A Geocomposite-Adhesive System for Rehabilitating an Upstream Dam Face

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ABSTRACT: The paper illustrates the use of an adhesive-geocomposite system for a concrete dam upstream facing rehabilitation in Italy. Careful planning and coordination between the owner, the consultant and the contractor, followed by preliminary on-site tests and laboratory tests, resulted in proposing a rehabilitation of the upstream facing and an overall waterproofing of the dam, based on a geocomposite, formed by different layers of polyvinylcloride (PVC) geomembrane and one layer of needle-punched nonwoven polyester (PET) geotextile.
The technological solutions for the application of the geocomposite-adhesive system are furthermore described.

1 FOREWORD

Zolezzi dam is a 22 m high concrete arch owned by ENEL SpA and located close to Genova. The arch is only 0,33 m thick at the top and 1.4 m above foundation plug. The crown of the arch is shaped into a free flow spillway and can be overtopped by a water head of 1.5 m. The lower abutments of the arch are rock, while the upper abutments are gravity, masonry walls. The dam was completed in 1923. After about 70 years of service the concrete of the arch and the mortar of the masonry abutments had deteriorated. Water on the downstream face was evident indication of distress.

The decision was made to waterproof the upstream face of the arch and of the gravity abutments to stop degradation. The waterproofing had to be efficient and fast installed in consideration of the 2 months long dry season. The quality of the protection had to be adequate to ensure a useful life similar to the previous service period of the structure.

2 SELECTION OF THE SYSTEM

The most efficient system for renovation, chosen among several alternate surface treatments considered, was the application of a multilayered geocomposite.

The geocomposite offered the advantages of an easy transportation of the necessary materials to the damsite (which cannot be reached by road), of a fast application and also of a previous experience resulted in good performance of PVC geomembranes used for renovation of several Italian dams (Cazzuffi, 1987).

In this case, for the first time in Italy, the application of the geocomposite was done with special adhesives using the "Geodam System", which consists of a 5.15 mm geocomposite formed by a multilayered polyvinylchloride (PVC) geomembrane reinforced with a nonwoven fibreglass scrim coupled to a polyester (PET) needle-punched staple-fibre nonwoven geotextile (Fig. 1).

The geocomposite is produced with the 'spray-on' system: 4 successive layers of plastisol are spread and polymerised, each layer having a different formulation as far as plasticisers, stabilisers and mineral charges are concerned. Thus, the characteristics of each layer are optimised with respect to the function it must perform.
The production of the geocomposite starts from what will be the external layer ("skin"). The skin is made especially resistant to UV rays, to plasticiser loss under high temperatures and to abrasion. The next layer, polymerised onto the skin, is more resistant and less pervious to maximise the barrier effect. A glass fibre nonwoven geotextile (μ=50 g/m²) is set into the plastisol prior to polymerisation to impart extra strength and dimensional stability. The presence of glass filaments increases considerably the module of the geocomposite at low strains. A third layer, practically equal to the previous one, is spread over the glass fibre reinforcement.Finally, a

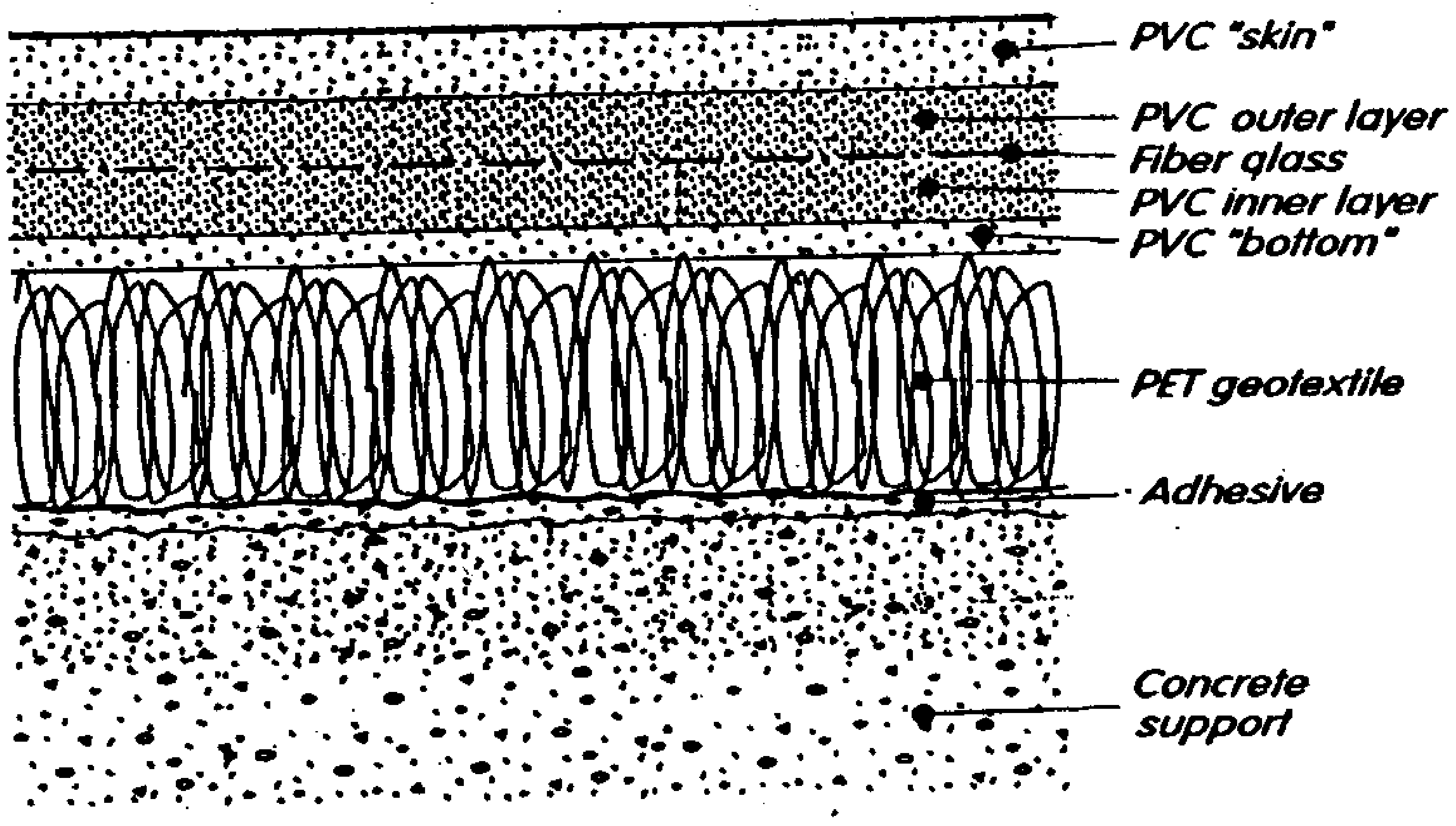

Fig. 1 Cross-section of the system adopted for waterproofing renovation of Zolezzi dam.

a fourth and last layer specifically resistant to the alkalis present in the cement of the concrete support, completes the geomembrane ("bottom" layer). The PET geotextile (μ=400 g/m²) is set over this fourth layer prior to polymerisation and gets, thus, intimately connected to the geomembrane. This intimate connection is reflected by the stress-strain curve which is very smooth and regular as a result of an even deformation of both materials.

3 GEOCOMPOSITE APPLICATION

The geocomposite is applied to the arch surface with the adhesive I (Geodam A20). The geotextile provides a continuous drain on the back of the waterproofing liner and collects any leakage or condensed water before it gets into the concrete. The adhesive I does not hinder the permeability of the geotextile backing as it does not penetrate the fibre mat. Such a result is obtained by a careful formulation of the adhesive so that its surface tension will be enough to moist the geotextile fibres. As an additional precaution, the adhesive is not placed over the whole surface of the support but, typically, on 50 % of it, on a chequered pattern (Cazzuffi et al., 1993).

A small amount of moisture diffuses through the geomembrane and some by-pass leak must be expected through the foundation rock, which must be evacuated downstream. For this purpose 100 mm wide and 5 mm thick high capacity drainage geocomposite (Tenax TNT 100) formed by a sandwich including two layers of nonwoven PP geotextile as filter and one layer of PE geonet as core was placed about 1 m above the bottom edge of the geomembrane. The drain slants down from each side, toward two drain pipes. The design called for the geomembrane below the drain to be fully sealed to the concrete using a polymer adhesive II (Geodam S10T) whose surface tension is such that the adhesive can saturate the geotextile backing of the geocomposite. Thus the geocomposite is directly bonded to the concrete.

The surface preparation called for in the design was sand-blasting and application of a low viscosity, two component, high penetration epoxy primer, to consolidate an outer thickness of a couple of centimetres of the arch concrete, thus guaranteeing a solid surface for the specified adhesive to bond.

Based on previous experiences (Sembenelli 1987), the upper edge of the geocomposite liner gets an additional clamping with a stainless steel strip fixed with stainless studs embedded with epoxy resin in the arch concrete and in the abutment masonry. The sides and lower edge of the geocomposite were, on the contrary, secured by cutting a slot in the foundation rock where a 0.25 m wide multilayer PVC band was embedded using a viscous liquid polyurethane sealant (Geodam A91PU) on the dry side and Emaco mortar on the water side. The space between the PVC band and the concrete was then backfilled with additional sealant material and the band was fusion welded over the edge of the geocomposite previously glued to the dam face. More mortar was applied to fill the slot up to the level of the original foundation rock. A combination of the two methods was used along the lowest part of the geocomposite, at the toe of the arch: a stainless steel band is fixed with studs in epoxy resin , to the edge of the PVC band which, in turn, is sealed to the geocomposite surface with polyurethane sealant. The upper edge is fusion welded to the geocomposite for top grade seal.

The protection of the overflow crest was given special attention since the dam is over-topped regularly. The geocomposite was extended to cover the crest weir and fixed with adhesive over 100 % of the weir surface after meticulous cleaning and patching of the concrete. For maximum insurance against damage by floating debris, 1 mm thick stainless steel pre-formed sheets, 1 m wide, were adhered to the geomembrane with the appropriate polymer adhesive I. The upstream and downstream edges were fixed with stainless studs set in epoxy-acrylic resin. Hilti CS 214 mastic was used along all joints between metal pieces.

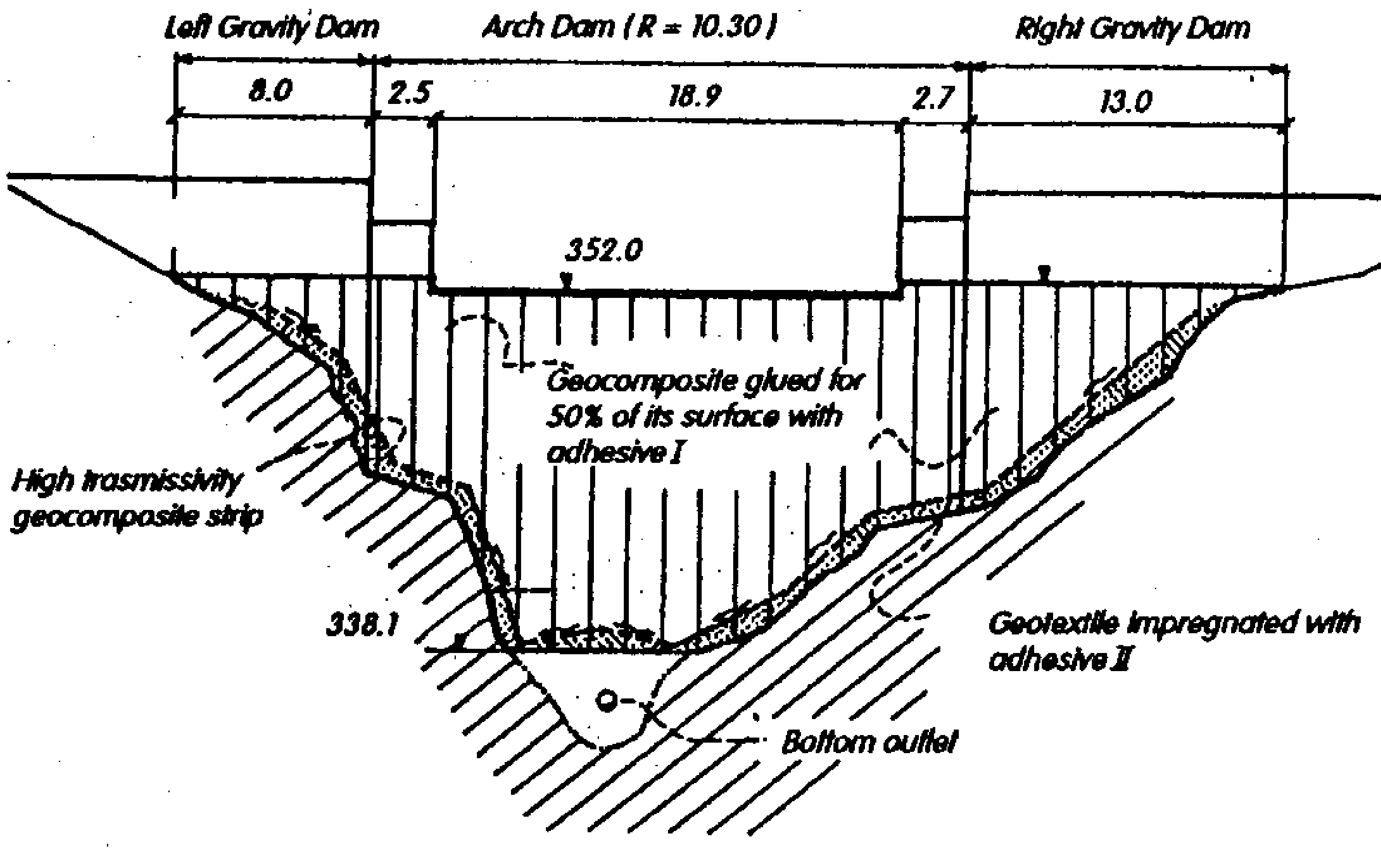

Fig. 2 Zolezzi dam renovation: plan of the geosynthetics application.

4. LABORATORY TESTS

It is evident that an important part of the design for this renovation work depended from the knowledge of the characteristics of the specified geosynthetic.

The studies for the development of this technology of application started in 1984. A comprehensive test program was carried out by the manufacturer to ascertain the characteristics of the individual components and results were available for use in the design stage. Preliminary on-site tests of the proposed adhesive I were made at the damsite in the spring of 1992 using aluminium test discs and a dynamometer to measure the adherence that could be developed as well as the pull-out strength of the existing concrete. Finally, the key parameters of the geocomposite, of the adhesives and of the sealant were extensively tested by the Special Materials Laboratory of ENEL SpA -CRIS in Milano.

The results of the tests performed on the different materials of the system are summarised in Tab. 1.

Table 1 Results of the tests carried out on the different materials for Zolezzi dam.

Test	Standard	Results	Unit
GEOCOMPOSITE			
Nominal Thickness	UNI 8202/6	5.15	mm
Mass per Unit Area	UNI 8202/7	3500	g/m²
Tensile Strength	UNI 8202/8	28.5 - 37.5 (1)	kN/m
Strain at Failure	UNI 8202/8	125 - 69 (1)	%
Tear Resistance	ISO 4674 A2	0.38 - 0.23 (1)	kN
Cold Bending	UNI 8202/15	- 40	°C
Transmissivity	UNI 8279/13	7.3 - 2.9 10E^{-6} (2)	m²/s
ADHESIVE I			
Pull-out resistance	Met. CRIS	0.7 - 0.7 (3)	MPa
Shear resistance	Met. CRIS	0.56 - 0.58 (3)	MPa
Peel resistance	Met. CRIS	8.4 - 8.2 (3)	N/mm
ADHESIVE II			
Pull-out resistance	Met. CRIS	1.8 - 2.7 (3)	MPa
Shear resistance	Met. CRIS	0.58 - 0.57 (3)	MPa
Peel resistance	Met. CRIS	8.1 - 14.9 (3)	N/mm
SEALANT			
Tensile Strength	UNI 8202/8	0.27 - 0.20 (4)	MPa
Pull-out resistance	Met. CRIS	1.2 - 1.2 (4)	MPa
Shear resistance	Met. CRIS	0.05 - 0.04 (4)	MPa
Peel resistance	Met. CRIS	2.14 - 2.00 (4)	N/mm

(1) : Longitudinal - transversal direction
(2) : Geotextile adhered to concrete under 2 and 100 kPa
(3) : Wet - dry concrete support
(4) : Fresh and after 6 months underwater curing at 20 °C
UNI : Italian National Standard Body
ISO : International Standard Organisation
CRIS : Research Center for Hydraulics and Structures

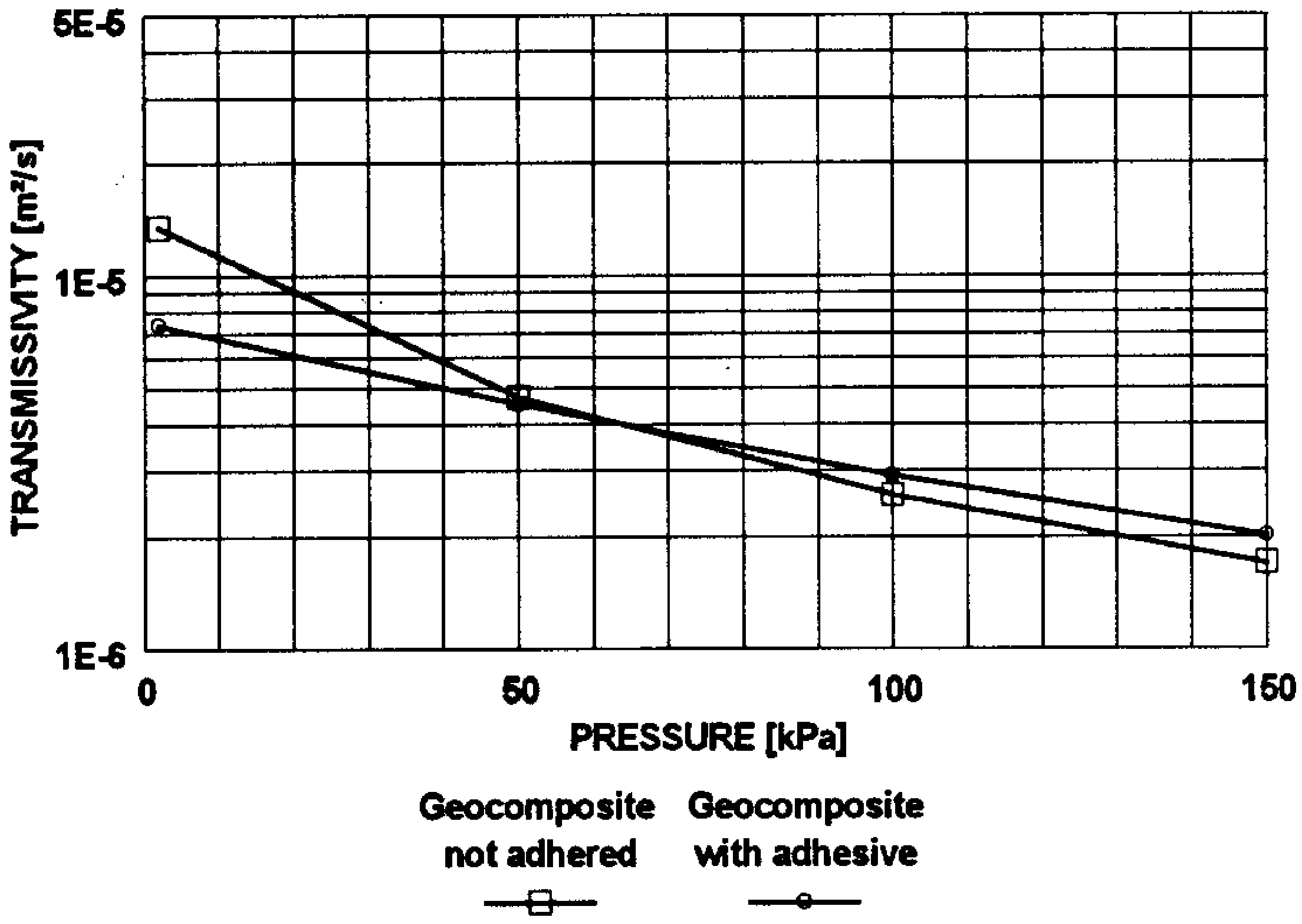

Fig. 3 Transmissivity tests on the geocomposite (average values out of three tests for each sample).

For the geocomposite the following tests were performed: nominal thickness, mass per unit area, tensile strength and strain at failure, tear resistance and cold bending. Thermal analyses provided a detailed check and identification of the polymers and of the other components present in the geocomposite, respectively PVC for the geomembrane layers and PET for the geotextile layer.

The transmissivity (in plane permeability) of the geotextile layer present in the geocomposite was also measured, using a radial-flow apparatus, under different normal pressures up to 150 kPa (Fig. 3). Transmissivity tests were carried out using both virgin specimens and specimens applied to a concrete support with the corresponding adhesive I: this was intended to evaluate the reduction in transmissivity eventually caused by the adhesive penetration into the geotextile layer. Results corresponding to both conditions (adhesive free and adhered geocomposite) prooved that the adhered geocomposite maintains its original transmissivity almost unchanged, thus allowing drainage under all foreseen loading conditions.

Comprehensive testing of the two adhesives were also performed, including adhesion tests to concrete surfaces, both dry and wet. Three different types of adhesion tests were actually carried out: pull-out (Fig. 4), shear (Fig. 5) and peel (Fig. 6). For all the types of tests referred to the adhesive I, the system (geocomposite + adhesive + concrete) failed within the geotextile layer of the geocomposite: the same behaviour was observed also for the adhesive II, excepting only for pull-out test in which the toughness of the geocomposite and of the adhesive was so high that failure of the system tooke place within the concrete in both conditions dry and wet.

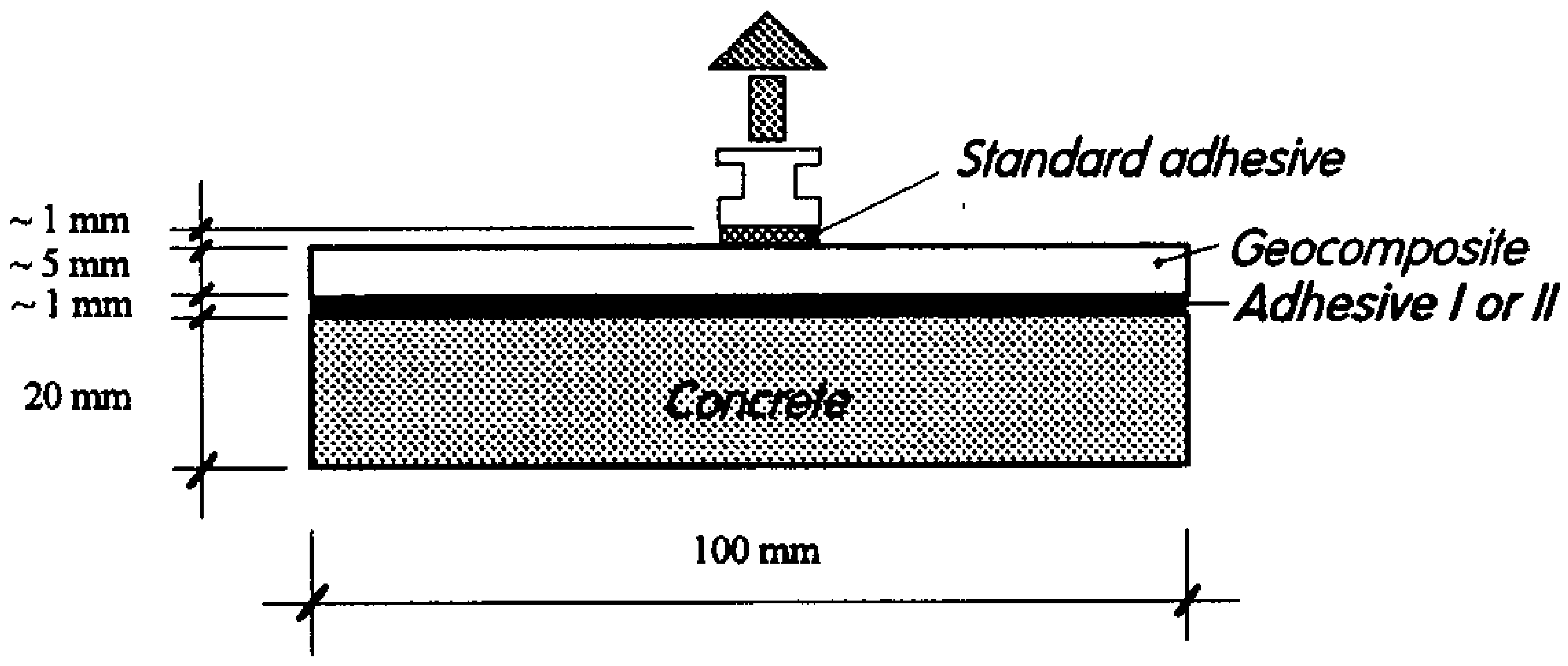

Fig. 4 Pull out test on the adhesives.

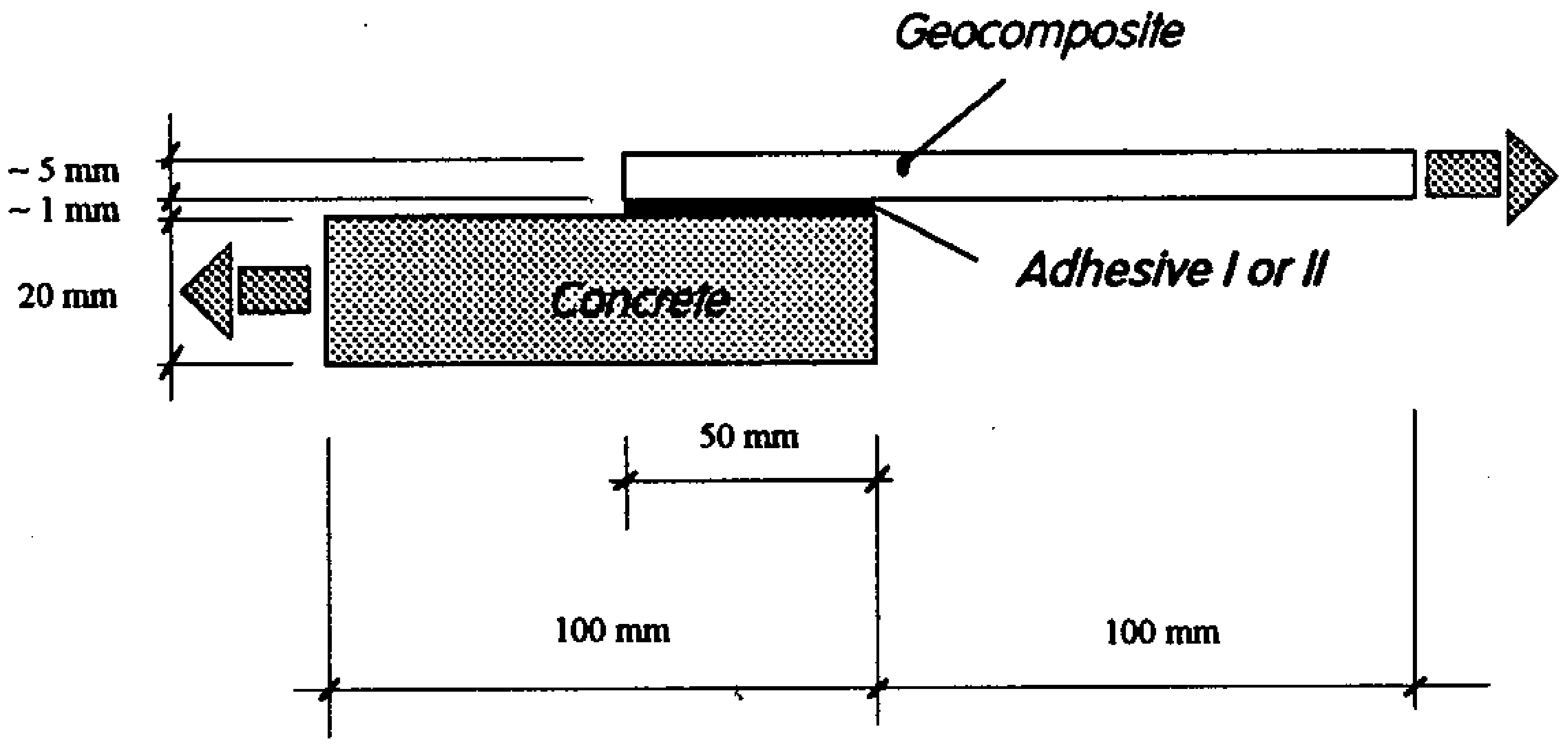

Fig. 5 Shear test on the adhesives.

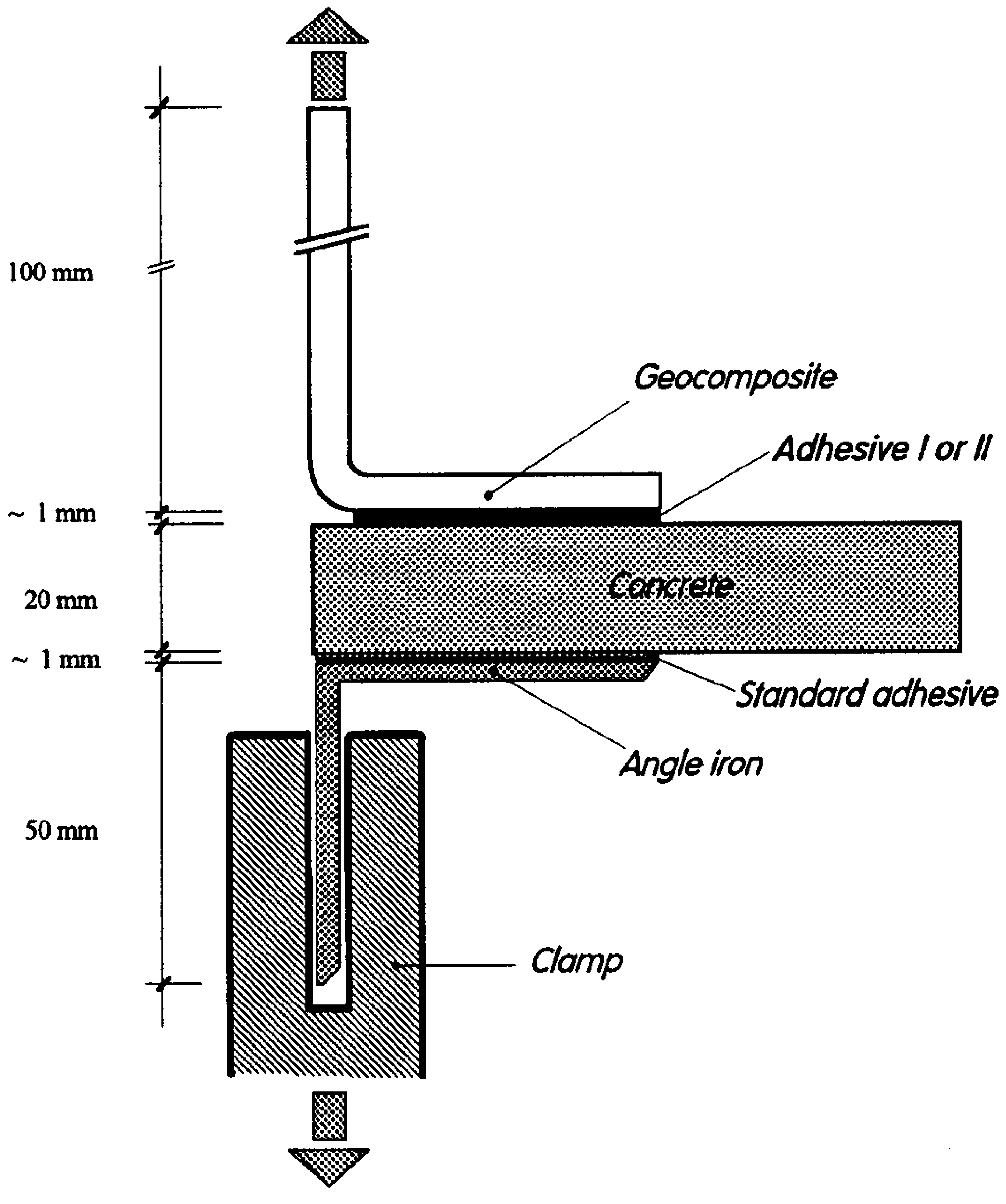

Fig. 6 Peel test on the adhesives.

On the sealant material, kept permanently submerged, tests were carried out at regular intervals for a duration up to 6 months. The change in material properties (thickness, weight, hardness, tensile strength and strain at failure) were recorded, together with the variation of adhesion characteristics from pull-out, shear and peel tests (see Table 1). Fatigue extension-compression tests were also made with 2000 cycles programmes, without noticing signs of failure.

5. CONCLUSIONS

The effectiveness of the treatment could be judged from the asymptotic decrease of the seepage conveyed by the drain pipes, with time (Fig. 7).

The entire renovation work, including mobilisation, cleaning, scaffolding, interruption for storms, clean-up, replacing the bottom outled and resurfacing lasted about 13 weeks.

The short construction time fit within a planned down time of the power plant.

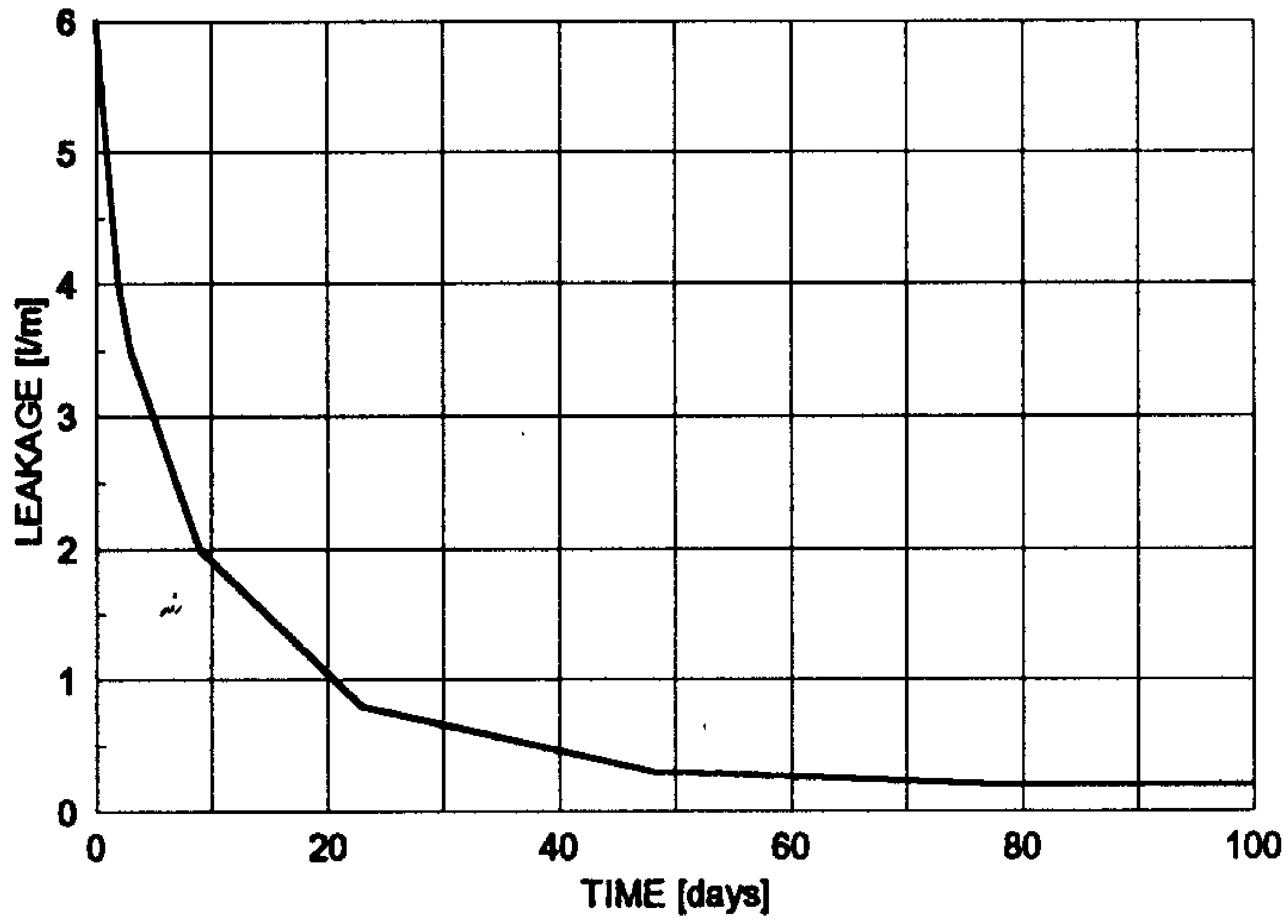

Fig. 7 Zolezzi dam: decrease in seepage with time after the renovation works.

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