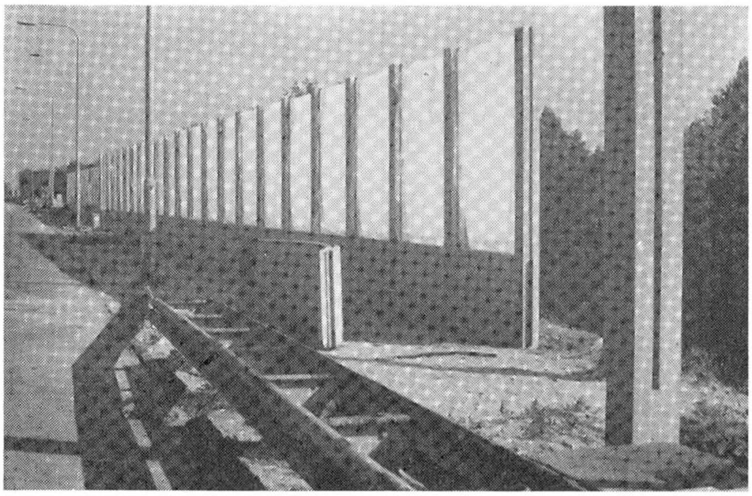

figure 5.

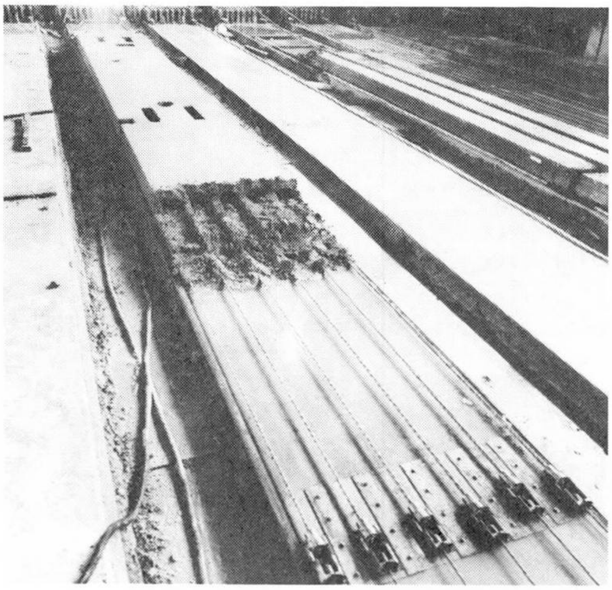

figure 6.

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