Geotextiles for Underpinning River Bridge Piers

H. Brandl
Technical University of Vienna, Austria

ABSTRACT: Two case histories of underpinning bridge piers are described, where a river flow velocity of 2 to 4 m/s and local turbulences had to be considered: In summer 1990 the common river pier of a highway and expressway triple-bridge settled 1.3 m due to a 14 m deep scouring which caused an international traffic chaos. The first and extremely urgent remedial measure comprised backfilling with rock material and grouting. This special grouting method only was possible by placing "geotextile expander bags" into the boreholes. The second case history refers to the strengthening of a bridge pier foundation in another river by installing jet grouting columns around the existing caisson. This measure required a temporary flexible cover of the river bed to prevent the cement grout from escaping which was achieved by placing geotextile mattresses filled with underwater concrete.

1. SAVING A COLLAPSING BRIDGE

1.1 Situation

During the main traffic period of summer holidays in Europe the river pier of a highway triple-bridge suddenly settled 1.3 m and tilted due to scouring. The 450 m long structures were heavily damaged and in a critical limit state of equilibrium. The failure caused an international traffic chaos by interrupting two of the most important traffic routes of Europe, as the bridge was located on the German-Austrian border in a montainous region. Moreover, the international and local railway traffic was also interrupted, because the bridge crossed several railway lines.

The bridge comprises 3 superstructures (five-field continuous girders each) for two highways and one expressway. They were founded on flat single footings in the year 1965. Only the river pier is common for all structures and rests on a strip foundation of 52.0 x 8.5 m.

The subsoil consists of young river sediments in a heterogeneous sequence of sandy gravels, uniform sands and silty interlayers. Borings drilled from a temporary island fill around the river pier showed that the scour had been 14 m deep and large caverns existed beneath the foundation.

1.2 Remedial works - overview

Extreme turbulences around the pier, a flow velocity of more than 4 m/s and the danger of an approaching highwater made it very difficult and risky to work in the river. The most important measures for saving and strengthening the river pier and its foundation are shown in Fig. 1 :

- Filling a temporary island around the pier.
- Installing of hydraulic jacks between superstructure and top of the bridge pier.
- Tying back the top of the river pier with strands of prestressed anchors which were fixed in the subsoil of the river bank.
- Wrapping of the fissured river pier with steel strands.
- Grouting of voids and caverns resp. caused by scouring beneath the footing.
- Soil improvement and partial

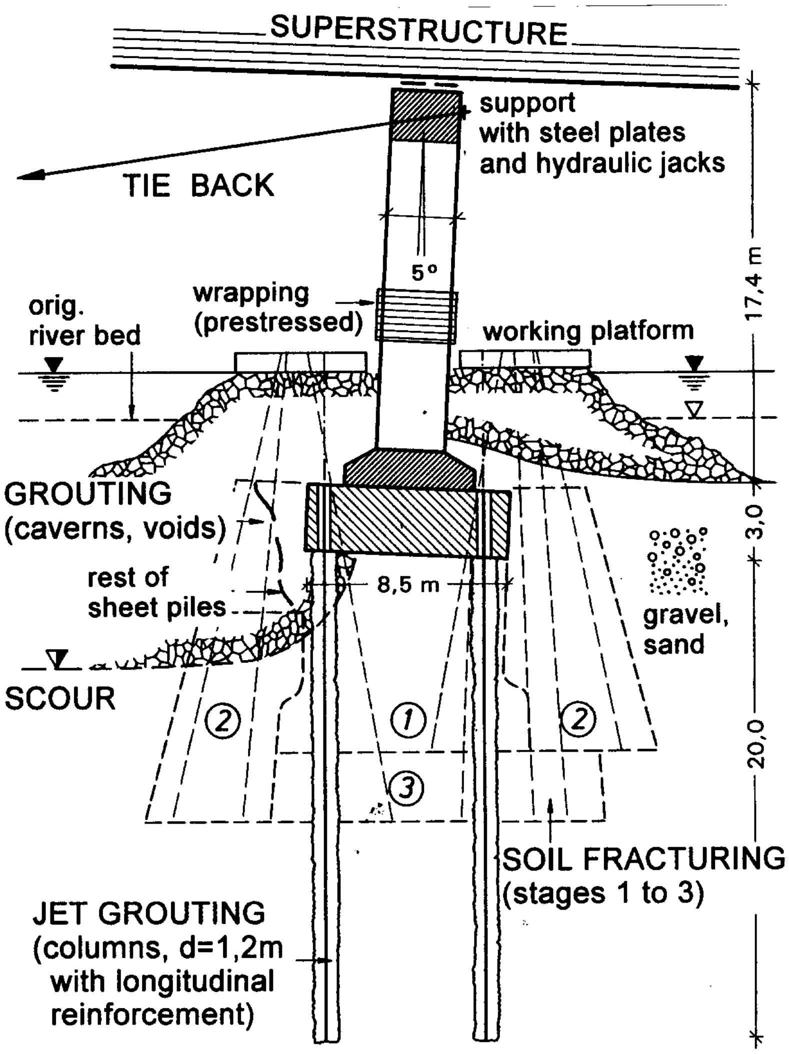

Fig. 1 Remedial works for a river pier which had settled 1.3 m and tilted due to a 14 m deep scour. The pier is 52 m long and carries three superstructures. Geotextile expander bags in the zone of grouting (caverns, voids)

relevelling of the bridge pier by soil fracturing in steps 1 to 3 (see Fig. 1).
- Installation of jet grouting columns around the whole strip footing thus forming a deep box foundation.
- Placing of auxiliary supports on either side of the adjacent piers.

1.3 Scour grouting with geotextile expander bags

Scouring had caused large caverns and voids beneath the existing footing. During the subsidence more than one third of the foundation had lost its subgrade. The local refilling with rock in turbulent water provided only a very loose density with large voids and even caverns. Moreover the original soil was heavily loosened and the washing out of fine gravel, sand and silt went on.

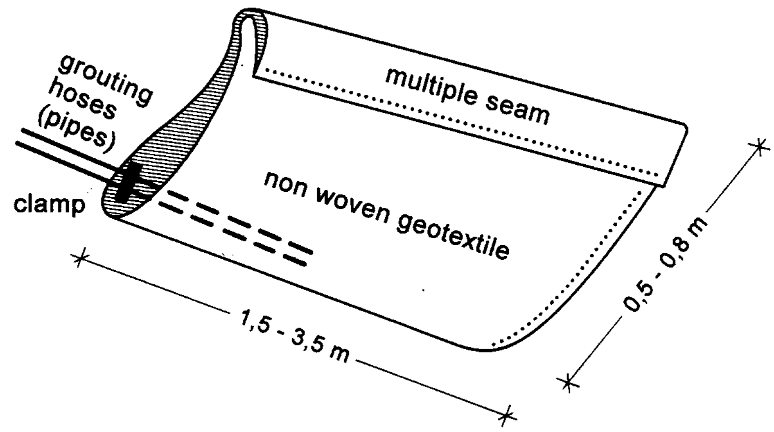

Fig. 2 System of "geotextile expander bags" with grouting hoses or sleeve pipes; schematical

Consequently, a rapid grouting of the voids and caverns was the most urgent measure to avoid a complete bridge collapse. But according to the high flow velocity of the water and the local turbulences it could not be performed in a conventional way. The grout material instantly would have been washed out. Therefore "geotextile expander bags" were fixed on toe of the grouting base or sleeve pipes as indicated in Fig. 2. The following procedure proved to be the best:
- Underground investigation by drilling boreholes (with casing).
- Installation of tightly folded "geotextile expander bags" by means of an auxiliary rod or stiff grouting hose.
- Pushing the geotextile expander bag (or bags) in the open void or cavern.
- Grouting of a rather plastic suspension (rich in cement and limestone filler) with low pumping rate to about 80 % of the theoretical volume of the geotextile bags.
- Addition of an accelerating agent (water glass) along a separate hose or pipe.
- Complete filling of the geotextile bags in steps and finally increasing the grouting pressure up to 200 kPa, thus expanding the bags significantly.

The grouting hoses or pipes were provided with injection holes and sleeves, spaced 20 cm. Thus the injection could be adapted very precisely to local subsoil conditions.

The geotextile expander bags consisted of a needle punched nonwoven made from polypropylene endlessfibres. It showed the following characteristics:

- thickness d = 3.0 mm
- weight g = 350 g/m2
- tear strength ≥ 21 kN/m at elongations of $\varepsilon \geq 50/80$ %
- CBR-puncture resistance ≥ 3.5 kN
- hydraulic properties:
  opening size D_W = 0.08 mm
  vertical k-value = 4×10^{-3} m/s

According to Fig. 2, the nonwoven geotextile was at first needled to form a bag at the end of the grouting pipe or hose. Then it was intensively folded and finally fixed to the grouting pipe with a clamp.

According to their flexibility the expanding geotextile bags filled the voids during grouting. Moreover these bags formed a primary "grain" structure (skeleton) within the caverns thus enabling a subsequent grouting of the whole underground.

The additional bridge settlements during this grouting phase (with an overlapping soil fracturing) could be limited to 5 cm. Simultaneously the bridge bearings were partially relevelled by hydraulic jacks thus avoiding a collapse of the superstructures. Since 1992 all lanes of the bridge have been again under full traffic.

2. STRENGTHENING OF A RIVER PIER FOUNDATION

The construction of the hydraulic power plant in Vienna will cause a backwater level which is several meters higher than the present level of the river Danube. This requires the raising of several bridges within a range of 1.5 to 4.3 m.

The paper focuses on a 23-field rail bridge which consists of two parallel superstructures with a total length of 850 m each. These structures were already lifted by 1.70 m. In this connection the piers and foundations had to be strengthened in order to provide sufficient safety factors: Due to the raised structures the forces, especially moments changed significantly, and moreover an increasing traffic had to be taken into consideration.

The subsoil consists of quaternary sandy gravel with boulders (4 to 7 m deep) underlain by tertiary sediments. Around the piers the river bed is protected with rockfills against scouring, which locally reach a depth of about 5 m.

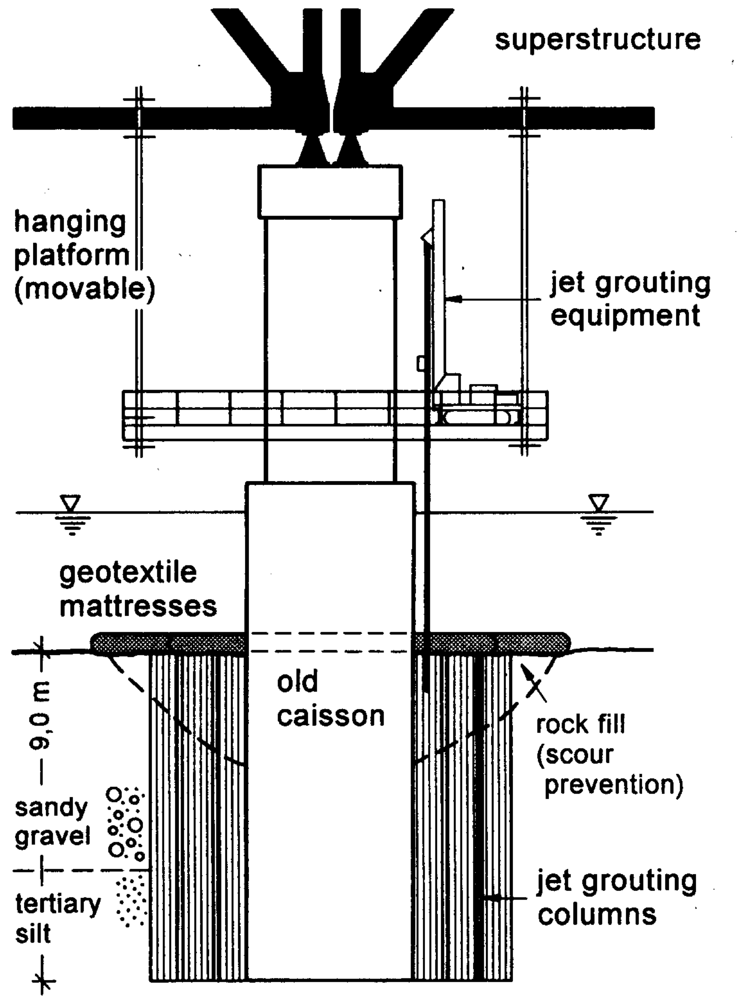

Fig. 3 Foundation strengthening of an old river bridge pier by a box-like enclosure with jet grouting columns. Cross section (schematical).
River bed covering with geotextile mattresses for high pressure grouting from a platform hanging on the superstructure

For underpinning old river piers a box-like enclosure consisting of piles or jet grouting columns or diaphragm walls has proved very effective. Due to the shipping lanes - and the high flow velocity of the river Danube it was not possible to fill a temporary island in this case. Furthermore, piling from a ship was too risky: Secant piles could not be installed precisely enough and moreover a new bridge was under construction in a distance of only 10 m!

The solution was a foundation strengthening by installing jet grouting columns from a platform hanging on the superstructure (trussed steel girders) - Fig. 3. In case of high-water the platform could be pulled up. But the problem was how to grout through the rock fill without any overburden in the river bed and how to avoid a washing out of the fresh grout material. The soil required a grouting pressure of 50 to 60 MPa.

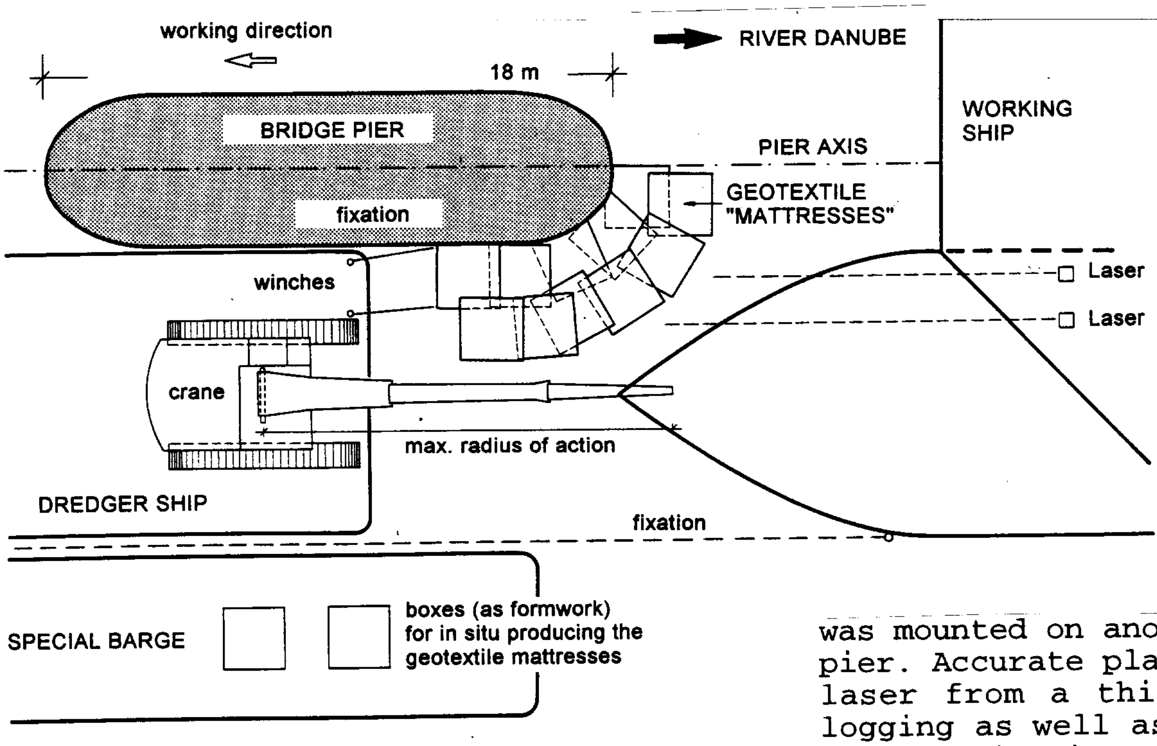

Fig. 4
Ground plan to Fig. 3 with scheme of producing and placing the geotextile mattresses around the river pier

The first design proposed underwater concrete to fill the voids within the rockfill and to place a 0.5 m thick concrete cover on it. This would have been very difficult requiring a local river back up. According to shipping requirements the concrete cover could be considered only an auxiliary measure and was to be removed after bridge lifting. Moreover the scour prevention should remain a flexible rock fill and not be changed into a rigid block.

In order to provide a flexible and removable cover "geotextile mattresses" were placed on the river bed around the pier (Fig. 4). These elements consist of geocomposite bags (2.0 x 2.0 x 0.5 m) filled with a special underwater concrete (type K5 with 350 kg/m3 cement). The geotextile mattresses were manufactured on a special barge near the river pier and placed by a crane which was mounted on another ship close to the pier. Accurate placing was controlled by laser from a third ship and by sonic logging as well as by hand (with rods). Several fixations and winches provided a precise handling.

The special barge carried several boxes which served as formwork for manufacturing the geotextile mattresses. These contained a geosynthetic net (mash width 45 mm, edge rope 16 mm) to carry the elements as indicated in Fig. 5. After placing the mattresses the top of the net was cut off. The flexible geocomposite and fresh concrete adapted themselves very closely to the rough river bed. The filled mattresses overlap each other by 0.3 m, thus forming a continuous surface.

While the net served only for carrying purposes, the geocomposite served as a container. It consisted of a 60μ membrane (100 % polyethylene) and a staple fibre nonwoven geotextile (100 % polypropylene). The total thickness of the composite was about 3.5 mm with a weight of appr. 550 g/m2. The strip tensile strength was more than 11 kN/m in both directions, with an elongation at break of at least 80 %. The sheets were welded with hot-air or by flamming.

The geotextile mattresses proved excellent, and jet grouting could be performed without any problem.

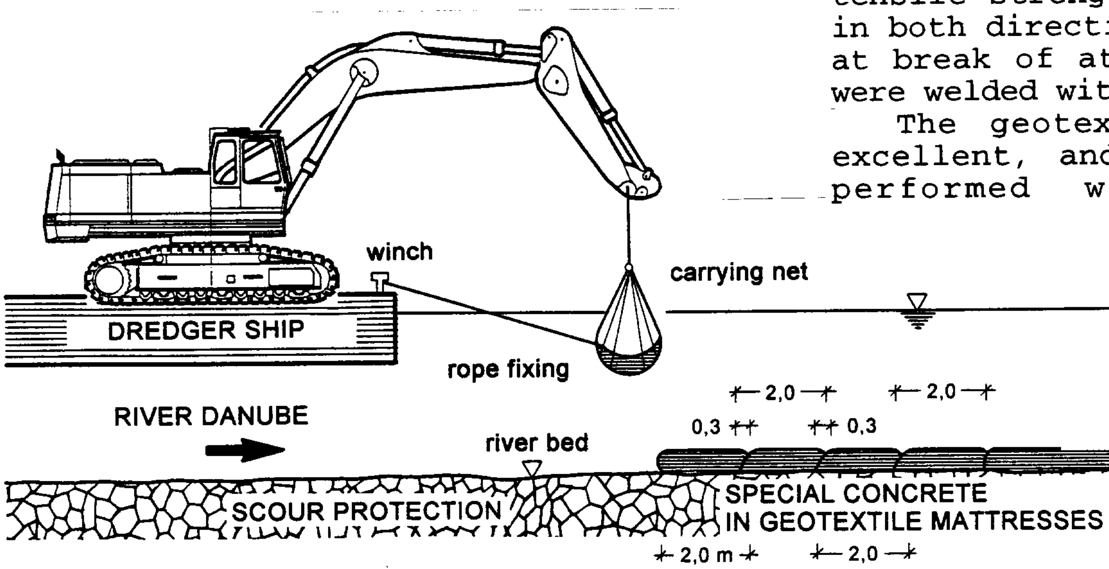

Fig. 5
Detail to Fig. 4: Placing the geotextile mattresses immediately after their filling with a plastic underwater concrete