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Creating the Tensile Structure for the Berkendael European School (Brussels)

Abstract

ART & BUILD Architects & Engineers have completed the design of the refurbishment of the old Berkendael European School located in Brussels. The solution arrived at the covered playground and the entrance is a large tensile structure, which allows the creation of a visual link between the old and the new part. The project is original as it consists of an asymmetric membrane without any of the cables and anchors at the ground level which generally form part of tensile structures. These had to be avoided as they create obstacles and attract young climbers.

Introduction

ART & BUILD architects and Engineers were chosen to design the refurbishment of the original 1899 school premises and integrate new functions into the inner city school grounds. The client was the Belgian Government (Régie des Bâtiments), the structural engineer was Verdeyen and Moenaert[1], and the team of Prof. Mollaert made membrane simulations and calculations from the "Vrije Universiteit Brussel".

The new European Primary School is designed to welcome 750 pupils in the 700 m^2 refurbished existing building and new structures which include a gymnasium, kitchen and refectory and a 600 m^2 covered playground.

The existing buildings and the park are listed and an adjacent site was purchased to provide car parking and main vehicular access for both cars and servicing.

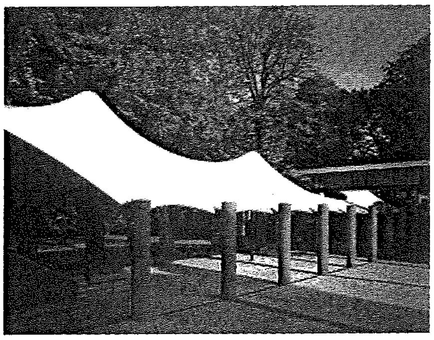

Figure 1: View of the membrane covering the playground.

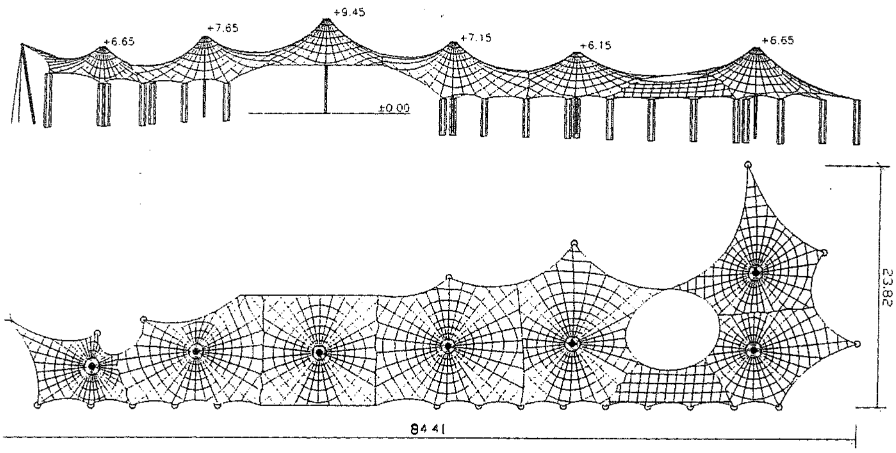

Figure 2: Plan and elevation of the textile membrane.

Design Strategies

Old and new buildings are distinct and add value to each other through the carefully studied rhythm of the openings and use of materials. The white tensile structure links both old and new and the park with its impressive trees. The large playground flows between the orthogonal buildings and random trees and is informally partly covered by the freeform (fabric) tensile structure, allowing children to play outside when it is raining. The tensile structure (figure 2) is an essential element in the composition, floating between the tall trees and flying around their trunks, it provides a canopy against rain, hail and snow, as well as shade against the sun.

The quality of the light is always appealing and the informal contour of its shadow softens the whole playground, linking hard and soft landscapes. Ease of maintenance was an issue from the start.

Compared with a glass roof involving cleaning with sophisticated ladders and catwalks, the fabric structure is relatively simple to clear, including only the use of a high pressure hose. This is of particular importance when considering the location of the structure under the dense tree canopies.

Safety in the playground including ball games and balls retrieval was also in favour of the fabric roof. Conversely, usual cables and anchors at ground level, generally associated with tensile structures, had to be avoided as they create obstacles and attract young climbers (Figure 3).

Structural Analysis

The structure consists of a pre-stressed membrane (815 m^2 of covered area for 981 m^2 of membrane) which consists of seven high point structures that are located on central columns made of tubular steel (Figure 3).

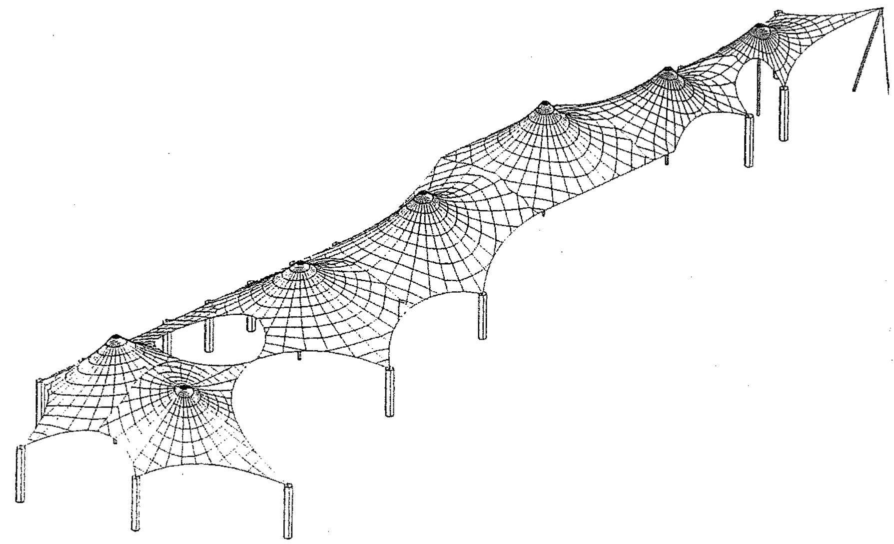

Figure 3: View of the textile membrane from below.

Estimated calculations show that these steel columns have to support a compression force of 20 to 65 kN, but the most requested steel column has to support a vertical force of 20 kN to 110 kN. All edge cables are fixed to concrete columns that act as cantilevers fixed to the ground, apart from one point at the entrance which is fixed to two foundation cables and a steel column (Figure 5). The membrane is made out of a PVC coated polyester fabric.

The problem of finding appropriate forms for stressed membrane structures can be tackled in a variety of ways. Common to all approaches is the need to ensure that the resulting surface shape is capable of withstanding the applied loading, while satisfying the constraints imposed by the architectural specifications.

The textile membrane designed by ART & BUILD (Figure 4) is totally asymmetric, which is not common for this type of construction. Due to the direct relationship between form and force distribution in membrane structures, compromises will often need to be made between what is wanted and what is structurally possible[2].

In theory, it would seem reasonable to aim at providing constant stress in the areas between the boundaries laid down by the architectural specification. Such a strategy ignores the loading conditions, which prevail, and the necessity of fabric from anisotropic textile panels. For example, radial high point structures designed using constant stress areas will suffer from large flat areas away from the central mast.

These areas will be liable to wind flutter, or even worse, pounding. The main requirement for practical form-finding systems is therefore the ability to derive smooth surfaces, which possess ample double curvature between arbitrary boundaries. It is additionally important that the surface curvature specification can be easily controlled.

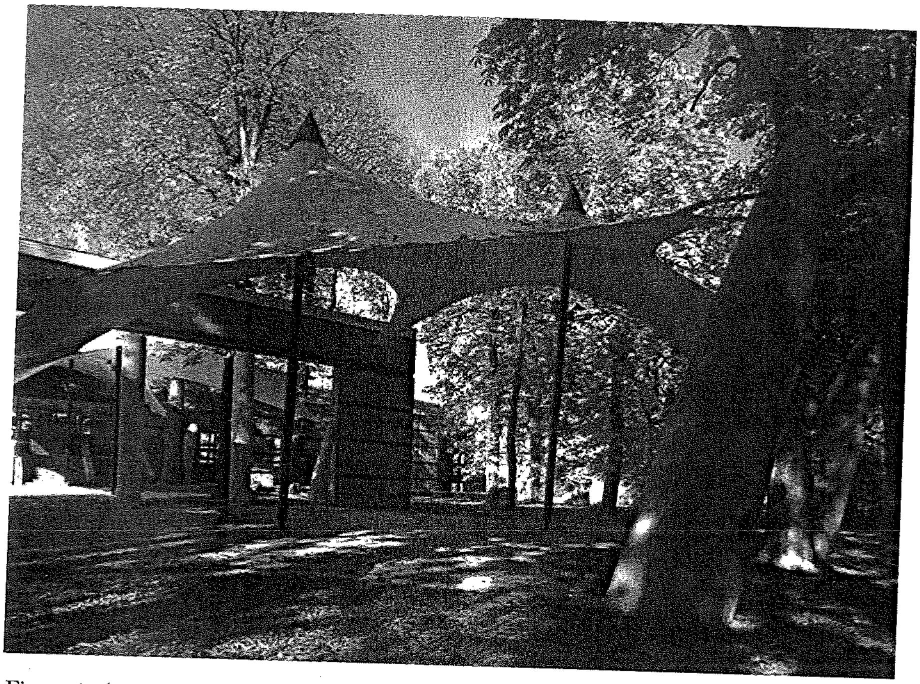

Figure 4 : Axonometric of the textile membrane.

Figure 5: View of the entrance from the car park.

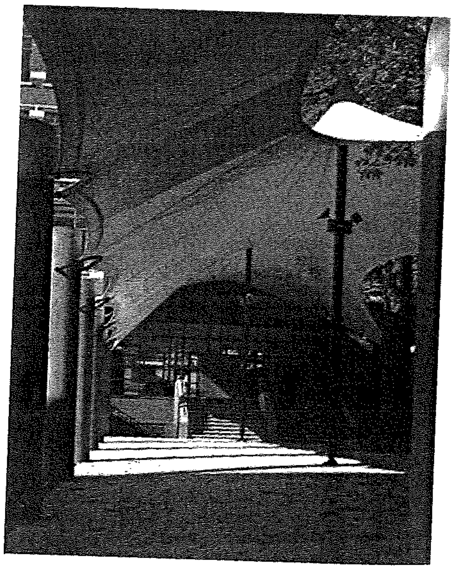

Figure 6: The textile membrane, view from the playground.

Calculations of the tensile roof were made a number of times to gradually meet design requirements and take the fixed points into account. First results showed dif-

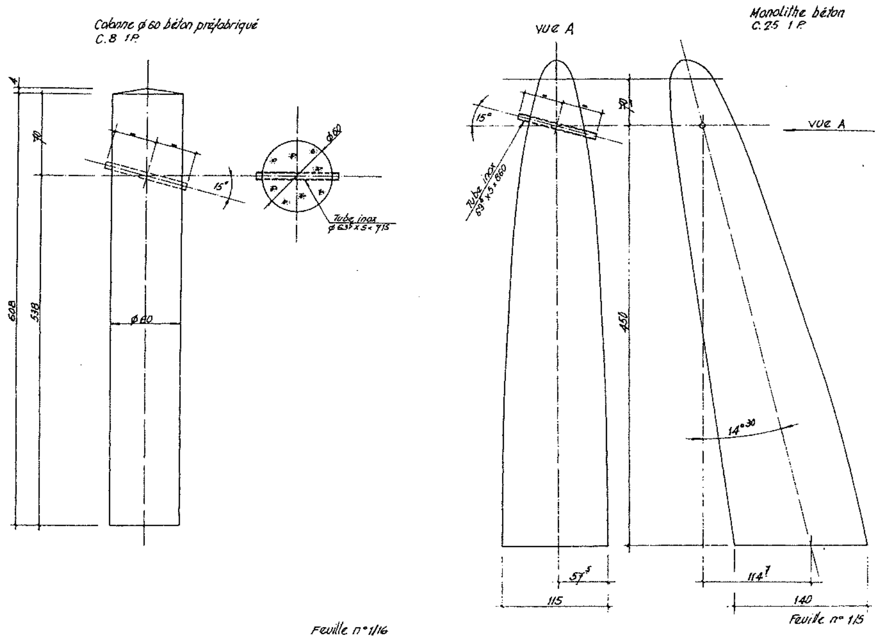

Figure 7: Typical monolithic columns.

ferent membrane shapes, which were totally different from the early architectural concept.

Lots of calculations and simulations were needed in order to obtain the architectural shape defined initially by ART & BUILD (Figure 6).

In order to stabilize the roof shape and to prevent fluttering and puncturing, the membrane is pre-stressed biaxially. The chosen pre-stressed shape also prevents a natural vibration with large amplitude through wind and serves as a vibration absorber. The pre-stress in the meridian direction at the low border of the structure is 4 kN/m and the pre-stress in the ring direction is 2 kN/m.

The weight of the membrane raw material is approximately 0.0125 kN/m^2. Inclusive all bracings the dead load is considered by Ge,k= 0.015 kN/m^2.

In order not to disturb the existing roots and branches of the large trees, it was not possible to design classical pillars and foundations in the traditional way. The final choice was a micro piling system, which supports a small concrete base with the monolithic column on top of it.

There are three micro piles per monolithic column (Figures 7 and 8). The diameter, orientation and length are a result of the direct tensile forces resulting from the textile membrane at the top of the monolithic column. Ground surveys were carried out in order to calculate the exact dimension of each micro pile (in total: 58 of 150 kN and 7 of 250 kN).

Horseshoe anchors are formed in painted galvanized steel and stainless steel wires. The connections of the textile membrane with the columns and monolithic

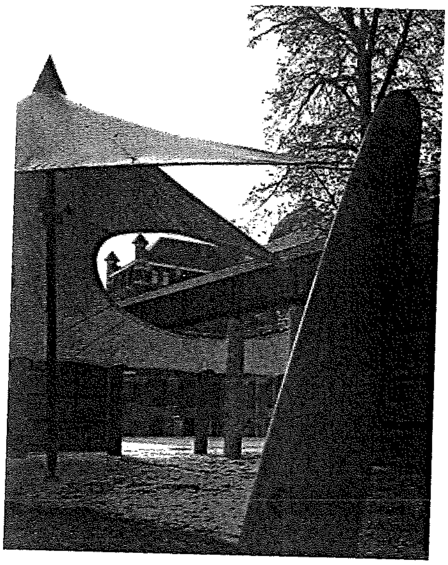

Figure 8: View of the monolithic column.

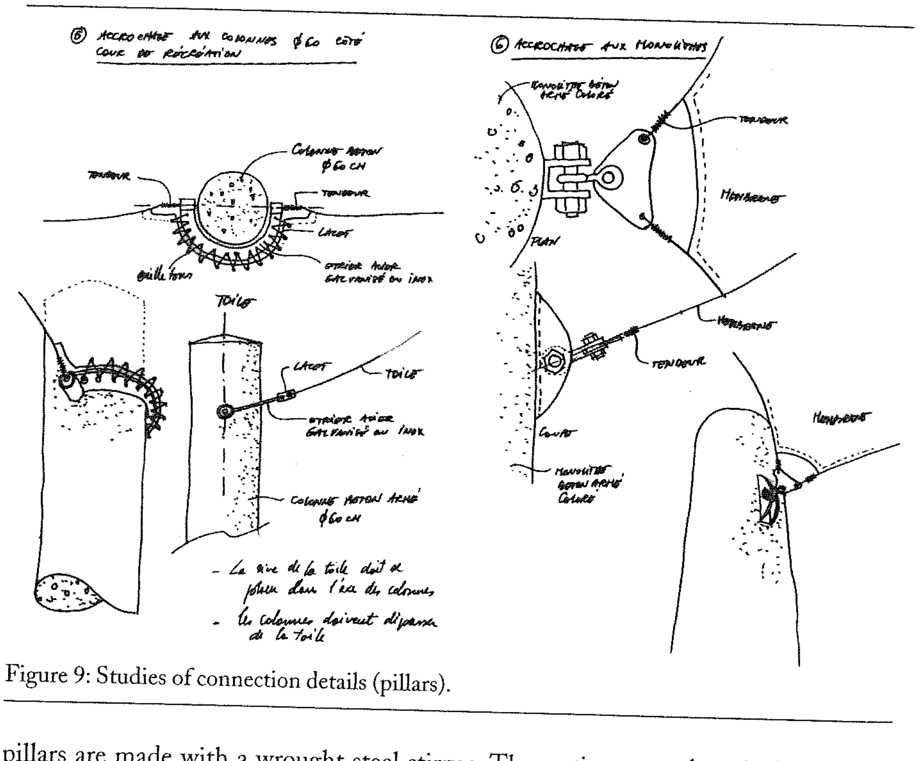

Figure 9: Studies of connection details (pillars).

pillars are made with a wrought steel stirrup. These stirrups are kept in location by axis, which cross the concrete pillar and columns (Figure 9).

The orientation of these connection pieces is variable in order to avoid folds in the membrane while allowing the evacuation of rainwater.

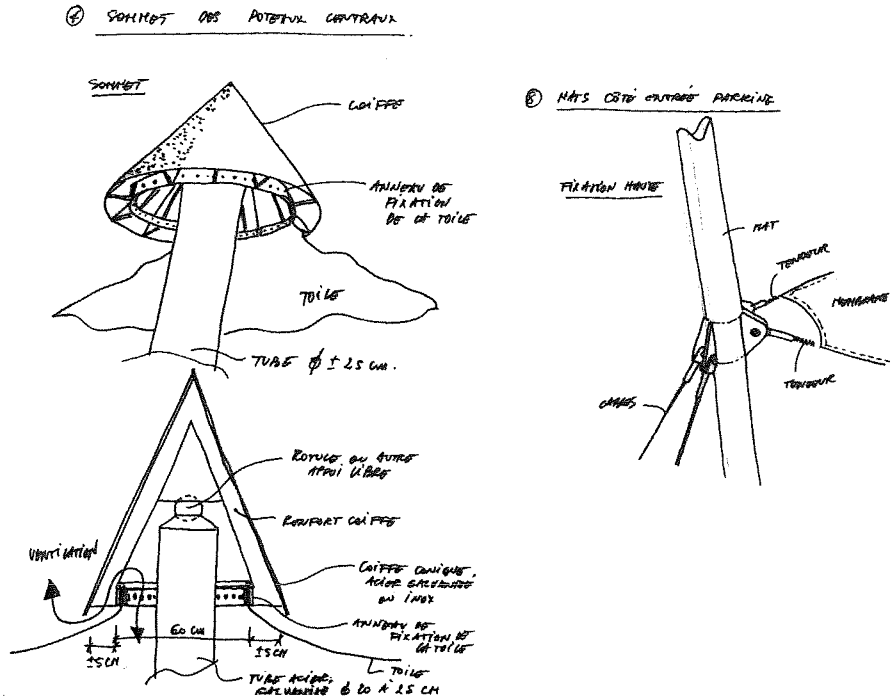

Figure 10: Studies of connection details (top of the membrane).

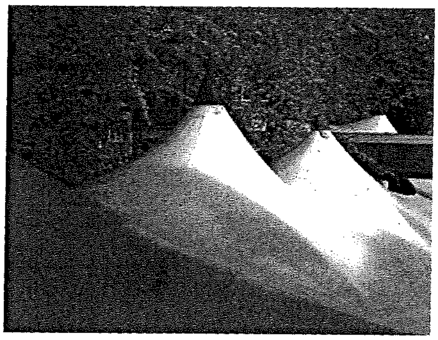

Figure 11: View of the membrane from above.

The textile membrane was erected in one week. It was manufactured as one element and was unrolled along the connections to the existing building and columns or monolithic pillars, which were built before.
Because of the impossibility of adjusting the connection elements, the fabric was first connected to each connecting element at its perimeter.

The membrane tension was achieved only by the introduction of the steel columns in the center. The final shape of the textile membrane was due to the adjustable height of these steel columns in the center.

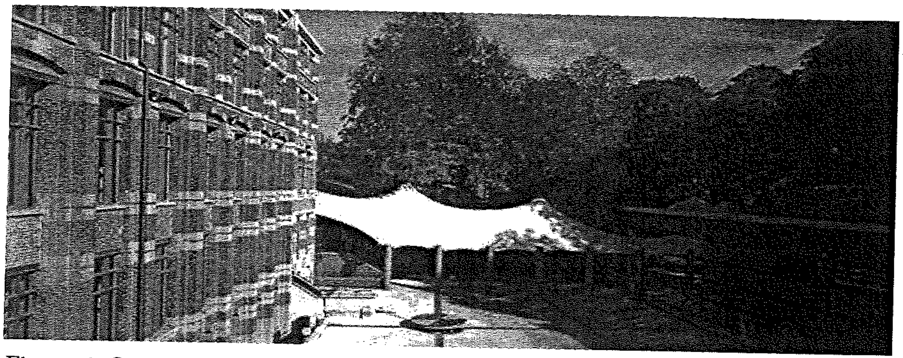

Figure 12: General view.

This solution meant very carefully designed anchor points for the fabric structure with virtually no tolerance once set in place. Experience showed that this created the biggest challenge for manufacturers used to adjustable cables.

Conclusion

ART & BUILD Architects and Engineers designed the refurbishment of the Berkendael European School. The conception of the textile membrane provides a clear solution, which allows the old and the new part to be linked together.

The textile structure is asymmetrical and without the usual cables and anchors to the ground. The structure takes into account the existing trees and is positioned very close to them.

This original concept designed in every detail shows a good solution for textile membrane for a school situation located in a complex area.

Notes

1 Engineering was carried out by Pierre D'HAENE and Martin VERAERT from VERDEYEN AND MOENAERT

2 INGENIEURBÜRO TESCHNER, European School, Brussels, Berkendael Atheneum, Proj. 9902 analysis. 1998.

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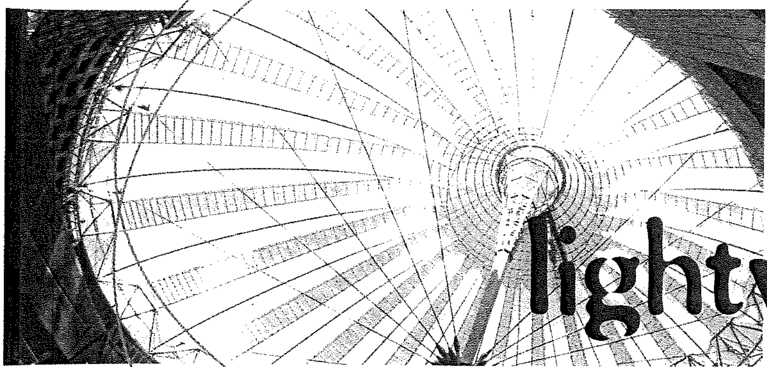
Marijke Mollaert (ed.)

The Design of membrane and lightweight structures



Proceedings of the symposium at the Vrije Universiteit Brussel September 15th - 16th, 2000 - Brussels

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The design of membrane and lightweight structures

Proceedings of the symposium

Marijke Mollaert (ed.)

Structures made out of wood, steel, concrete or brick have been studied for many years, are taught in institutes and at universities and are very well known to everyone involved in the building industry.
Since the mid-fifties however, a new type of construction entered the world of building and has been studied and developed ever since. Nowadays building with flexible, lightweight materials such as coated membranes, cables etc. has become a new form of construction with its very own principles and characteristics.
The aim of the proceedings of the symposium *The design of membrane and lightweight structures*, held in Brussels in September 2000, was to increase interest in and appreciation of membrane and lightweight building. Architects, engineers, constructors - as well as professors and students interested or involved in the design and manufacture of non-conventional structures - will find in this book valuable information about existing lightweight constructions, material properties, design concepts and research topics. The rather new type of construction has been looked at in all its aspects, from material characteristics to statical analysis, and from concept to execution.
Contributions by international speakers with years of experience are included to illustrate the wide range of applications: the Planet M pavilion and the Cycle Bowl at Expo 2000, the Millennium Dome, the Eden project and many more.

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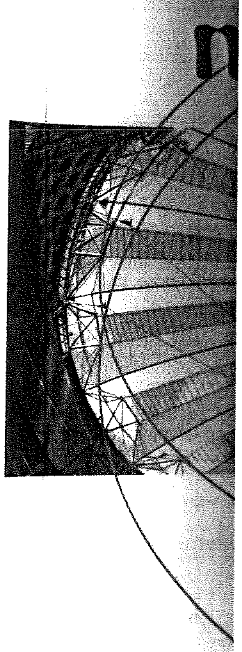
The design of membrane and lightweight structures Marijke Mollaert (ed.)



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