EUROPEAN NO•DIG 2023 Conference ITALY

ROTECH
risanamento e rinnovamento tubazioni

The unique intervention with GRP pipes DN 2700 - PN 6 – 1 km inside the concrete diversion tunnel In S. Valentino (BZ – Italy)

Ing. Sabatino Riccio
Project Manager
ROTECH SRL

25th May 2023

CLIENT AND CONTRACTORS

Client	ALPERIA ViPower AG
R.U.P	Dr. Ing. Giacomo Fantoma
Construction Management	Dr. Ing. Daniele Faggin
Ass. Dir. of Works	Dr. Ing. Stefano Pernici
Ass. Dir. of Works	Geom. Alessandro Olivotto
C.S.E	Dr. Ing. Giovanni Carlini
Project designer	Dr. Ing. Roberto Bertero
Project designer	Dr. Ing. Vittorio Tresso

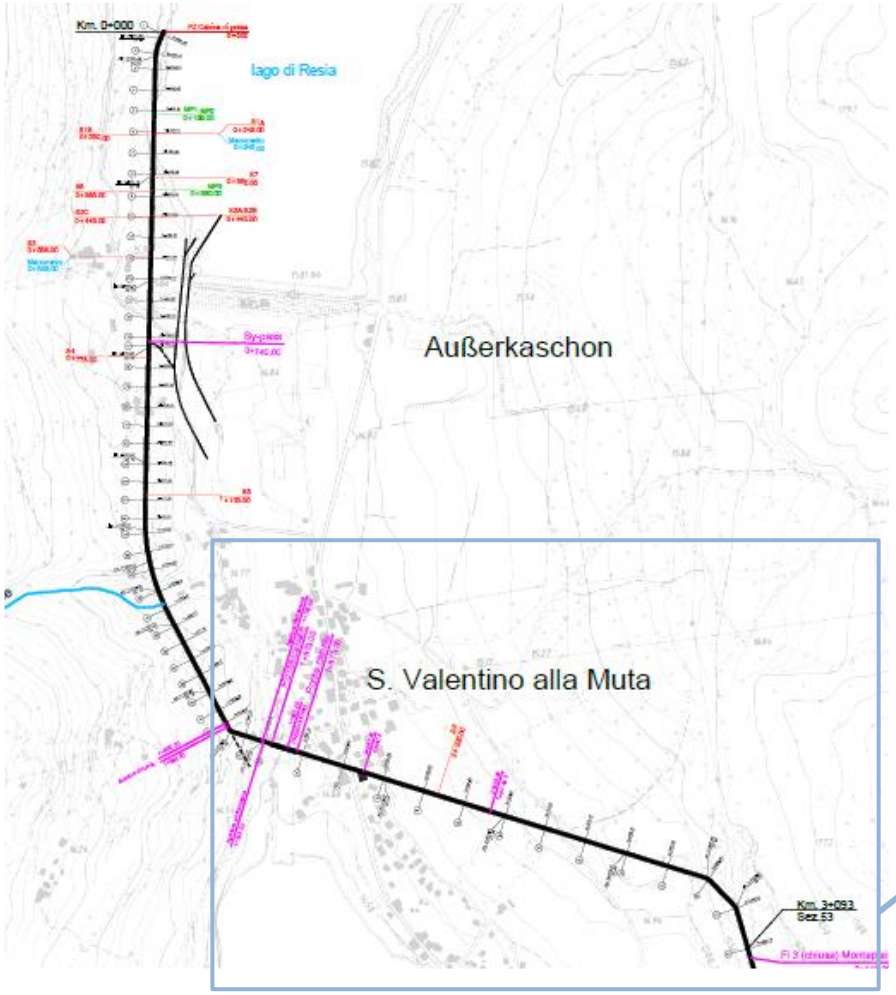
CONTRACTORS

Rotech Srl
Relining GRP (OS35)

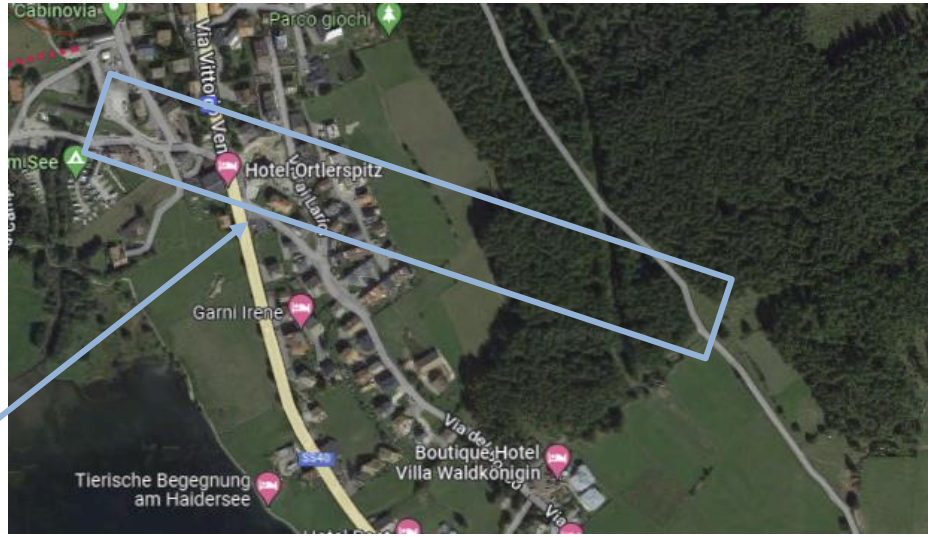
P.A.C. S.P.A.
Gallery Preparatory Works (OG2)

Project Manager: Ing. Sabatino Riccio
Site Manager: Geom. Franco Congiu
Site Manager: Geom. Paolo Gallus

GEOGRAPHICAL POSITION

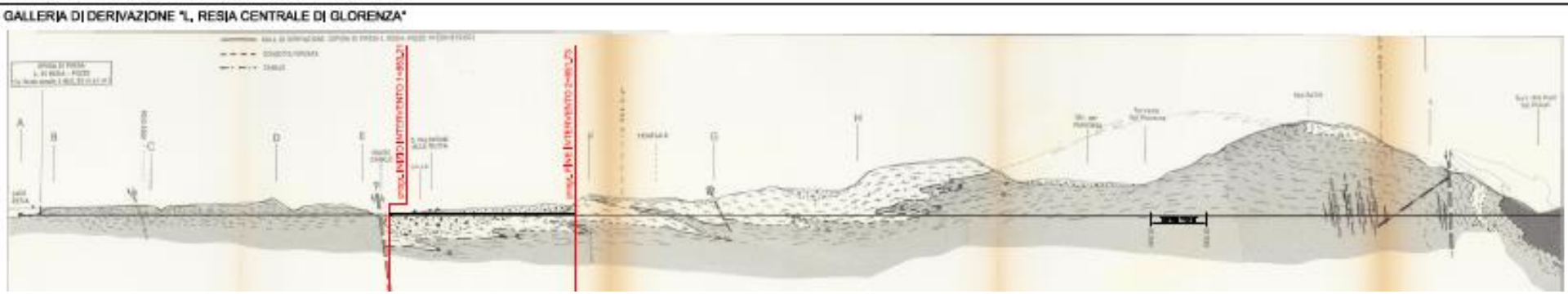


The tunnel runs for a length of approximately 12 km up to the power station. The relining section involves 1 km located in San Valentino (BZ)

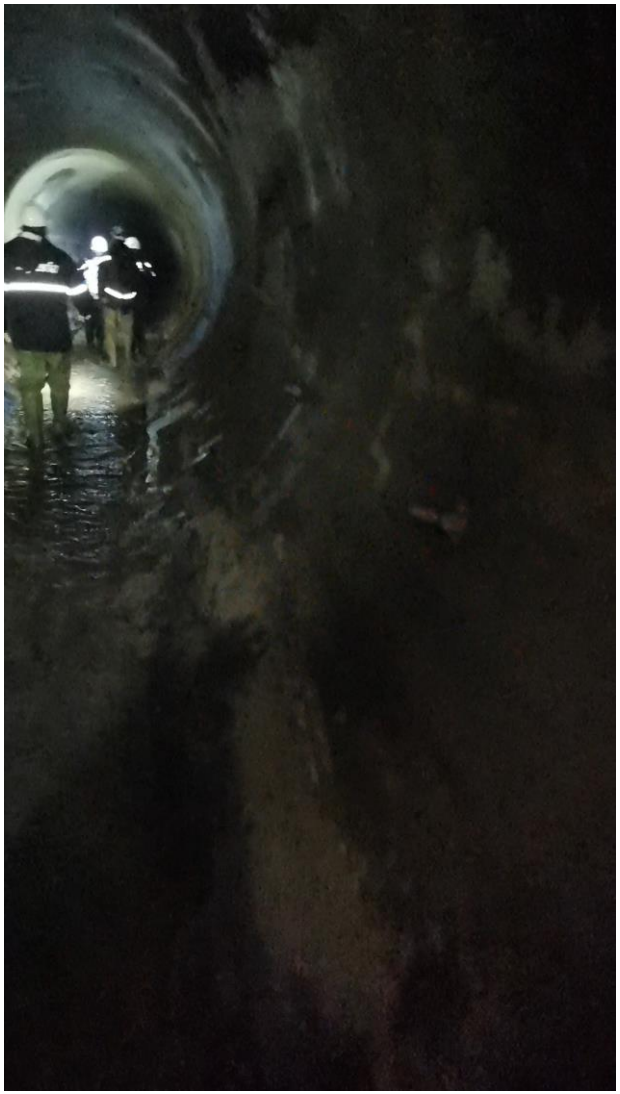


GEOGRAPHICAL POSITION

Relining GRP: Length = 998,72 m
Progressive Relining Start : 1853,00
Progressive Relining End : 2851,72



GALLERY INITIAL CONDITION



No cracks have ever appeared in the tunnel.

Purpose: restoring the hydraulic functionality.

Considering the size of the GRP pipes and taking into account the grout injections, preparatory activities were necessary for the relining works.

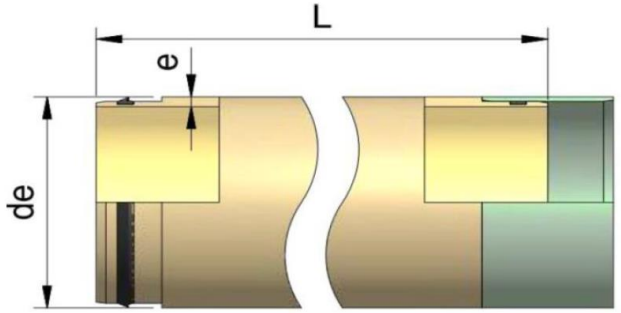
STATE OF THE TUNNEL AFTER INTERVENTION TO LIMIT WATER INGRESS

Operations carried out manually:

- water jet cleaning
- levelling of the bottom of the tunnel
- localized demolition and scarification
- eliminating the riveting (consisting of plates and bolts)

GRP PIPE: FLOWTITE GREY

DN 2700 – PN 6 – SN 10000 – WATER PRESSURE SYSTEM (Amiblu)

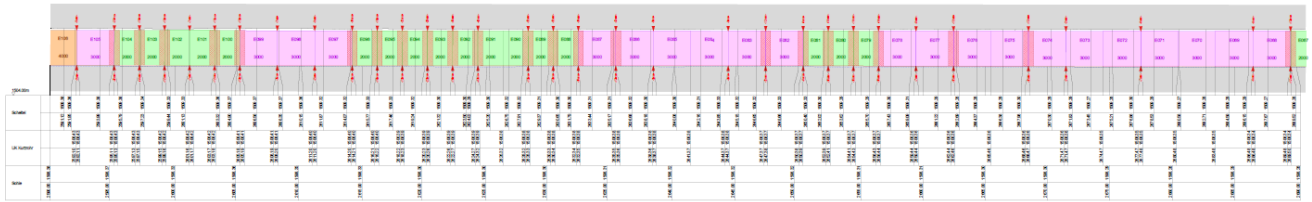


		Unità	Tubazione	Manicotto
Diametro nominale	DN		2700	2700
Pressione nominale	PN	bar	6	6
Rigidezza nominale	SN	N/m²	10000	10000
Diametro esterno	d_e	mm	2759 +6/-1	2773 +5/-1
Diametro Maschio tubazione	d_{ps}	mm	2758.5 +0.5/0.5	
Diametro interno, minimo	d_{min}	mm	2656.5	2745
Spessore, minimo	e	mm	50.5	14
Densità materiale PRFV	$\rho_{r,Co}$	kg/dm³	2.0	1.6
Modulo a trazione circonferenziale	E_{CT}	GPa	10.0	
Modulo a flessione circonferenziale	E_{CF}	GPa	20.0	
Modulo a trazione longitudinale	E_{LT}	GPa	6.0	
Resistenza a trazione circonferenziale, specifica	σ_{CT}	N/mm²	129.3	
Resistenza a trazione longitudinale, specifica	σ_{LT}	N/mm²	22.0	
Coefficiente di Poisson	v		0.22	
Coefficiente di dilatazione termica	α_L	1/C°	$26 * 10^{-6}$	
Scabrezza Idraulica	k	mm	0.029	
Lunghezza manicotto	L_{co}	mm		367

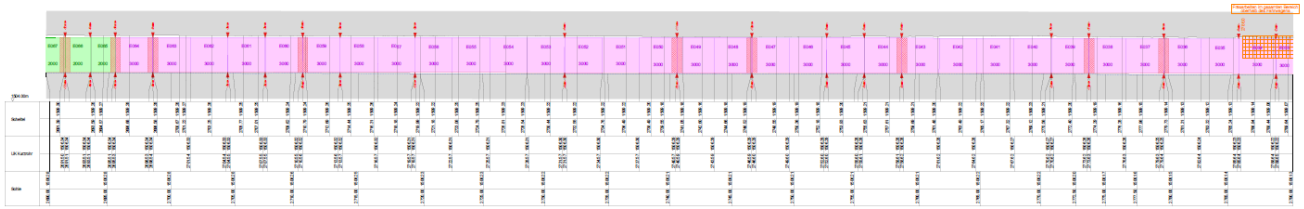
EN 1796: GRP pipe system for water supply with or without pressure
I valori della tabella precedente sono stati calcolati in base a un primo disegno della tubazione. Possono essere aggiornati con il disegno revisionato di produzione.

THE PROJECT - PLANIMETRIC PROFILE

Following the 3D laser-scan measurement, a plano-altimetric profile was obtained.



Therefore, pipes of different lengths were used: 2, 3, 4 and 6 m.



THE UNLOADING AND STORAGE OF PIPES

Pipe unloading and transport

The pipes arrived from Spain on special wheeled transport.

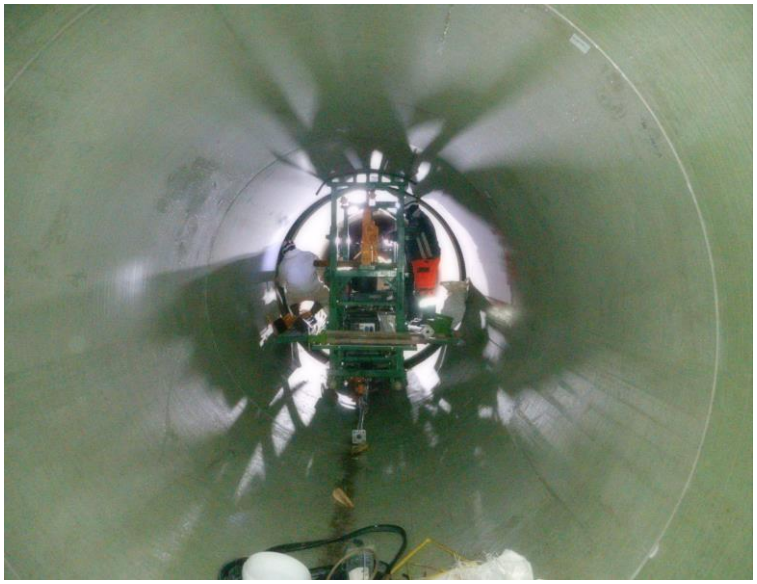
Each transport included 12 metres of pipes.

Storage area

PIPE UNLOADING AT THE ONLY INSERTION POINT

Each pipe weighs 1 ton meter, two excavators were used to unload and insert the pipes.
The pipes were transported inside for a length of 1 km using specially designed carts.

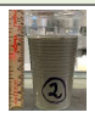
Once the pipes reached the point specified in the laying plan, they were coupled using a hydraulic system.
The connection was carried out with special equipment to ensure that the pipe was inserted into the coupling sleeve.



GAP INJECTION BETWEEN GRP PIPE AND EXISTING TUNNEL

Creteo®Inject CC 854 SM

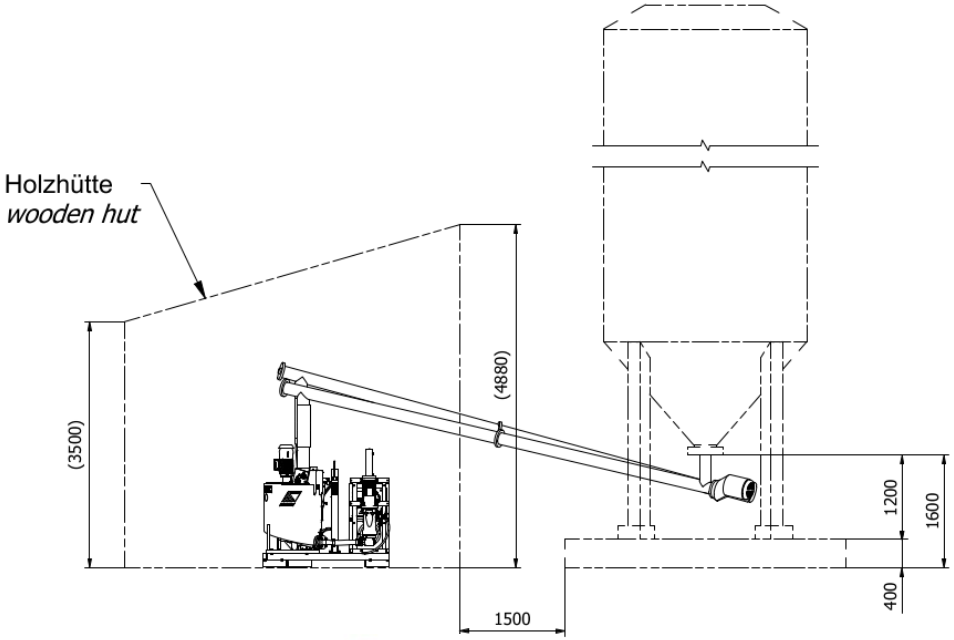
Malta per ancoraggi con superfluidificante

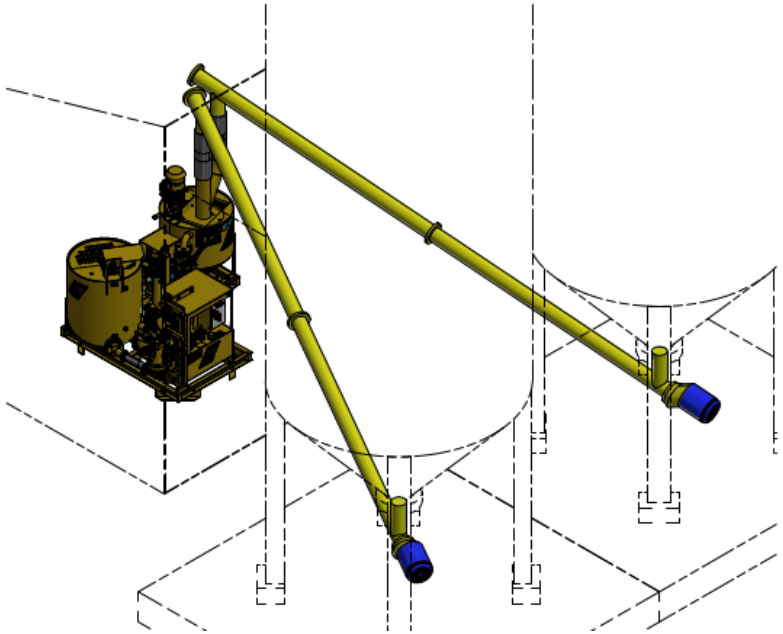
CreteoInject CC 854 SM Alperia____Partschins				
Prova 1115 09.11.2021	W/F (acqua/miscela)	Miscela di base (GM)	GM + 0,2 % FM	GM + 0,4 % FM
		0,60	0,50	0,40
P-Numero		2	4	6
Densità apparente	kg/lt	0,995	0,995	0,995
Peso specifico	to/m³	1.665	1.750	1.850
				
ABM	mm	400	400	450
				
Massa sedimentata			Vertikal	Vertikal
24 Std	%	-2	-1	0
				
Inizio solidificazione	h	< 5	<4	< 3
Resistenza alla compressione				
DF (1d)	Mpa	0,50	1,70	2,90
DF (3d)	Mpa	1,40	2,20	5,20
DF (7d)	Mpa	2,00	3,80	6,80
DF (14d)	Mpa	2,50	4,60	7,50
DF (28d)	Mpa	3,20	6,50	10,50
DF (28d)	Mpa	per la miscela di base con un W/F di 1,00	1,2 per il calcolo statico	

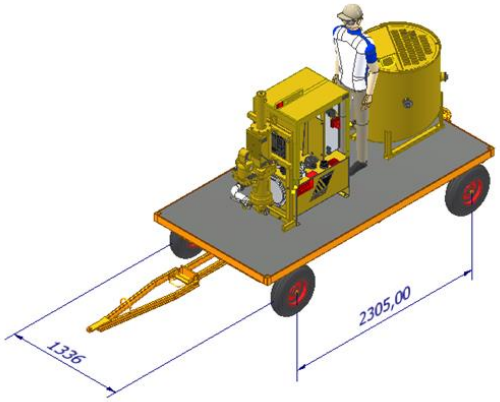
Dati tecnici:

Cod. art.	**2000694375**
Imballaggio	
Quantità per unità	1.000 kg/cf.
Granulometria	0 – 0,09 mm
Resa malta bagnata	ca. 0,995 kg/l
Valore W/F	**0,40 + 0,4 % fluidificante**
Fabbisogno d'acqua	400 l/t
Peso specifico malta fresca	ca. 1.850 kg/m³
Misura di assettamento (ABM)	ca. 450 mm
Unità di sedimentazione (24 h)	ca. -0,0 %
Inizio della presa	ca. 3,0 h
Resistenza alla compressione (28 d)	> 7,0 MPa
Resistenza alla compressione (28 d) dietro al tubo	con W/F di > 0,40 – 1,00 > 2,5 MPa
Tempo di lavorazione	< 180 min

THE GROUT INJECTION DESIGN - THE CHOICE OF THE INJECTION SYSTEM

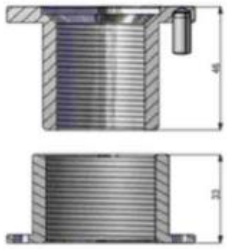


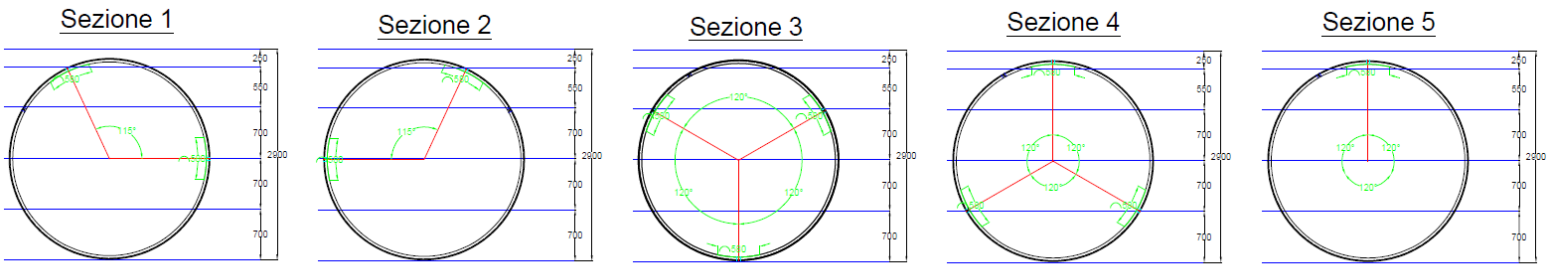


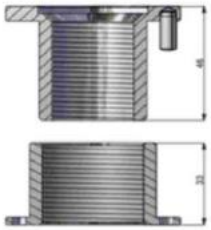


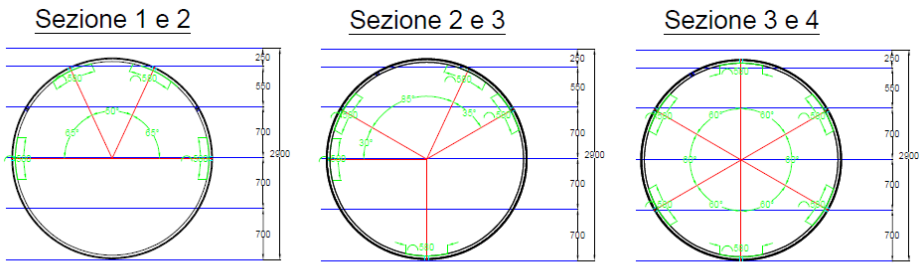
THE GROUT INJECTION DESIGN - THE INJECTION VALVE AND ITS POSITION IN THE PIPE

Stainless steel injection nipples were installed on the pipe by the manufacturer where the mortar was injected and then sealed with a plug and laminated.



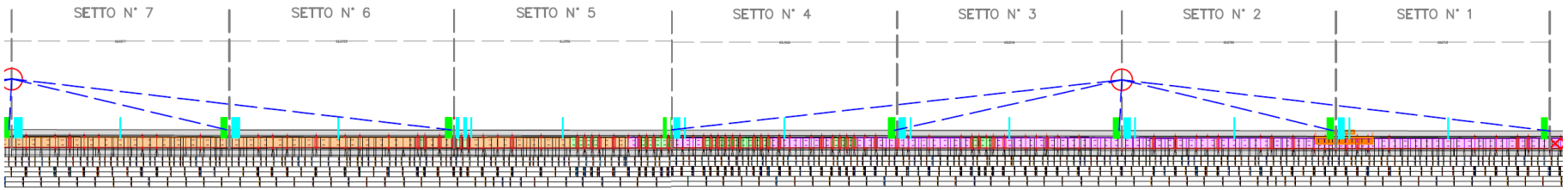


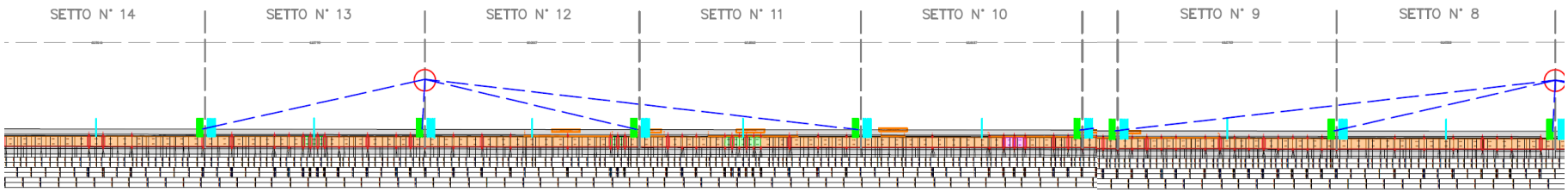




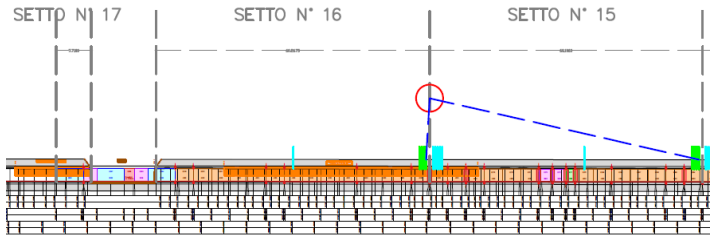
THE INJECTION SEPTA

17 internal sections every 60 m.
The injection design required a pump to be positioned at a distance of 120 m from the injection point.





4 sections were completed from one point.



THE INJECTION SEPTA

The mortar was stored outside in 14 silos of approximately 20 ton each.

The mixed mortar was pumped into the tunnel through DN 50 pipes for a length of 900 m to another mixing plant located on a mobile cart.

The injection was carried out in layers so as not to create a floating effect, from downstream to upstream.

FINITE ELEMENT MODELLING OF THE PIPE

5. Lagerung und Einwirkungen

Die Lagesicherung erfolgt durch Abstützungen (Verkeilungen) beidseits des Scheitels im Abstand von 30°, 60° und 90°.

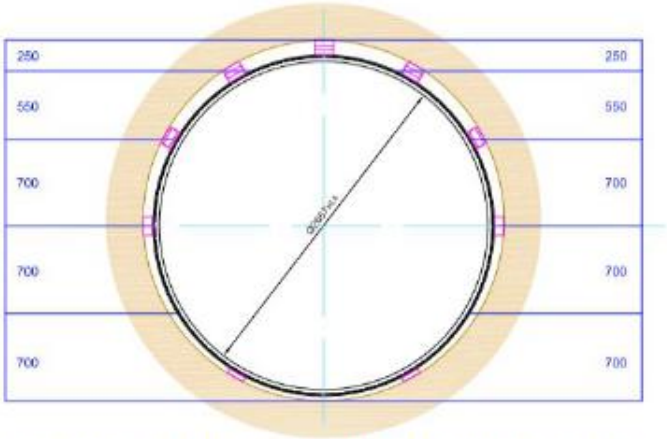
Auch wenn die Verfüllung des Ringraumes zwischen Liningrohr und Altrohr mit Dämmer lagenweise durchgeführt wird, muss als hydrostatischer Druck auf das Liningrohr der volle Druck des Verfüllmaterials bis zum Spiegel des Verfüllmaterials bei der letzten Lage angesetzt werden (RSV-Merkblatt 3.2 "Verfüllen von Ringräumen bei der Renovierung von Abwasserleitungen und -kanälen durch Liningverfahren", März 2016)

$i := 1,2..2$

Spezifisches Gewicht des Verfüllmaterials:

Verfüllmaterial $i := 1$ $\gamma_{Ds_i} := 16.65 \cdot \frac{kN}{m^3}$

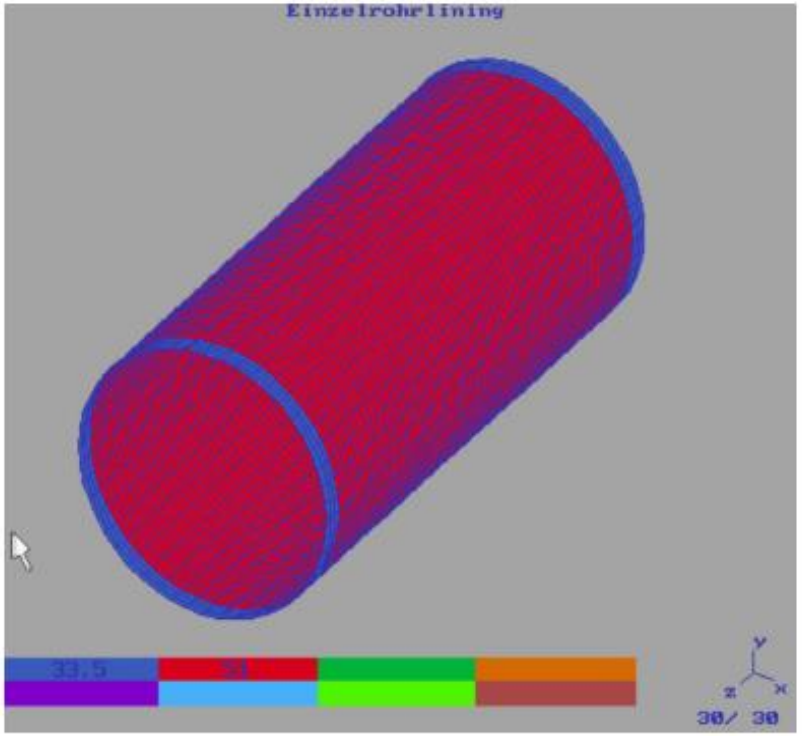
Verfüllmaterial $i := 2$ $\gamma_{Ds_i} := 18.5 \cdot \frac{kN}{m^3}$



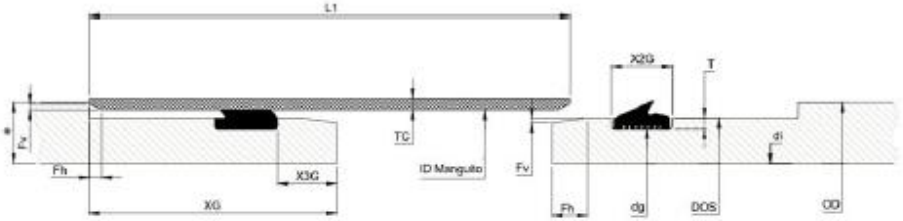
Für die Berechnung angesetzte Lagesicherung des Liningrohres mit den nacheinander einzubringenden Lagen

The deformation of the pipe during the injection phase was verified (FEM).

Die Liningrohr wird als räumliches Schalensystem diskretisiert.



FINITE ELEMENT MODELLING OF THE PIPE SLEEVE



Using a FEM model, the deformation of the coupler during the injection phase was verified.

Die Manschette wird als räumliches Schalensystem diskretisiert.

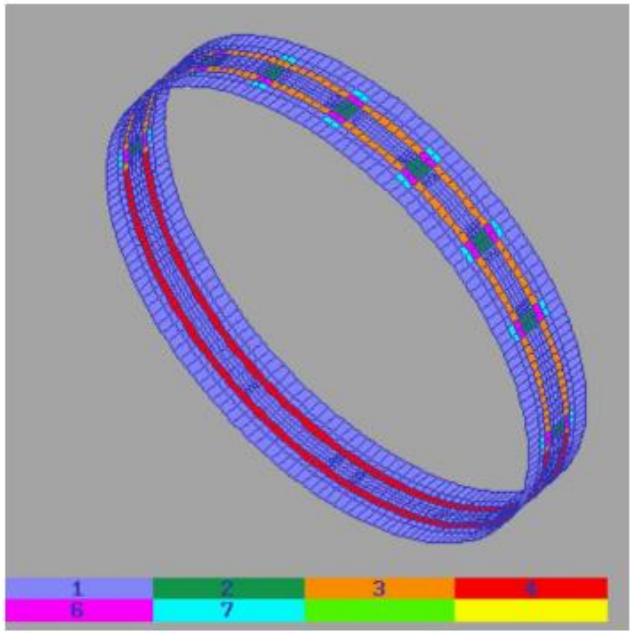
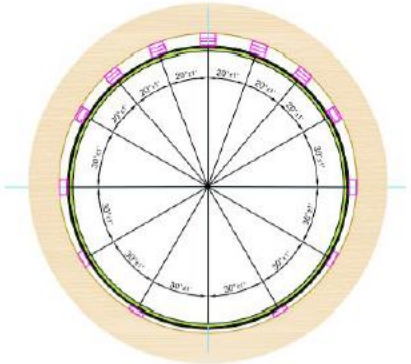


Abbildung 2: FEM-Netz der Manschette

5.2 Lagerung und Einwirkungen

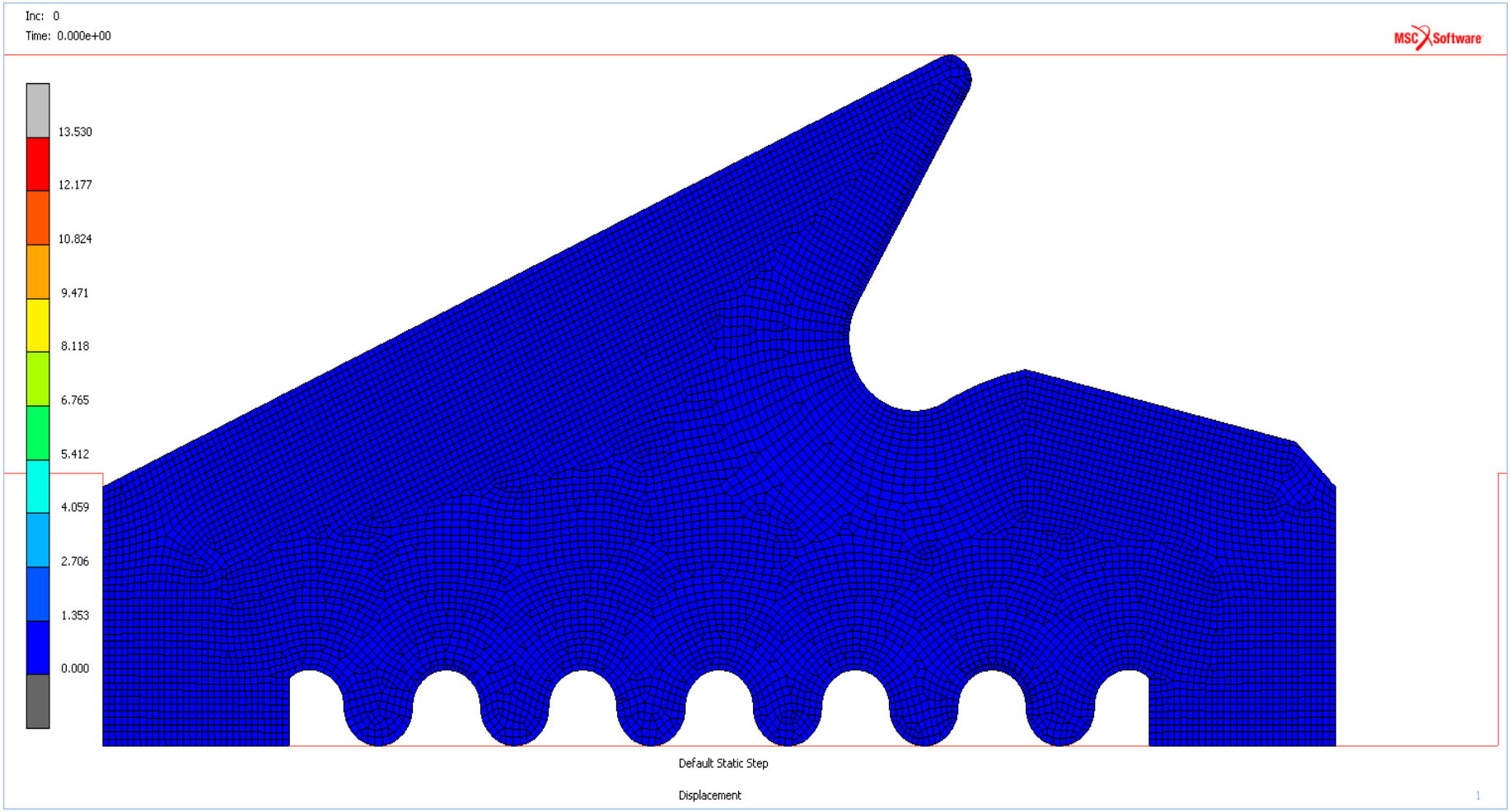
5.2.1 Lagerung und Steifigkeit der Keile

Die Lagesicherung erfolgt durch Abstützungen (Verkeilungen) beidseits des Scheitels im Abstand von 20°, 40,° 60° und 90° (Kämpfer), die zwischen dem Altrohr und der Manschette eingebracht werden (s. Abbildung 2).
Somit wird die aus dem Auftrieb resultierende Vertikalkraft aus den Rohren zunächst über die Dichtungen in die Manschette eingeleitet. Von dort wird sie auf die Abstützungen verteilt, die sie ihrerseits ins Altrohr einleiten. Die Manschette hat dabei analog einer Schwelle die Funktion, die weitgehend gleichförmige Last aus der Dichtung tangential bis zu den Auflagern weiterzuleiten (s. Abbildung 1).



Being the most delicate part of the system, several wooden supports were introduced.

FINITE ELEMENT MODELLING – Mortal injection




ROTECH

THE LAMINATIONS SYSTEM

Maximum permissible opening in the joints 0.3° or 19 mm.

The joints were laminated with resins and glass fibre with a width of 500 mm and a thickness of 20 mm.

THE LAMINATIONS SYSTEM

SEBASTIAN Composites Testing

Prüfergebnisse

Die Prüfergebnisse beziehen sich ausschließlich auf den vorliegenden Prüfgegenstand P22-46364. Etwaig angegebene Sollwerte wurden vom Auftraggeber zur Verfügung gestellt. Die SBKS GmbH & Co. KG übernimmt für die Richtigkeit dieser Angaben keine Gewährleistung.

APS/DWA M143-20:2005-11 // Wasserdichtheit

Prüfdatum	2022-02-14	**Verfahren**	APS
Prüfer(in)	B. König	**Konditionierung**	23 °C / 50 % r. F.
		Prüffläche	Kreis Ø 45 ± 5 mm
		Prüfflüssigkeit	Fluorescein-Lösung
		Prüfzeit	30 min
		Prüfdruck	0,5

Parameter	Ergebnis	Beurteilung
Wasserdichtheit	3 / 3 dicht	erfüllt

DIN EN ISO 14125:2011-05 Verfahren A // Dreipunktbiegeversuch

Prüfdatum 14.02.2022
Prüfer(in) B. König

Parameter	Einheit	Sollwert	Ergebnis	Stabw.	Beurteilung
Biegemodul	MPa	./.	9218	341	./.
Biegespannung bei Maximum	MPa	./.	236,4	9,7	./.
Biegedehnung bei Maximum	%	./.	3,9	0,2	./.
Gesamtwanddicke	mm	./.	19,6	0,2	./.

Einzelheiten zur Prüfung sind dem Prüfprotokoll im Anhang zu entnehmen.

Bernd König, Dipl.-Ing. (FH)
Laborleitung

St. Wendel, 2022-02-14

Der Anhang zu diesem Bericht umfasst 1 Seite(n).

Prüfbericht B22-65859 vom 2022-02-14 Seite 3 von 3

Report

Start Time: 14/02/22 16:53:20 End Time: 15/02/22 13:38:20 Sampling rate: 900sec Data number: 84
Temp Alarm HI: 40 °C Temp Alarm Low: -16 °C RH Alarm HI: 99 %RH RH Alarm Low: 29 %RH
Temp MAX: 22.6 °C @16:53:20 14/02/22 Temp MIN: 3.7 °C @05:53:20 15/02/22 Temp AVG: 6.73 °C
RH MAX: 98.3 %RH @23:23:20 14/02/22 RH MIN: 20.6 %RH @16:53:20 14/02/22 RH AVG: 83.10 %RH

No.	Time	(%RH)Humidity	(°C)Temperature	(°F)Temperature	(°C)WB	(°F)WB	(°C)DP	(°F)DP
1	14/02/22 16:53:20	20.6	22.6	72.7	15.5	59.9	-1.1	30.1
2	14/02/22 17:08:20	24.0	15.7	60.3	9.0	48.2	-4.8	23.4
3	14/02/22 17:23:20	52.7	16.3	61.3	11.4	52.6	6.6	43.9
4	14/02/22 17:38:20	52.6	18.9	66.0	13.6	56.5	9.0	48.2
5	14/02/22 17:53:20	66.0	19.3	66.7	15.4	59.8	12.8	55.0
6	14/02/22 18:08:20	68.0	20.4	68.7	16.7	62.0	14.3	57.7
7	14/02/22 18:23:20	55.7	14.3	57.7	10.1	50.1	5.6	42.0
8	14/02/22 18:38:20	74.3	8.9	48.0	6.9	44.4	4.6	40.2
9	14/02/22 18:53:20	84.6	6.8	44.2	5.7	42.2	4.4	39.9
10	14/02/22 19:08:20	89.9	6.1	43.0	5.4	41.7	4.6	40.2
11	14/02/22 19:23:20	92.7	5.8	42.4	5.3	41.5	4.7	40.5
12	14/02/22 19:38:20	94.2	5.6	42.1	5.2	41.3	4.7	40.5
13	14/02/22 19:53:20	95.0	5.7	42.3	5.3	41.6	5.0	40.9
14	14/02/22 20:08:20	95.7	5.7	42.3	5.4	41.7	5.1	41.1
15	14/02/22 20:23:20	96.2	5.6	42.1	5.3	41.6	5.0	41.1
16	14/02/22 20:38:20	96.5	5.7	42.3	5.5	41.8	5.2	41.3
17	14/02/22 20:53:20	97.0	5.7	42.3	5.5	41.9	5.3	41.5
18	14/02/22 21:08:20	97.1	5.7	42.3	5.5	41.9	5.3	41.5
19	14/02/22 21:23:20	97.4	5.7	42.3	5.5	41.9	5.3	41.6
20	14/02/22 21:38:20	97.4	5.7	42.3	5.5	41.9	5.3	41.6
21	14/02/22 21:53:20	97.7	5.7	42.3	5.5	42.0	5.4	41.7
22	14/02/22 22:08:20	97.7	5.6	42.1	5.4	41.8	5.3	41.5
23	14/02/22 22:23:20	97.9	5.6	42.1	5.5	41.8	5.3	41.5
24	14/02/22 22:38:20	98.0	5.6	42.1	5.5	41.8	5.3	41.6
25	14/02/22 22:53:20	98.0	5.6	42.1	5.5	41.8	5.3	41.6
26	14/02/22 23:08:20	98.3	5.5	41.9	5.4	41.7	5.3	41.5
27	14/02/22 23:23:20	98.3	5.6	42.1	5.5	41.9	5.4	41.6
28	14/02/22 23:38:20	94.7	5.6	42.1	5.2	41.4	4.8	40.7
29	14/02/22 23:53:20	88.3	5.6	42.1	4.8	40.6	3.8	38.9
30	15/02/22 00:08:20	87.4	5.5	41.9	4.6	40.3	3.6	38.4

Test samples taken to verify both the mechanical resistance and the tightness under the internal pressure of the tunnel during its service.

The temperature and humidity values inside the tunnel were constantly registered.

THE LAMINATIONS SYSTEM

VALVE LAMINATION

Lamination 500x500x20 mm

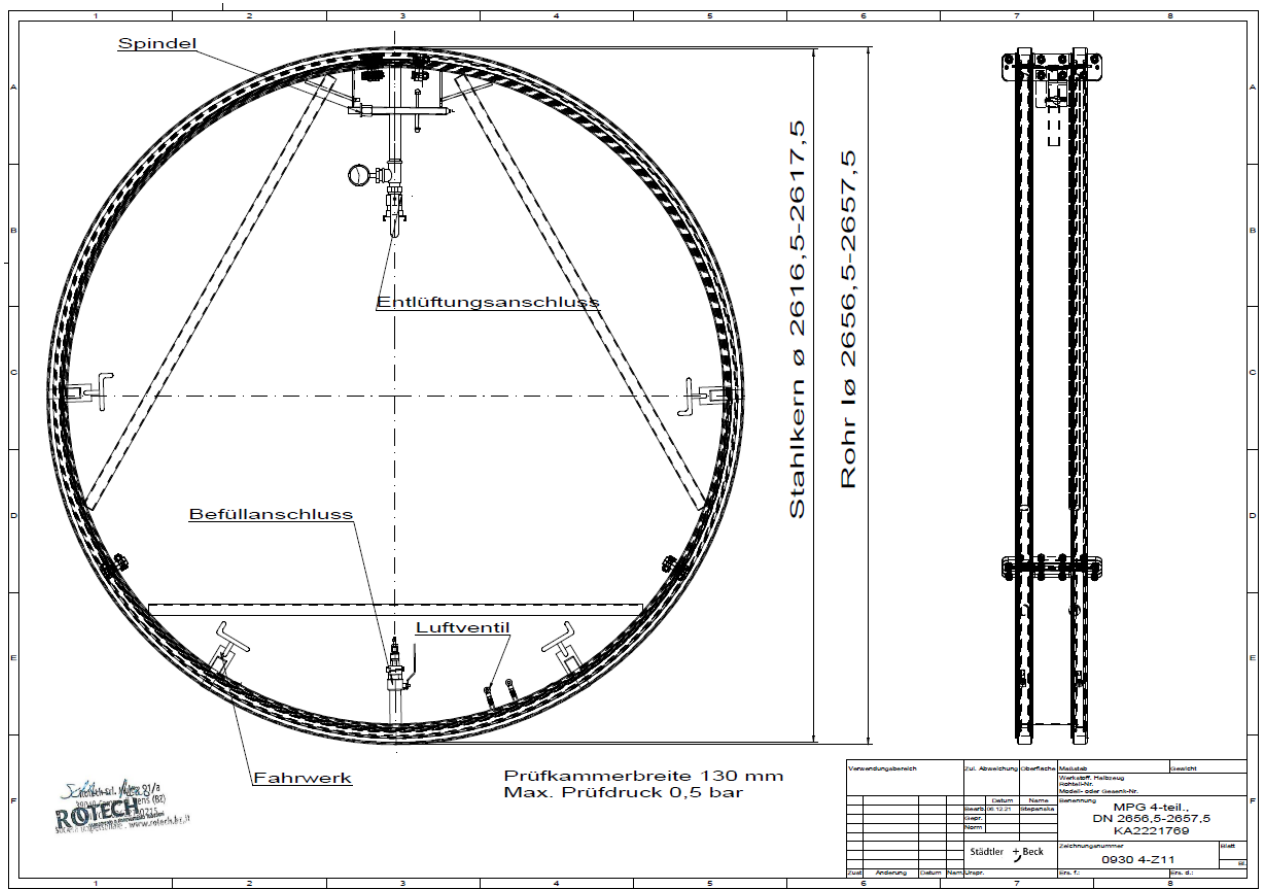
CONNECTION WITH THE OLD TUNNEL

CONNECTING PRFV PIPES AND EXISTING TUNNEL

The connection between the existing tunnel and the GRP pipes was made through a REDEX-type coupling.

THE JOINT LEAK TEST UNI EN 1610

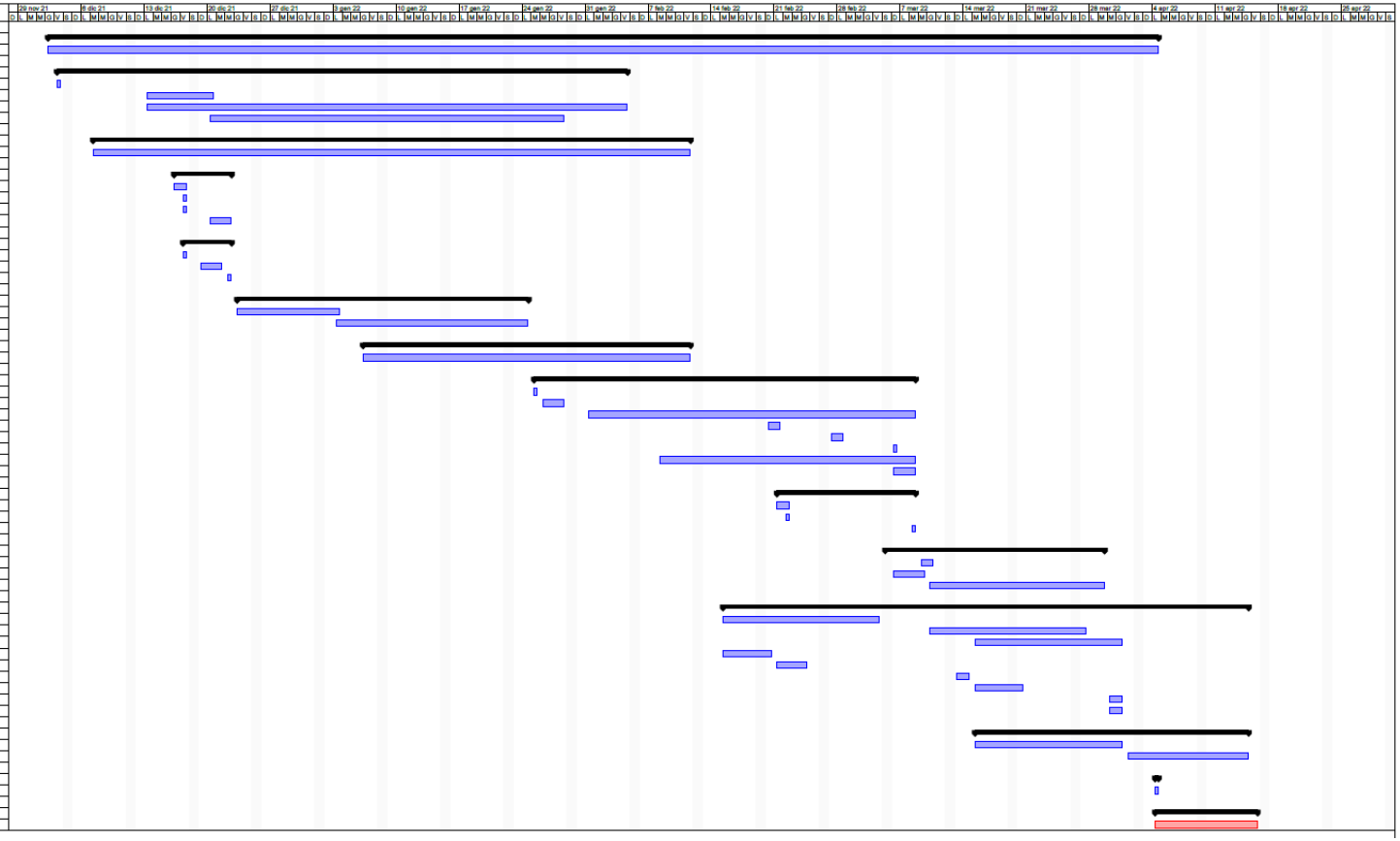
Sealing test on joints according to EN 1610



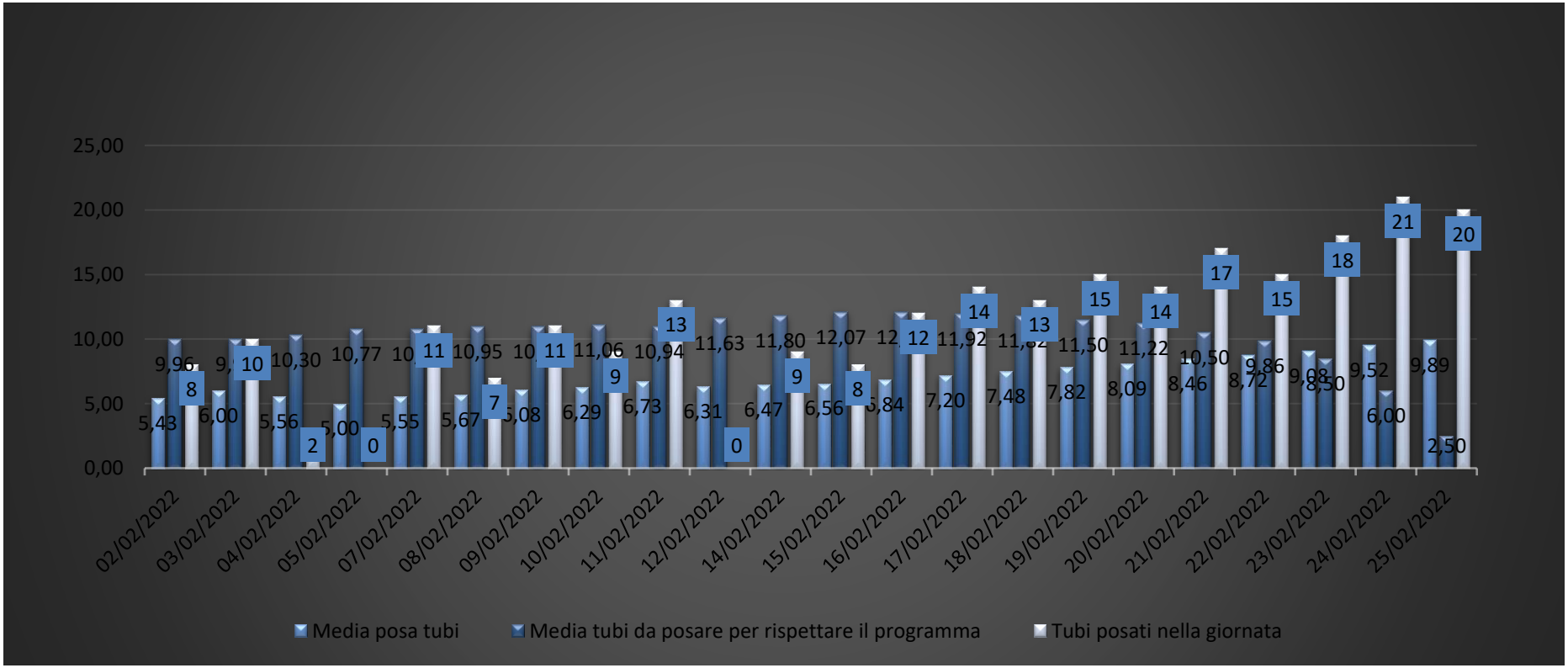
- Pressure 500 mbar
- Duration 5 min.

THE WORK SCHEDULE

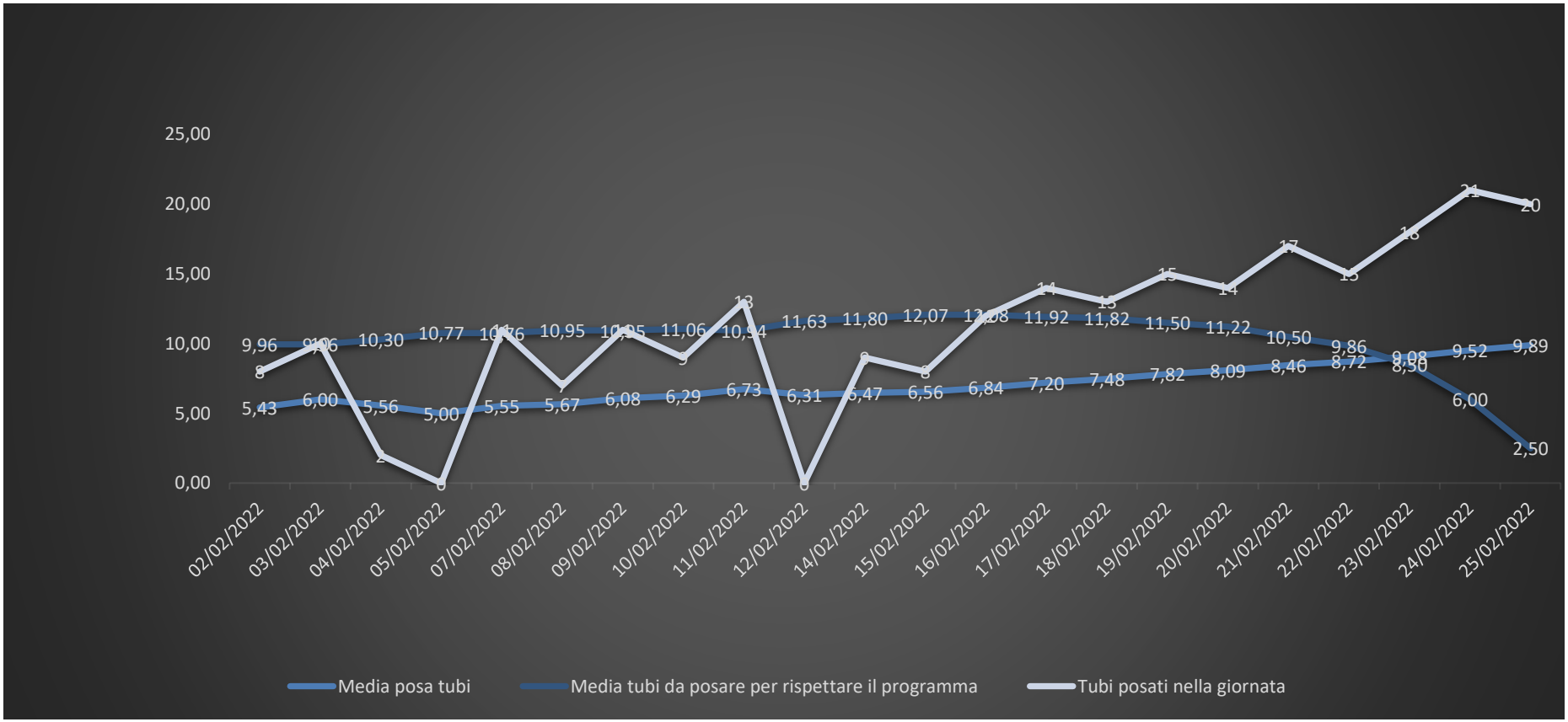
	Nome	Data di Avvio	Data di chiusura
1	**ESECUZIONE LAVORI**	**02/12/21 8.00**	**04/04/22 17.00**
2	ESECUZIONE LAVORI	02/12/21 8.00	04/04/22 17.00
3	**IMPIANTO CANTIERE**	**03/12/21 8.00**	**04/02/22 17.00**
4	CONSEGNA MEZZI D'OPERA	03/12/21 8.00	03/12/21 17.00
5	INSTALLAZIONE CONTAINER E WC	13/12/21 8.00	20/12/21 17.00
6	IMPIANTO ELETTRICO E IDRICO	13/12/21 8.00	04/02/22 17.00
7	POSIZIONAMENTO SILOS	20/12/21 8.00	28/01/22 17.00
8	**CONSEGNA TUBI**	**07/12/21 8.00**	**11/02/22 17.00**
9	CONSEGNA TUBI	07/12/21 8.00	11/02/22 17.00
10	**CONSEGNA AREE E VERFICA GALLERIA**	**16/12/21 8.00**	**22/12/21 17.00**
11	PREPARAZIONE RAMPA (PAC)	16/12/21 8.00	17/12/21 17.00
12	CONSEGNA AREA BOX	17/12/21 8.00	17/12/21 17.00
13	CONSEGNA GALLERIA	17/12/21 8.00	17/12/21 17.00
14	CONSEGNA AREA SILOS	20/12/21 8.00	22/12/21 17.00
15	**RELINING**	**17/12/21 8.00**	**22/12/21 17.00**
16	ATTIVITA' TOPOGRAFO	17/12/21 8.00	17/12/21 17.00
17	POSA TUBI (UN TURNO DA 10 ORE)	19/12/21 8.00	21/12/21 17.00
18	MESSA IN SICUREZZA AREA CANTIERE	22/12/21 8.00	22/12/21 17.00
19	**PERIODO NATALIZIO**	**23/12/21 8.00**	**24/01/22 17.00**
20	RIENTRO	23/12/21 8.00	03/01/22 17.00
21	FERMO CANTIERE - DECRETO GIUDICE	03/01/22 8.00	24/01/22 17.00
22	**CONSEGNA TUBI**	**06/01/22 8.00**	**11/02/22 17.00**
23	CONSEGNA TUBI (DA CONFERMARE)	06/01/22 8.00	11/02/22 17.00
24	**RELINING**	**25/01/22 8.00**	**08/03/22 17.00**
25	RIPRISTINO AREA CANTIERE	25/01/22 8.00	25/01/22 17.00
26	POSA TUBI (UNA SQUADRA)	26/01/22 8.00	28/01/22 17.00
27	POSA TUBI (DUE SQUADRE)	31/01/22 8.00	08/03/22 17.00
28	POSA TUBI (TRE SQUADRE)	19/02/22 8.00	21/02/22 17.00
29	POSA TUBI (TRE SQUADRE)	26/02/22 8.00	28/02/22 17.00
30	POSA TUBI (TRE SQUADRE)	06/03/22 8.00	08/03/22 17.00
31	PROVA DI TENUTA A PRESSIONE	08/02/22 8.00	08/03/22 17.00
32	ACCOPPIAMENTO TUBI/STRALIS	06/03/22 8.00	08/03/22 17.00
33	**IMPIANTO MISCELAZIONE**	**21/02/22 8.00**	**08/03/22 17.00**
34	INSTALLAZIONE IMPIANTO	21/02/22 8.00	22/02/22 17.00
35	PROVE IMPIANTO	22/02/22 8.00	22/02/22 17.00
36	PROVA IMPIANTO PIU' POMPA	08/03/22 8.00	08/03/22 17.00
37	**INIEZIONE INTERCAPEDINE**	**05/03/22 8.00**	**29/03/22 17.00**
38	INIEZIONE INTERCAPEDINE FASE 1 PK 1853.00	09/03/22 8.00	10/03/22 17.00
39	INSTALLAZIONE TUBI/CAVO ELETTRICO	05/03/22 8.00	09/03/22 17.00
40	INIEZIONE INTERCAPEDINE FASE 2 PK 2851.72	10/03/22 8.00	29/03/22 17.00
41	**LAMINAZIONI**	**15/02/22 8.00**	**14/04/22 17.00**
42	LAMINAZIONE FASE 1 (50 GIUNTI PARZIALI)	15/02/22 8.00	04/03/22 17.00
43	LAMINAZIONE FASE 2 (50+40+NIPPLES)	10/03/22 8.00	27/03/22 17.00
44	LAMINAZIONE FASE 3 (50+40+NIPPLES)	15/03/22 8.00	31/03/22 17.00
45	PREPARAZIONE SOTTOFONDO TESTATA PK 2851.72	15/02/22 8.00	20/02/22 17.00
46	LAMINAZIONE TESTATA PK 2851.72	21/02/22 8.00	24/02/22 17.00
47	PREPARAZIONE SOTOFONDO TESTATA PK 1853.00	12/03/22 8.00	14/03/22 17.00
48	LAMINAZIONE TESTATA PK 1853.00	15/03/22 8.00	20/03/22 17.00
49	INSTALLAZIONE REDEX PK 2851.72	30/03/22 8.00	31/03/22 17.00
50	INSTALLAZIONE REDEX PK 1853.00	30/03/22 8.00	31/03/22 17.00
51	**CHIUSURA GALLERIA (PAC)**	**15/03/22 8.00**	**14/04/22 17.00**
52	CALCESTRUZZI	15/03/22 8.00	31/03/22 17.00
53	RIPRISTINI	01/04/22 7.00	14/04/22 17.00
54	**CONSEGNA OPERA**	**04/04/22 8.00**	**04/04/22 17.00**
55	CONSEGNA OPERA	04/04/22 8.00	04/04/22 17.00
56	**SMOBILIZZO CANTIERE**	**04/04/22 8.00**	**15/04/22 17.00**
57	SMOBILIZZO CANTIERE	04/04/22 8.00	15/04/22 17.00



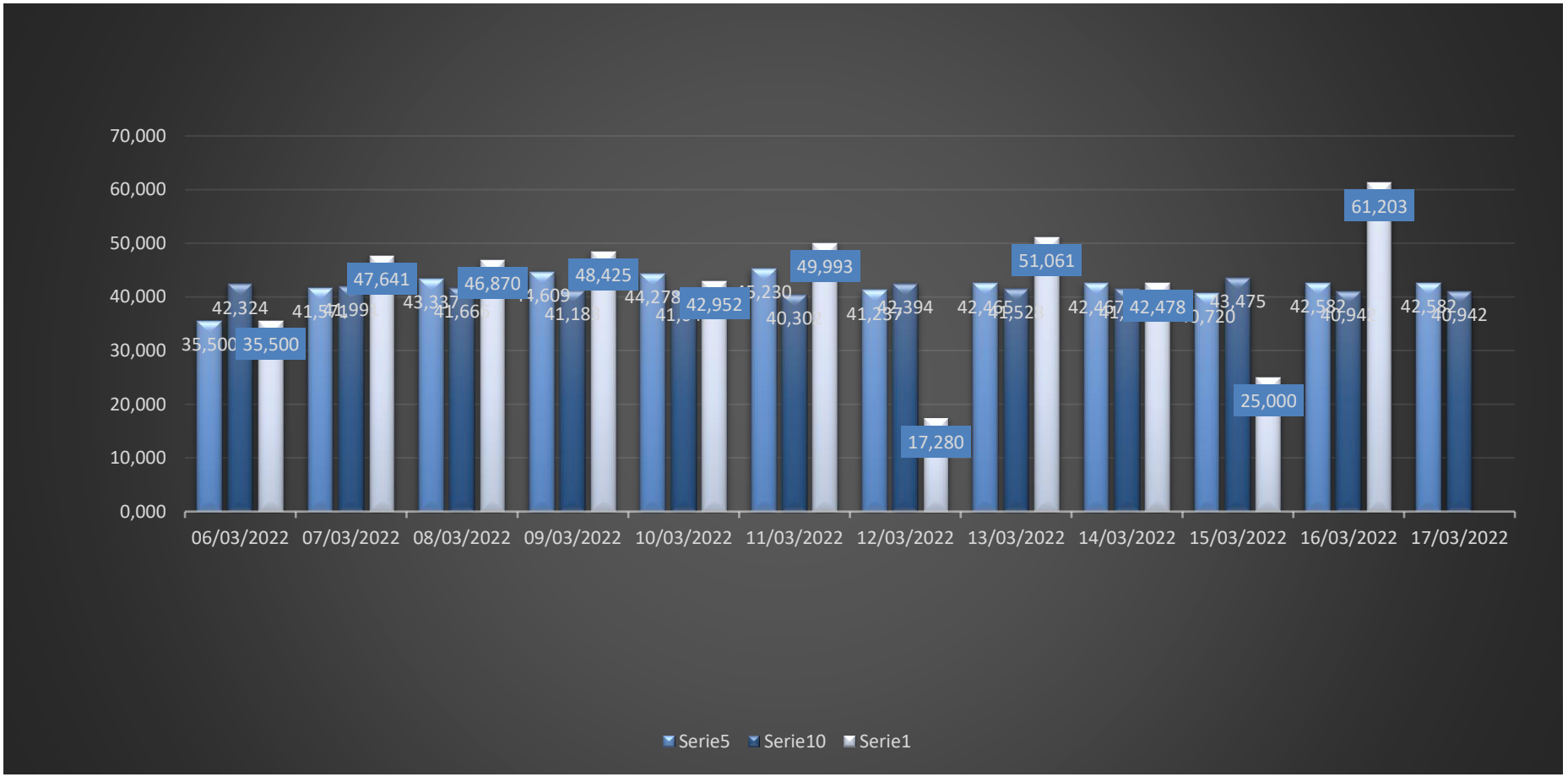
THE WORK SCHEDULE: SIMULATION AND PIPE-INSTALLATION CONTROL



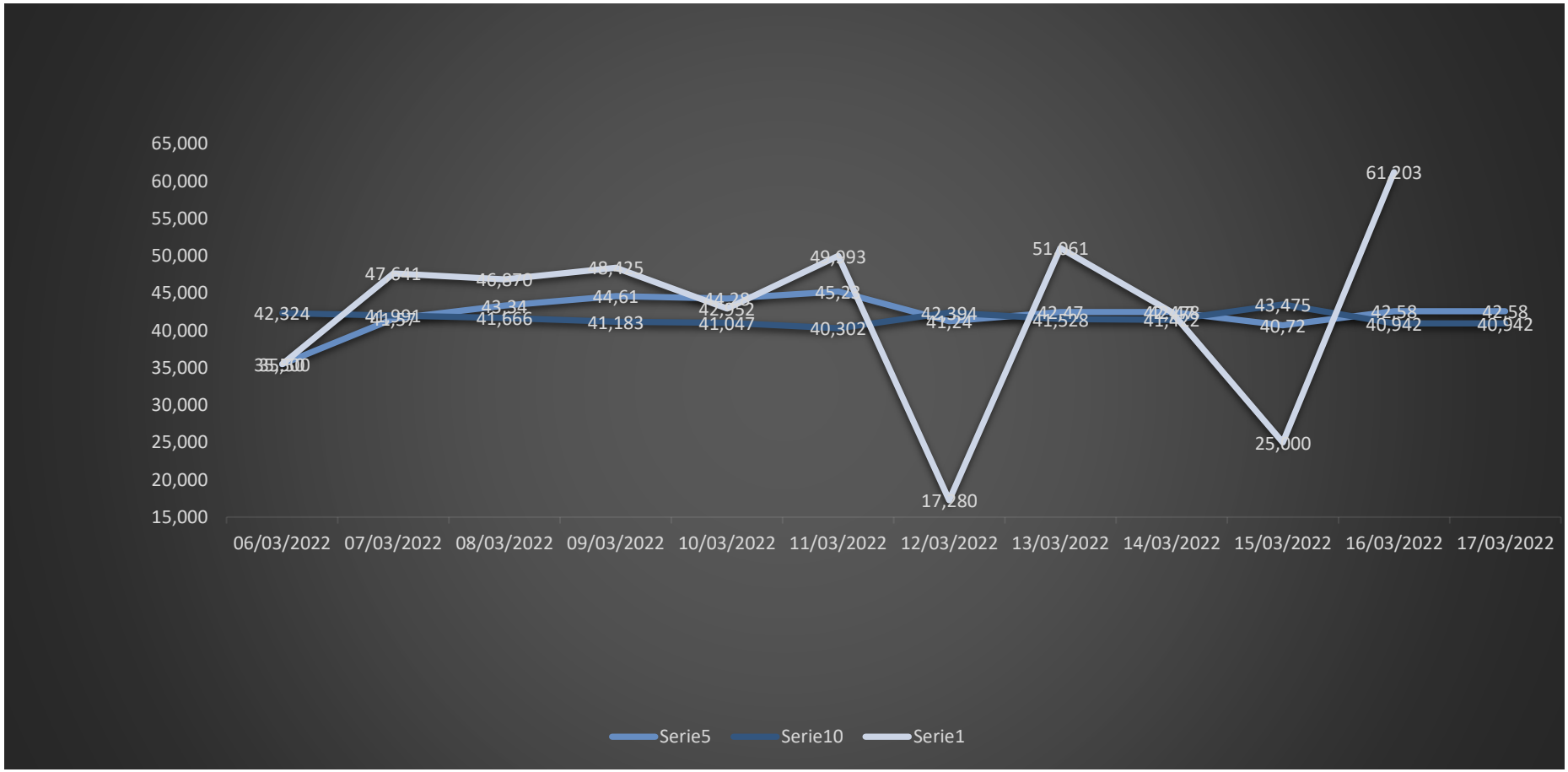
THE WORK SCHEDULE: SIMULATION AND PIPE-INSTALLATION CONTROL



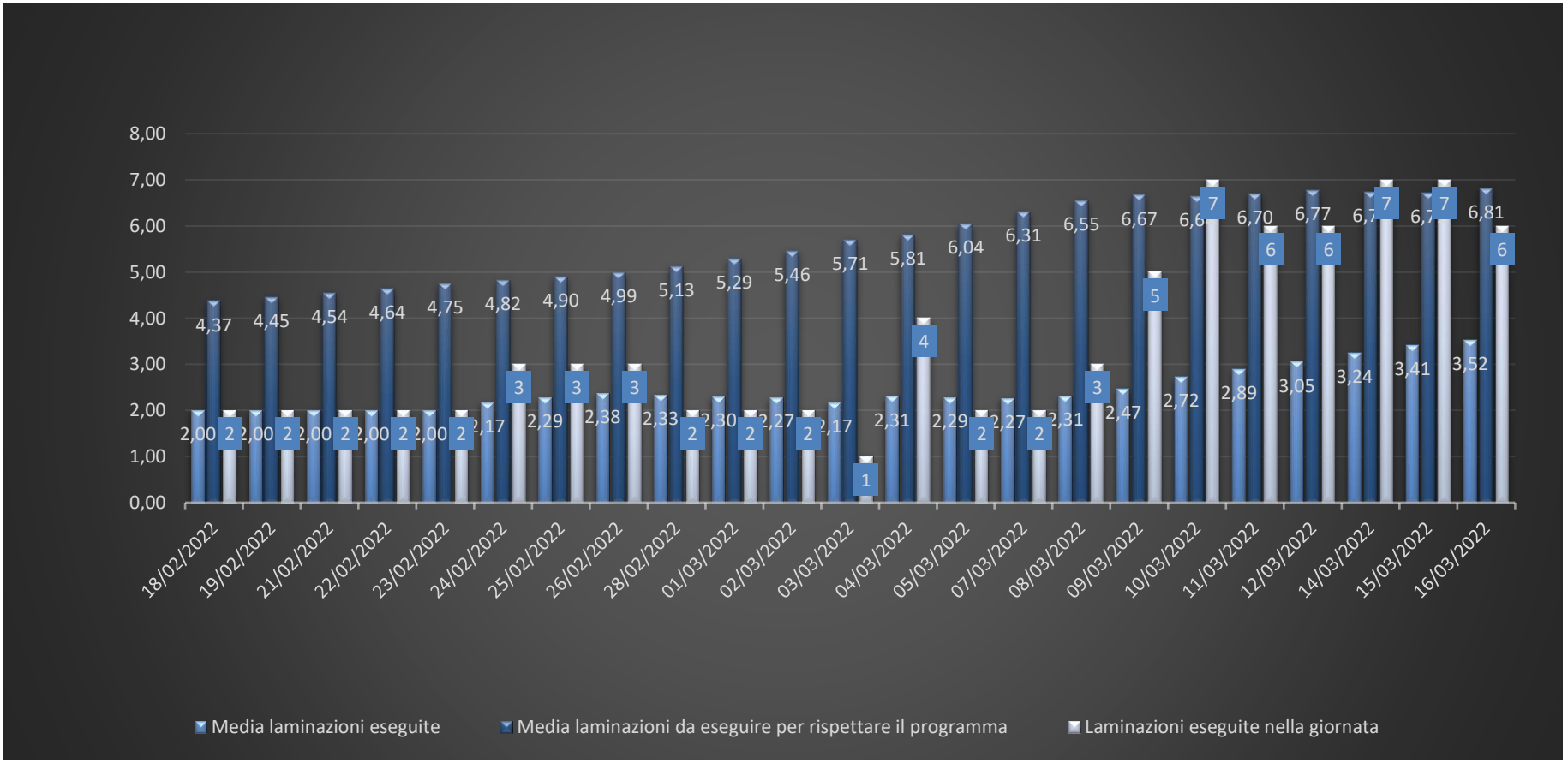
THE WORK SCHEDULE: SIMULATION INJECTION PHASE AND CONTROL



THE WORK SCHEDULE: SIMULATION INJECTION PHASE AND CONTROL



THE WORK SCHEDULE: SIMULATION LAMINATION PHASE AND CONTROL



THANK YOU FOR YOUR ATTENTION

Ing. Sabatino Riccio