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Paper 3

THE UNIQUE INTERVENTION WITH GRP PIPES DN 2700 - PN 6 – 1 KM INSIDE THE CONCRETE DIVERSION TUNNEL IN S. VALENTINO (BZ – ITALY)

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ABSTRACT: the project describes the intervention with GRP pipes DN 2700 - PN 6 – 1Km inside the concrete diversion tunnel in S. Valentino supplied by the Resia Lake watershed serving the hydroelectric plant in Glorenza (BZ).

The tunnel crosses the above village as far as the hydroelectric station; to reach the project site, a single excavation was planned to allow the pipes insertion. The installation of the new pipeline was carried out by inserting each piece of GRP in the access window and then transporting it for 1 km further where a terminal fixing system was built. Going backwards, the coupling of the pieces was continued following the "Installation Plan". The single pieces were transported inside the pipeline with special equipment, which allowed handling in narrow spaces considering the outer coupling diameter of 2778mm.

The injection of the gap, between the tunnel and the GRP pipeline, was carried out from the inside of the new pipeline, by means of special valves already prepared by the manufacturer.

The lamination of the joints with fiberglass was crucial to ensure the continuity to the hydraulic and structural seal.

The works, completed according to schedule, confirmed the choice of No Dig as the optimal solution.

1. STATE OF WORK – SITUATION OF THE EXISTING STRUCTURE

The purpose of this article is to illustrate the relining work carried out on a section of the reinforced concrete tunnel in San Valentino, which is part of the hydroelectric plant at Glorenza (Autonomous Province of Bolzano), operated by Alperia Vipower Spa.

The Glorenza plant’s main headrace tunnel is fed by the reservoir of Lake Resia, it extends for 12’094 m to the surge shaft, and it is situated above the underground power plant at the entrance to the valley, the so-called Val di Marzia. The pressure tunnel is lined with reinforced concrete, it has a circular cross-section with an internal diameter of 3.20 m at the beginning and then, 400 m further on, 3.00 m.

The altitude of the intake structure at Lake Resia, measured with the inverted arch method, is 1’462.36 m ASL, and the altitude at the surge shaft is 1’444.87m ASL, so that there is a height difference of 17.49 m, which corresponds to an average gradient of 1.44%.

The purpose of the relining work was to seal the existing tunnel using an internal lining intending to eliminate water loss by the structure in the section in question, which is about 1’000 m long.

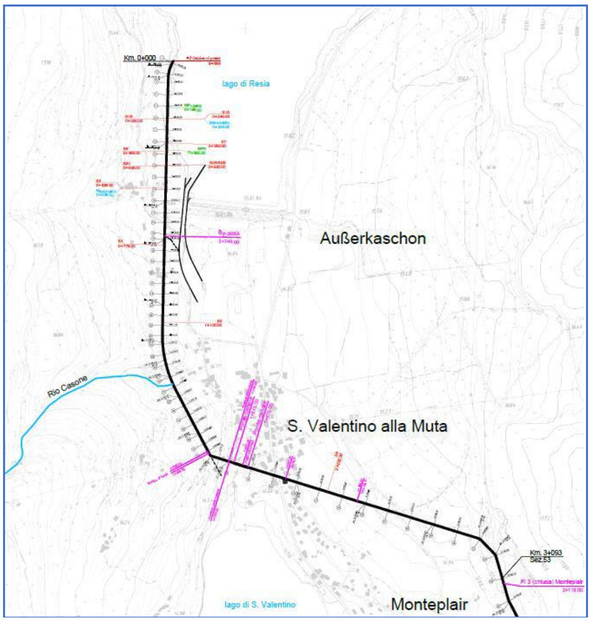

Figure 1. Plan layout of the diversion tunnel

The technology used in the project was relining with new DN 2700 GRP pipes. The pipes were placed inside the tunnel and then sealed to each other, subsequently, shrinkage-compensated mortar was injected into the gap between the external surface of the pipes and the internal surface of the tunnel.
In the section in question, the tunnel has a maximum internal hydraulic load of approximately 4.5 bar and a maximum external hydraulic load — due to the presence of groundwater — of approximately 1.8 bar. The mechanical parameters of the GRP pipes are such that the pipes are certain to be able to absorb up to 6.0 bar in stress from both internal and external water pressure.
The work carried out served not just to restore the tunnel's original hydraulic performance but also to structurally reinforce the tunnel without altering its static properties. Although inspections carried out over the years had not revealed that such a reinforcement would be strictly necessary, it did nevertheless improve the tunnel overall.

2. PRELIMINARY ACTIVITIES FOR THE GRP PIPES

To verify the actual geometric dimensions of the tunnel, a 3D laser scan survey was performed on the entire tunnel section that the project involved. The survey made it possible to identify any potential obstacles and/or irregularities in the tunnel and generate both, cross sections and longitudinal sections; those permitted the actual geometries (e.g., radii of curvature) of the existing tunnel to be defined precisely.
The section to be rehabilitated, passes underneath the town of San Valentino and continues to the hydroelectric power plant. Aiming to reach the tunnel, a single excavation (14 m x 3 m) was carried out and at this location, all the sections of the new GRP piping were inserted into the tunnel.

Figure 2. Orthophoto of the intervention area.

In order to gain access to the tunnel, its upper part was demolished and this operation consisted of the steps listed below:

- The area next to the tunnel was excavated. To do this, a temporary structure of lego-blocks was constructed on the north side of the excavation, which allowed the connecting road to the adjacent square to remain open. The material excavated was placed at the worksite to be used again to backfill the excavation at the end of the project.
- The upper part 1.60 m of the reinforced concrete tunnel (i.e., 10 cm below the horizontal centreline of the cross section) was wire-cut and demolished. As a result, a section of the tunnel, 14 m long and 1.60 m high, was removed.
- The areas around the opening were laid out to permit the different equipment to access the tunnel.

At the recommendation of the Safety Coordinator during execution, to enable workers to work safely, a forced ventilation system was installed in the access window immediately downstream of the section that the project involved.

To prepare the tunnel for the installation of the appointed pipes, the following operations were carried out manually:

- safety preparations;
- water jet cleaning of the internal lining of the tunnel;
- levelling of the bottom of the tunnel, which in certain parts was eroded and had minor surface holes that needed to be restored;
- localized demolition and scarification of any concrete areas that would constitute obstacles to the relining operation;
- cleaning of the tunnel, including removal of any obstacle material that might be in the tunnel;
- closing the clapet valves and applying resin to close and seal any cracks where water was leaking into the tunnel;
- eliminating the riveting (consisting of plates and bolts) that had been installed during previous strengthening operations, since this riveting might obstruct the insertion of the new pipes.

3. TECHNICAL CHARACTERISTICS OF THE GRP PIPES

The pipes that were used had the following technical characteristics:

- Nominal diameter: DN 2700
- Maximum external diameter: 2’759 mm (+6/-1 mm)
- Minimum internal diameter: 2’656.5 mm
- Minimum wall thickness: 50.5 mm
- Pressure resistance — nominal pressure class: PN ≥ 6 bar
- Transverse mechanical strength — stiffness: SN ≥ 10’000 N/m^2.

The lengths of the single pieces were defined following the project of the laying plan, based on the plano-altimetric development of the tunnel by choosing pieces of 2 m, 3 m, 4 m and 6 m.
The client, Alperia Vipower Spa, chose GRP pipes because they have several advantages:

- GRP piping permits operations with a service life of 150 years with high resistance to impact and abrasion;
- unlike steel piping, GRP piping does not degrade through oxidation;
- the manufacturing of GRP pipes takes place in facilities with certified quality control systems, which makes it possible to obtain pipes that are completely uniform in all its parts;
- the pipes can be manufactured and delivered to the construction site quickly, as this project required;
- installing the pipes does not need either complex operations inside the tunnel or welding, making it possible to work faster and finish the project much sooner;
- although the internal diameter is smaller, the hydraulic characteristics of the existing tunnel do not change with the new pipes, since there are no additional losses in pressure because the interior surface of the GRP pipes is smoother.

The pipe sections were connected using sleeve joints, and a good seal was ensured by the use of slotted EPDM gaskets that integrated with the sleeves themselves. The joints can maintain their hydraulic sealing characteristics even when the axes of adjacent pipes are misaligned at different angles. Technical characteristics:

- External diameter: 2’773 mm (+5/-1 mm)
- Minimum internal diameter: 2’745 mm
- Minimum thickness: 14 mm
- Length: 367 mm
- Pressure resistance — nominal pressure class: PN ≥ 6 bar
- Transverse mechanical strength — stiffness: SN ≥ 10’000 N/m^2.

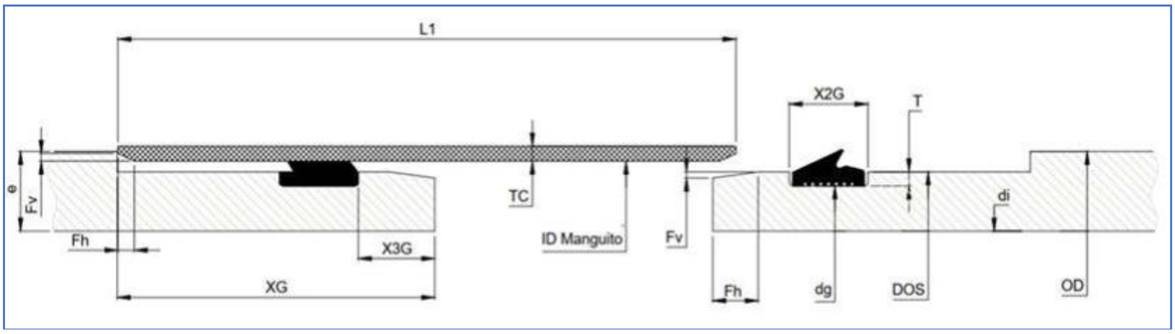

Figure 3. Pipe-sleeve coupling system detail.

4. COUPLING THE GRP PIPES TOGETHER

After the tunnel had been prepared and the internal lining scarified, a 3D laser scan survey had to be carried out again in detail to enable a specific assembly plan for the coupling.

This detailed plan for laying the pipe sections was of crucial importance for both, planning and carrying out the installation of the piping, and it made it possible to ensure, as the individually numbered pipes were being installed, that each pipe section was placed at the point envisioned in the plan.

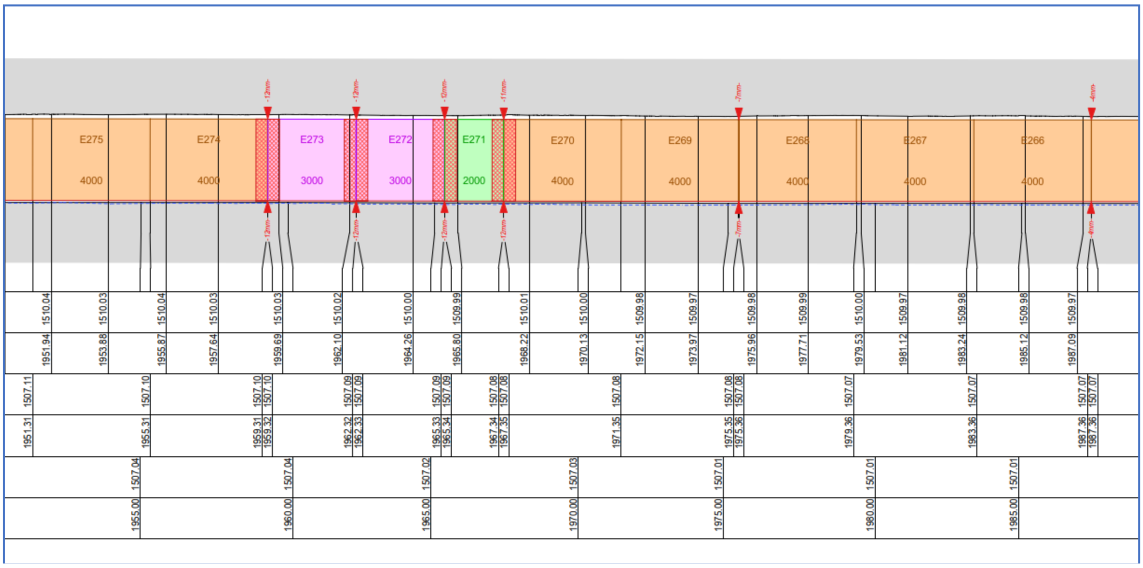

Figure 4. Laying plan for the new GRP pipes marked and numbered

The pipe sections, manufactured by the Spanish company Amiblu Pipes Spain, began arriving on site on December 13, 2021, and continued to be delivered to the site through February 8, 2022. In all, 85 oversize truckloads with 12 m of pipes per load, were needed to transport the pipes.

Figure 5. Pipe transport truck

To lay the GRP pipes, each pipe section was inserted through the access window and then transported downstream approximately 1 km to a point where a system for fixing the pipes in place had been installed. The pipe sections were coupled together one after another, moving back upstream, in accordance with the pipelaying plan prepared beforehand.

Adjacent pipe sections were connected using a special equipment that permitted each pipe to be centered and locked in place in its final position. In addition, anti-floating devices were inserted to keep the single sections stable when mortar would be injected later on.
Because the external diameter of the sleeve was 2’778 mm and the diameter of the existing tunnel was only 2’902 mm, each pipe section, which were 2, 3, 4, or 6 m in length, was transported through the tunnel using an equipment that permitted movement in confined spaces.

Length of pipe section	2 m	3 m	4 m	6 m	**TOTAL LENGTH OF RELINING**
No. of sections placed	42	80	164	3	
Total meters	84	240	656	18	**998 m**

Figure 6. Overview of the installed sections and respective lengths

After the inside of the sleeve and the corresponding rubber gasket had been carefully cleaned, lubricating paste was spread both on the internal surface of the gasket and on the ends of the pipe section that was being connected. A thrust force was applied to the heads of the pipe sections in a parallel manner on both sides of the new structure so as to have the pressure be uniform.

Figure 7. Transport and insertion of GRP pipes in tunnels

Since the joints are the most vulnerable element for the hydraulic tightness of the system, each joint was subjected to tightness tests with specific air equipment according to UNI EN 1610, at a pressure of 0.5 bar for a duration of 5 min. The joints whose opening exceeded the limits indicated by the manufacturer, in particular those where the tunnel showed plano-altimetric variations and which did not pass the tightness test, were subsequently laminated.

Figure 8. Execution of leak test on single joint

The installation of the pipe sections was concluded with the insertion of the last section, specially cut to 3 m in length, which was placed between one section downstream and another section upstream. This last pipe section was lowered into place from outside and connected using STRAUB-OPEN-FLEX 3 joints previously positioned in place and subsequently tightened.

Figure 9. Joint connection system STRAUB OPEN FLEX3 – Last GRP piece

5. INJECTION OF MORTAR INTO THE ANNULAR GAP

To assemble the existing tunnel and the new GRP piping into a single structure, mortar was injected into the annular gap from inside the new piping, via special valves that the manufacturer had built into the pipe sections in accordance with the instructions from the designer.

The different types of mortar were produced on site. Premixed mortars were stored in specific silos, and when water was added to them, the specific weight of the resulting mix was checked to ensure that it complied with the technical specifications elaborated during the planning phase. Given that, there would be water behind the pipe sections in the tunnel, a thinner was also added to the mortar to improve its technical characteristics.

To isolate the areas that would be injected, the tunnel section that the project involved was divided into 17 subsections that were each approximately 60 m in length. Via injection, a mortar crown was created between the tunnel and the GRP pipe sections.

The company had prepared a detailed plan for injecting the mortar, this indicated which pipe sections would need to have valves and the locations where the internal mixing system would need to be placed.

Figure 10. Mortar sealing

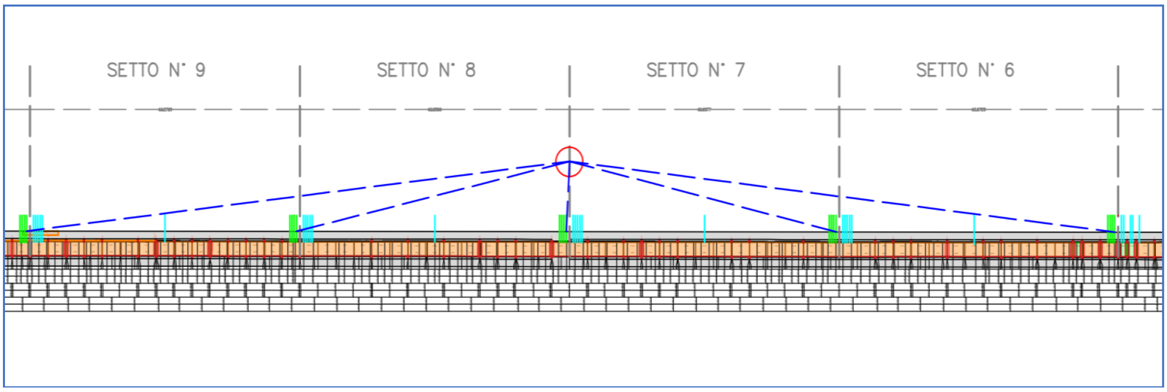

Figure 11. Mortar injection phase design

The mortar used was of a special type so that the aggregates would not segregate during injections. The mixing system was installed outside the tunnel, and the mixed mortar for injecting was transported through the tunnel via a DN 50 polyethylene pipe.

Figure 12. Mortal injection system

Crucial to the injection process was the injection plan, which provided for the injection to take place by layers, in successive steps, to not create any voids and, in particular, to keep the injection pressure outside the pipe sections from placing any particular stresses on the pipe.
For additional protection, fiberglass was laminated over the injection and drainage valves, to keep water from leaking through.

Figure 13. Grout injection phase through valves

6. LAMINATION WORK

The pipe manufacturer had indicated that for the hydraulic and structural seal to be continuous, the joints needed to be manually laminated with fiberglass by certified workers, because the laminating of the joints was crucial for the rehabilitation.

The laminating of the joints consisted of the following steps:

- smoothing the surfaces to be laminated;
- filling hollow spaces in the pipes with fiberglass paste;
- laminating the surfaces in layers until the laminated areas had a minimum thickness of 20 mm and a width of 500 mm;
- sealing the lamination with a layer of pure resin.

Figure 14. Laminated joints and nipples

In accordance with the manufacturer’s instructions, at locations specified in the pipe-laying plan where the angle between joints was greater than 0.3°, the surface was manually laminated by applying fiberglass as the standard with a pressure class of PN 6.

At both ends of the section of the tunnel that the GRP piping was installed in, connecting sections 1.60 m long were created. Each connecting joint was made on top of high-strength, strongly adhesive mortar and then laminated over in order to make the transition between the new piping and the existing tunnel gradual.

7. CONCLUSION

At the end of the final inspection, which took place on March 29, 2022, it was confirmed that the work had been carried out using all the technical measures that were feasible and, as far as could be observed visually, in a workmanlike manner.

The project, which involved a substantial investment by the company that operated the power plant, confirmed that the use of No-Dig technology not only permitted the tunnel to be restored with hydraulic-seal and mechanical-strength characteristics comparable to a completely rebuilt tunnel, but it also made it possible to complete the work quickly and reduce environmental impact considerably.

The time available for the work was limited by the drawdown and filling situation of the basin upstream. Time was important not just for that reason, but also because shutting down the plant would have meant lost power production for the company that operates the power plant. Accordingly, a simulation for every major phase of the work (i.e., pipe laying, injection, and lamination) was prepared, and updated daily, so that the state of progress of the work could be known at any time.

Figure 15. Simulation of pipe insertion

The GRP piping rehabilitated the tunnel statically and hydraulically with a better quality-to-cost ratio than other technologies are currently able to achieve. In addition, the time required, the environmental impact of the work, and consequently the amount of time that the hydroelectric company had to interrupt energy production were all reduced significantly.

The works were completed on schedule, confirming the choice of No-Dig as the optimal solution combined with short execution times. Special thanks for their professionalism and cooperation go to all the people who took part in the project and made it possible, in particular: Giacomo Fantoma - Sole Procedure Manager Alperia Vipower Spa, Daniele Faggin - Works manager and Work direction Alperia Vipower Spa, Roberto Bertero - Project Manager Hydrodata Spa, Vittorio Tresso - Project manager Hydrodata Spa and Giovanni Carlini – Health and Safety director during execution and design phase.

Figure 16. Status of the tunnel at end of work