EUROPEAN NO•DIG 2023 Conference ITALY

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CONSTRUCTION OF A COLLECTOR SEWER IN ROME BY MICROTUNNELING IN GEOLOGICALLY COMPLEX SOLIS AND IN AN URBAN CONTEXT OF PARTICULAR ENVIRONMENTAL AND ARCHAEOLOGICAL VALUE

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The Project

“Collettore Isola Farnese Crescenza – III lotto (eliminazione scarichi F77, F81 e by-pass depuratore Giustinianella)” ; the Company is ACEA and the Contractor is the JV CIPRIANI / ICOP

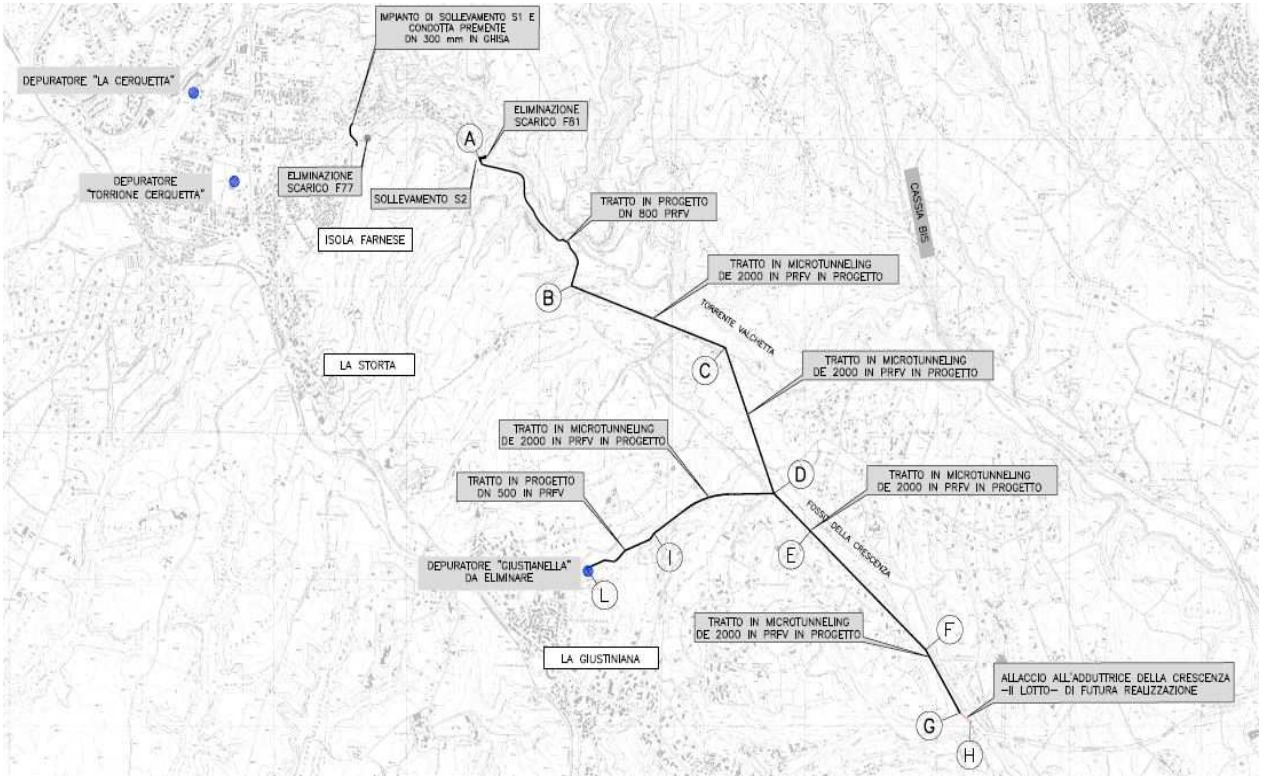
Purpouse of the project

It’s a part of a bigger project collecting all discharging of the North West area of Rome to the Cleaning Plant of Roma Nord serving 80.000 people

SOW: it is big collector from Isola Farnese, along Vejo park, to the II lot , nearby the GRA.

Very high value of the area and morphological constraints the reasons for ACEA to deploy innovative state of art MICROTUNNLLING:

- #7 MT for a total length of approx. 5,500 m,
- approx.1,800 m by open trench.
- GRP pipes DE 2047mm
- #6 deep shaft in secant piles
- **Drive length to the maximum of the technology > 1265m ! World Record for microtunelling with GRP PIPES**



CHALLENGES

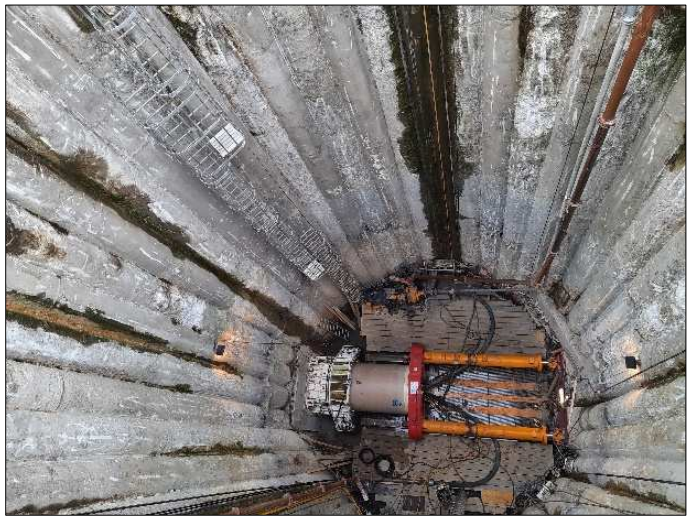
- very long drives, n.°3 drive with a sinlge drive length over 1,000 meters, and the longest in the world using GRP pipes, section B-C having a length of 1,215 meters;
- considerable variety of soils crossed, from gravel to sand, from silt to clay, even over-consolidated, even along in a single drive;
- Very high cover, in section D-C, more than 60 meters of cover;

Above all that represented already critical drilling conditions we directly experienced the presence of swelling clays in groundwater, that required the use of complex operating techniques to successfully complete the drives and safe recover the TBM.

THE WORKS

#7 drives for a total length of appr. 5.000m
including shafts, with a depth up to 25 m, to be built by a secant pile walls.

Section	Length (m)	Pipe type	External Diameter (mm)	Maximum Coverage (m)	Soil type* crossed	Drilling Starting Date	Drilling Ending Date
A-B	90	GRP	1200	10.3	1, 2	17/08/2020	27/08/2020
B-C	1235	GRP	2047	60	2	10/10/2020	16/01/2020
D-C	1069	GRP	2047	60	2, 3	06/03/2021	16/07/2021
D-E	376	GRP	2047	25	3	26/08/2021	18/09/2021
F-E	1150	GRP	2047	45	3	01/11/2021	19/12/2021
F-G	501	GRP	2047	6	3	26/05/2022	28/06/2022
D-I	970	RC	2120	10	3, 1	16/08/2022	01/10/2022

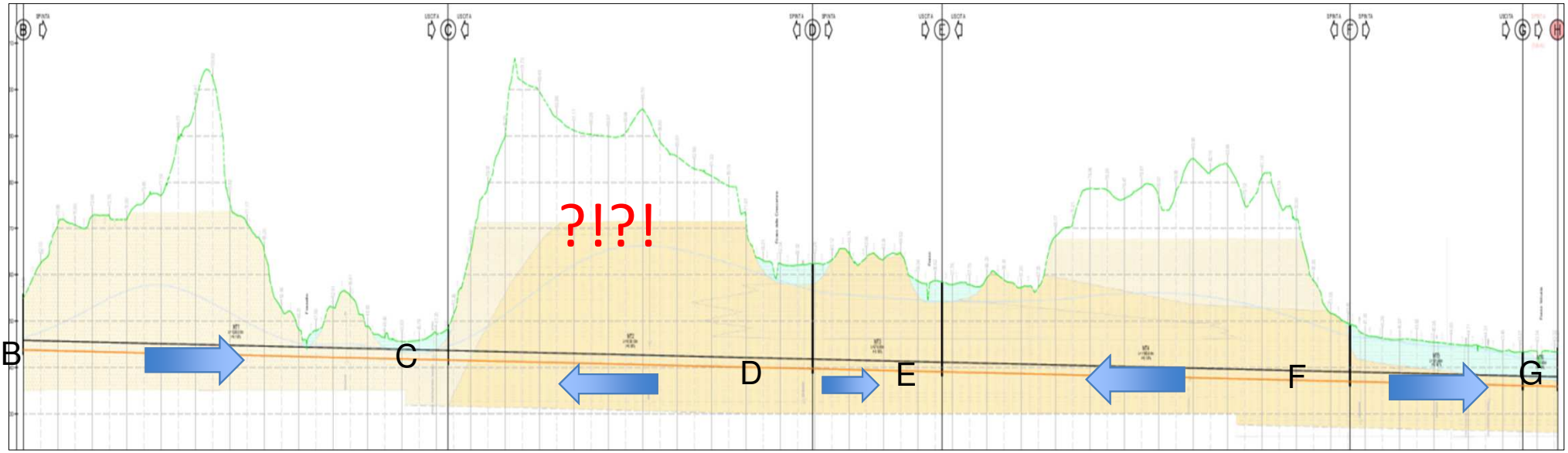


SUBSOIL PROJECT CONDITION

The *Fosso della Crescenza Formation* is a typical geological unit of the area and it is predominant: consisting of gravels, fine silty sands, and greenish-grey clays of fluvial and fluvial-lacustrine environments. Almost all the drives this kind of soil did not present particular execution difficulties.

Sacrofano stratified tuffs: slightly coherent fallout pyroclasts, with sandy-silty granulometry and pedogenised levels

Fosso della Crescenza formation: deposits of fluvial and fluvial-lacustrine environment in silty-sandy and sandy-silty facies, moderately thick (s), with thick clay intercalations (a)



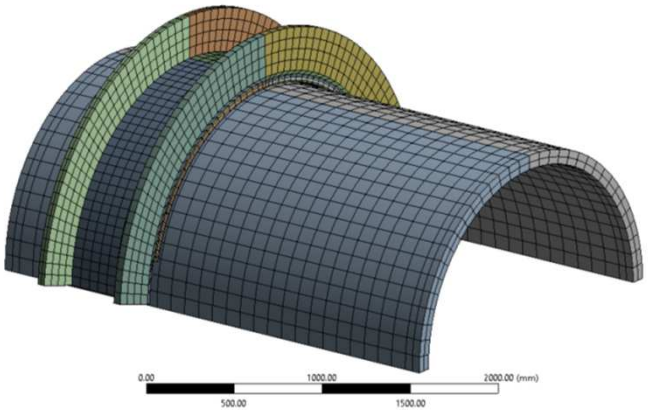
The biggest execution problem was encountered found in the section D-C, where the overburden heights were such as to make impossible an in-depth investigation of the lithological and granulometric variability that this formation may present.

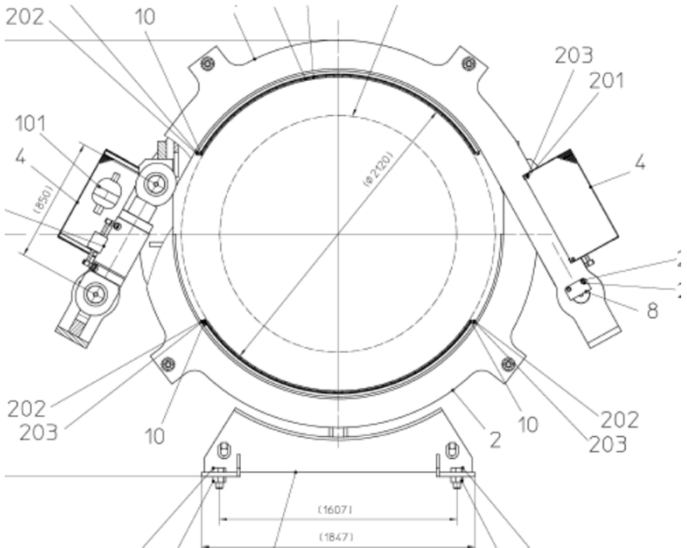
PIPES

The standard GRP Pipes was specially designed and manufactured to fulfill to the microtunelling project requirements:

Spinta	Uscita	Lunghezza C-C [m]	Diam. Esterno tubo [mm]	Diam. Interno tubo [mm]	Rigidezza [N/m2]	Tipo	Peso [Kg/m]	Max Spinta amm. [KN]
B	C	1.235,00	2047	1897	50000	PRFV	1021	8086
D	C	1.069,13	2047	1877	80000	PRFV	1151	9606
D	E	376,00	2047	1885	64000	PRFV	1099	9000
F	E	1.185,00	2047	1877	80000	PRFV	1151	9606
F	G	501,48	2047	1907	40000	PRFV	955	7319
D	I	976,87	2047	1877	80000	PRFV	1151	9606

- first pipes: special 1st joint and **antiroll connections**
- pipe brake. a **pipe clamp** is used to hold the installed pipe when a new pipe is lifted in place during the connection. Static check with FEM in combination to Pipe Brake design (HK) was managed.
- **interjack station**: special efforts for design and preliminary tests





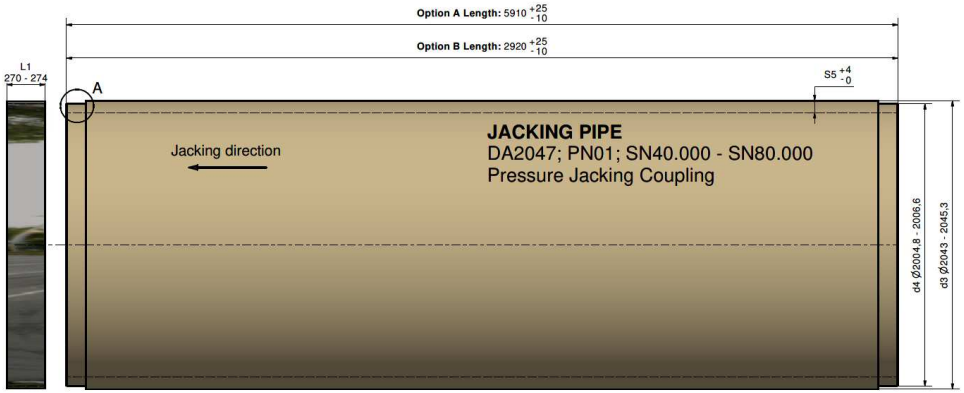
GRP pipes

manufactured by AMIBLU are centrifugal cast GRP pipes

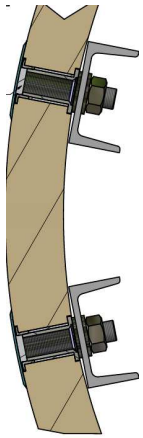
with a) internal liner with resins >=1mm; b) middle layer: resin, fiberglass, sand; c) external layer: resin and sand. The joint is water tightness due to groundwater system

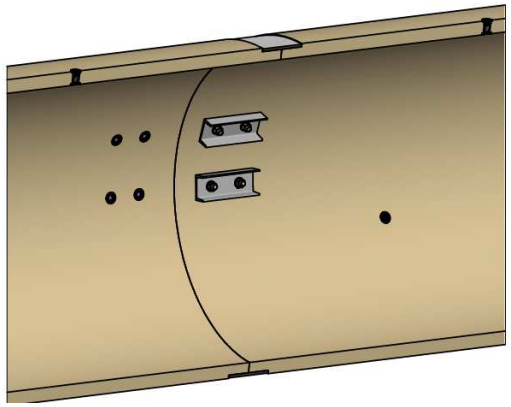
specification

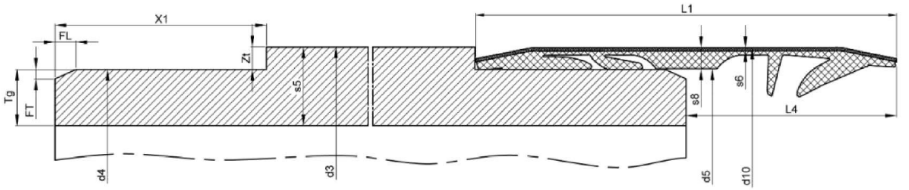
PN01bar ; RG>40.000-80.000N/m2 ;VF > 7.300-9600kN; pipe length: 6000mm.



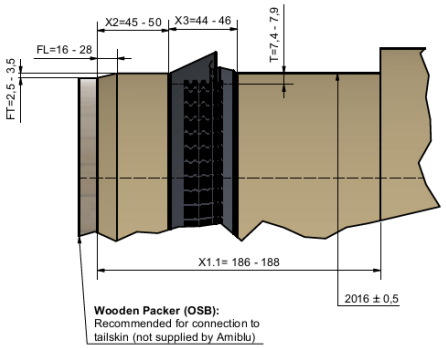
DE pipe	SN	s5	
		min	max
2047	40000	70,0	74
2047	50000	75,0	79
2047	64000	81,0	85
2047	80000	85,0	89

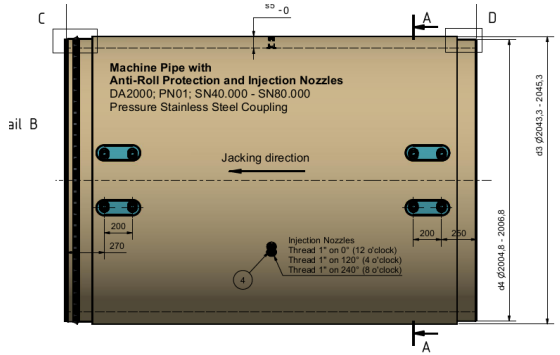






Detail

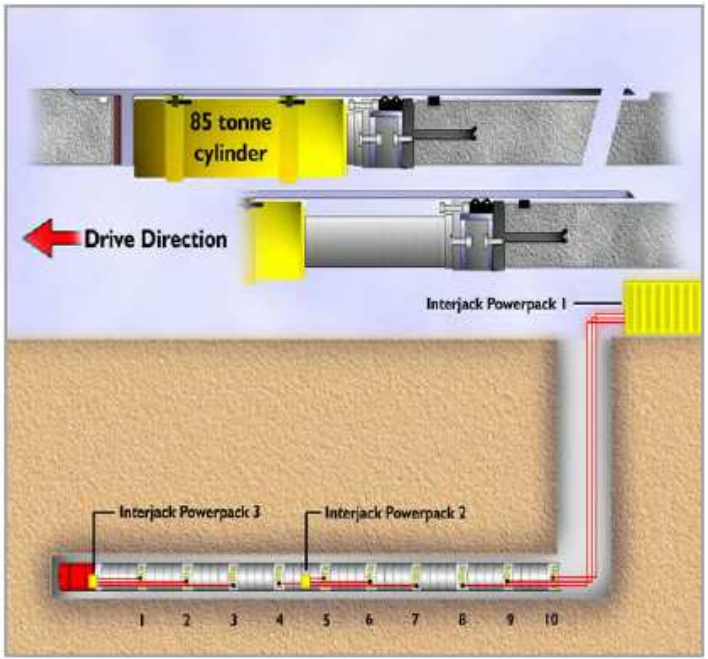


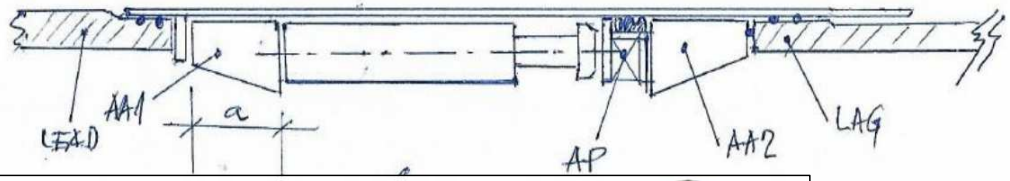


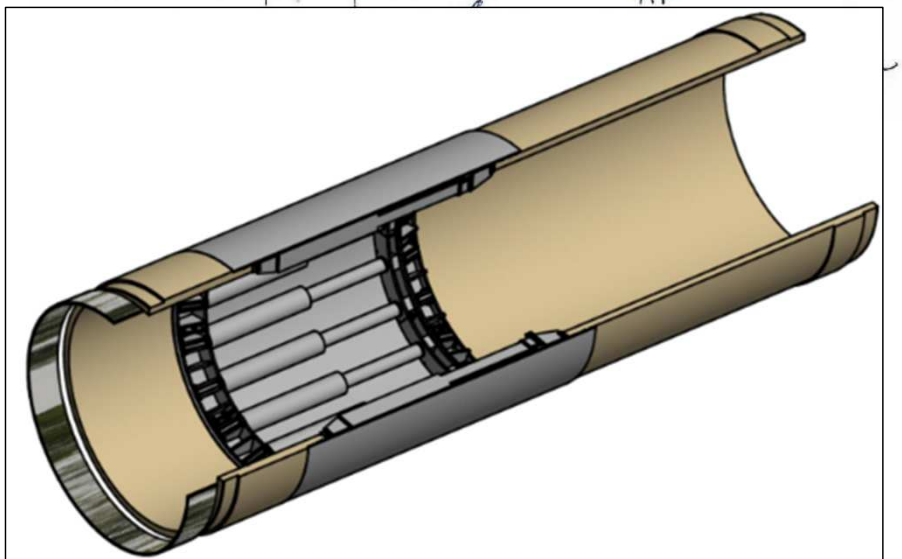
THE EARTH OF THE PROCESS : INTERJACK STATION !!

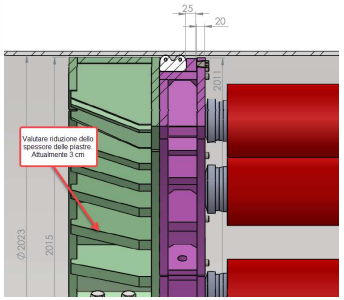
In challenging/long microtunnelling works IJS system is essential for a successfull project.
JF can be theoretically calculated but at the end all «tools» shall be properly in place to face high level of unexpected high friction;
Long drives+clays+high cover) >>> high jacking forces !! >> full set of reliabe IJS is mandatory !
IJS were designed in cooperation with AMIBLU and the following elements were engineered and produced:

- Steel cylinder, IJS station, produced by ICOP that fits with
- Lead Pipe: element connecting to the front of the metal piece;
- Lag Pipe: male element inserted after the intermediate jacking station;
- Interjack adapter ring intended to transfer the jacking force compensating the small thickness of the pipe (M1,M2)
- Interjack Active Seal: ring provided with gasket, intended as an additional measure to prevent any leakage from the gasket of the Lag Pipe (AP)







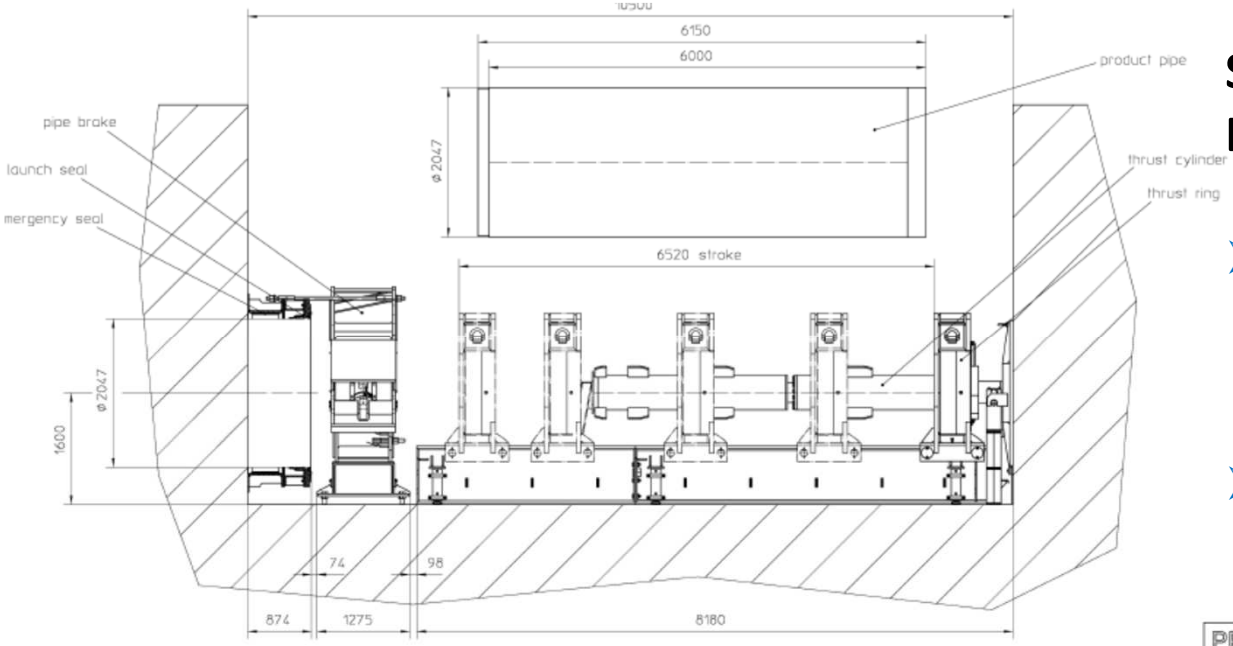


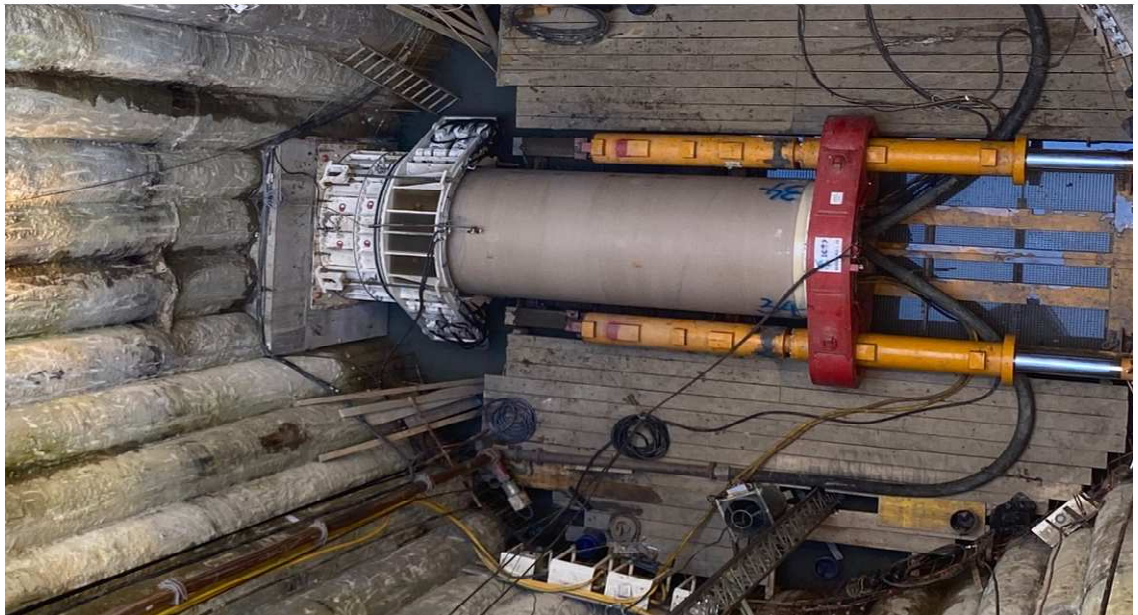
A IJS prototype was manufactured and tested with full assembly to check the functionality of the elements and establish the correct on-site assembly method.

The operating procedure was to a steel base frame on which the elements are positioned and after assembling the adapter rings, they were connected by sliding them on the track by means of special jacks wit dywidag bars.

EACH IJS: n.15 jacks – 700mm stroke – 85 ton >>>

STARTING SHAFT INSTALLATION LAYOUT





SPECIAL ITEMS CONSIDERED DURING ENGINEERING PHASE:

- **Emergency seal**: it's imortant to manage ground water in case of damages on the main seal;
- **Pipe brake**: we considered it necessary due to high water pressure and very low pipe-soil friction; an enlarged pipe brake 600mm was the output from the FEM calculation
- **Compact jacking frame** for 6m pipes. Longer pipes 6m brings the benefit but a compact Jacking frame was deployed to limit shaft diameter D=11,3m (VF=11.000kN)

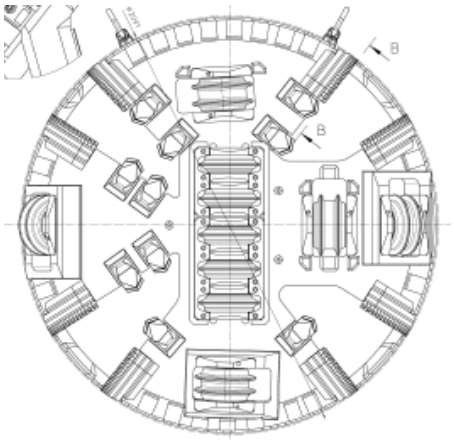
Drive D-C:

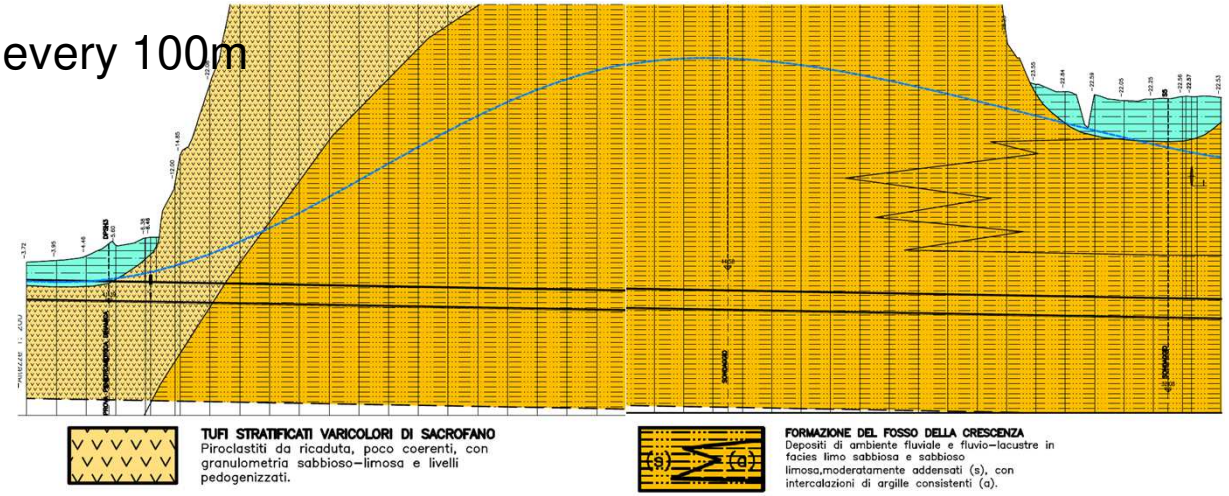
Alignment straight, i=+0,18%; shaft depth 20m to the invert; cover 20m > 63m> 5m.

Assumed subsoil condition: 0-990m “formazione del fosso della Crescenza”, con facies prevalentemente sabbioso-limose **(s),** costituita da depositi di ambiente fluviale e fluvio-lacustre in facies limo-sabbiosa e sabbioso-limosa, moderatamente addensati; 900m-1215m “tufi stratificati varicolori di Sacrofano”, ovvero piroclastiti da ricaduta, poco coerenti, con granulometria sabbioso-limosa e livelli pedogenizzati»

Drillig set up

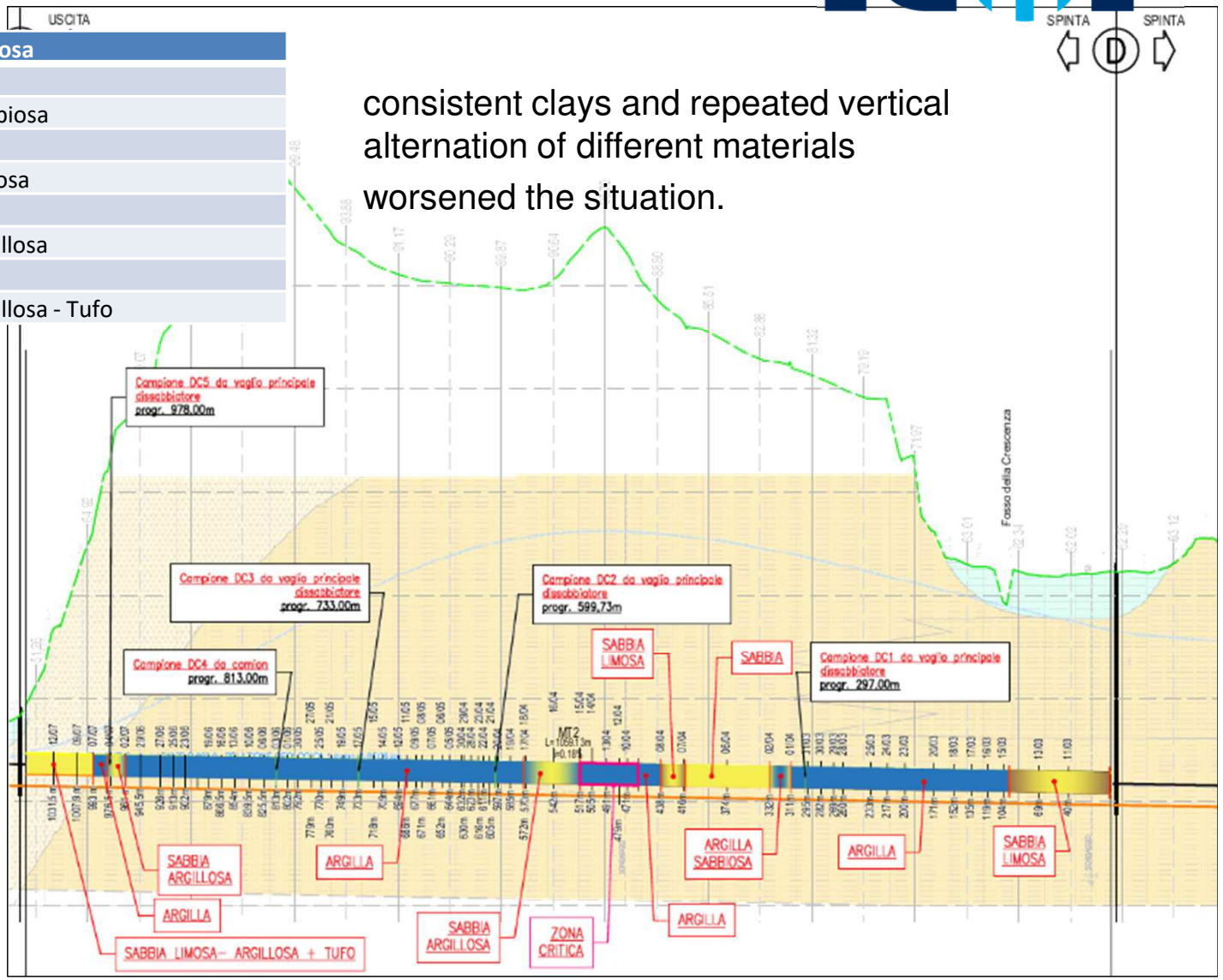
- TBM: HK AVN1600TB + mixed ground cutting head
- separazione plant including centrifuge final stage
- Double line for lubrication;
- Injection points spaced 12m at 120°
- IJS: the first at 70m and then every 100m





0m – 98m	Sabbia limosa
98m – 311m	Argilla
311m – 332m	Argilla sabbiosa
332m – 416m	Sabbia
416m – 438m	Sabbia limosa
438m – 517m	Argilla
517m – 572m	Sabbia argillosa
572m – 993m	Argilla
993m – 1064m	Sabbia argillosa - Tufo

consistent clays and repeated vertical alternation of different materials worsened the situation.



1. From the beginning extensive presence of clay, reduced the drilling speed while increasing the JF; from +420m IJ was used to restart;

2. At +620m the tunnel was blocked also with IJ stations;

3. A special recovery procedure was therefore implemented and after 72hrs the tunnel was moving again!

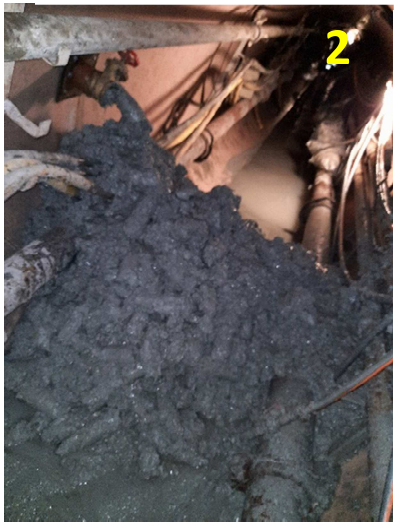
REASONS

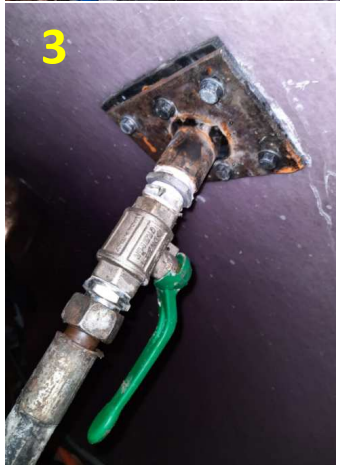
A. the clay, in combination with water, was swelling and closing around the pipe so that the overcut anular space became zero;

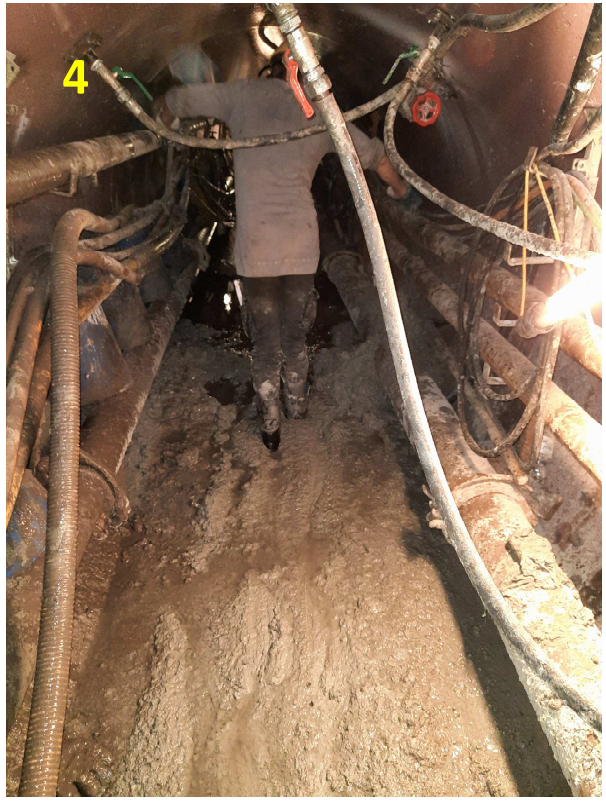
B. ground stresses with high cover jammed the pipe with additional increased friction and jacking force.

RECOVERY PROCEDURE

1. Soil relief valves were installed in the jammed section to release the external pressure (fig.1);
2. The ground was squeezed inside the GRP pipes and the external pressure was reduced until the pipe was able to move again (fig.2)
3. Additional lubrication points were installed for lub in the blocked section and related boxes for remote control (fig.3)
4. Polimeric mixture was injected to lubricate while reducing the negative impact of solid contribution of bentonite
5. Flushing between injection points and release valves was implemented to restore the missing overcut







How we completed the drive ?

A. The above procedure was implemented also after the restart and to the end of the drive, for the pipes that were passing through the critical section !

B. An extensive use of IJS was activated ! Up to 5 IJS for 50cm advance

C. An hard work inside the tunnel was performed to allow restart and completion of the drive (fig.4)

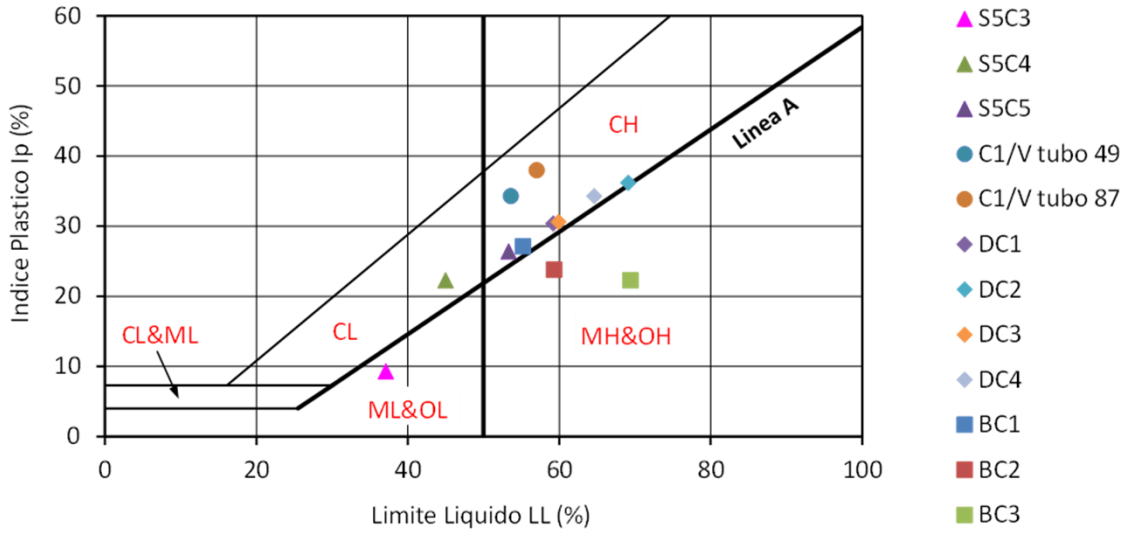
Additional investigation were performed in order to understand the causes that led to the blockage; it was identified the rheology of the soils crossed:

- samples taken during preliminary boreholes;
- in the relief valves installed on the pipes between chainage 420 and 560 of section D-C;
- in the excavated material from section D-C, and B-C;

Classifica USCS	Indagine di progetto			Valvole sfogo Tratto D-C		Materiale rimaneggiato Tratto D-C				Materiale da vaglio Tratto B-C		
Descrizione campione	S5C3	S5C4	S5C5	C1/V tubo 49	C1/V tubo 87	DC1	DC2	DC3	DC4	BC1	BC2	BC3
	ML	CL	CH	CH	CH					CH	MH	MH
Limite liquido WL (%) =	37,10	45,00	53,30	53,60	57,00	59,20	69,10	59,90	64,60	55,20	59,30	69,40
Limite Plastico WP (%) =	27,80	22,70	26,90	19,30	19,00	28,80	32,90	29,30	30,30	28,10	35,50	47,10
Indice Plastico Ip (%) =	9,30	22,30	26,40	34,30	38,00	30,40	36,20	30,60	34,30	27,10	23,80	22,30
Frazione argillosa (%) =	31,10	62,90	57,10	51,00	51,10	58,20	52,80	65,90	48,90	41,20	38,40	17,00
Attività =	0,30	0,35	0,46	0,67	0,74	0,52	0,69	0,46	0,70	0,66	0,62	1,31

Casagrande plasticity line line A=0,73(LL-20)

IP= LL-PL



Initial data: L=37% - 43%

Execution data: LL= 53% - 69%

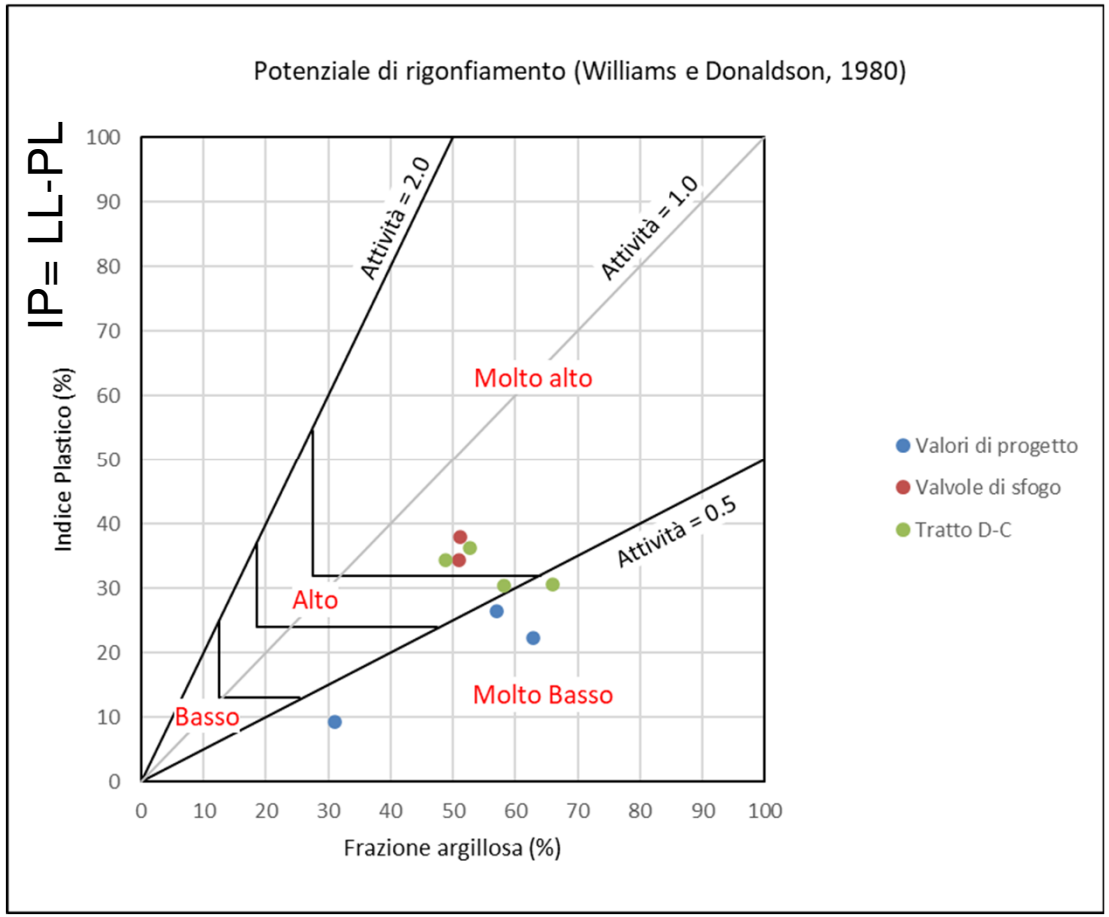
Reference values are:

Non critical soil ----> LL 20-50 and PL 10-20

Critical range soil --→ LL > 50 and PL >20

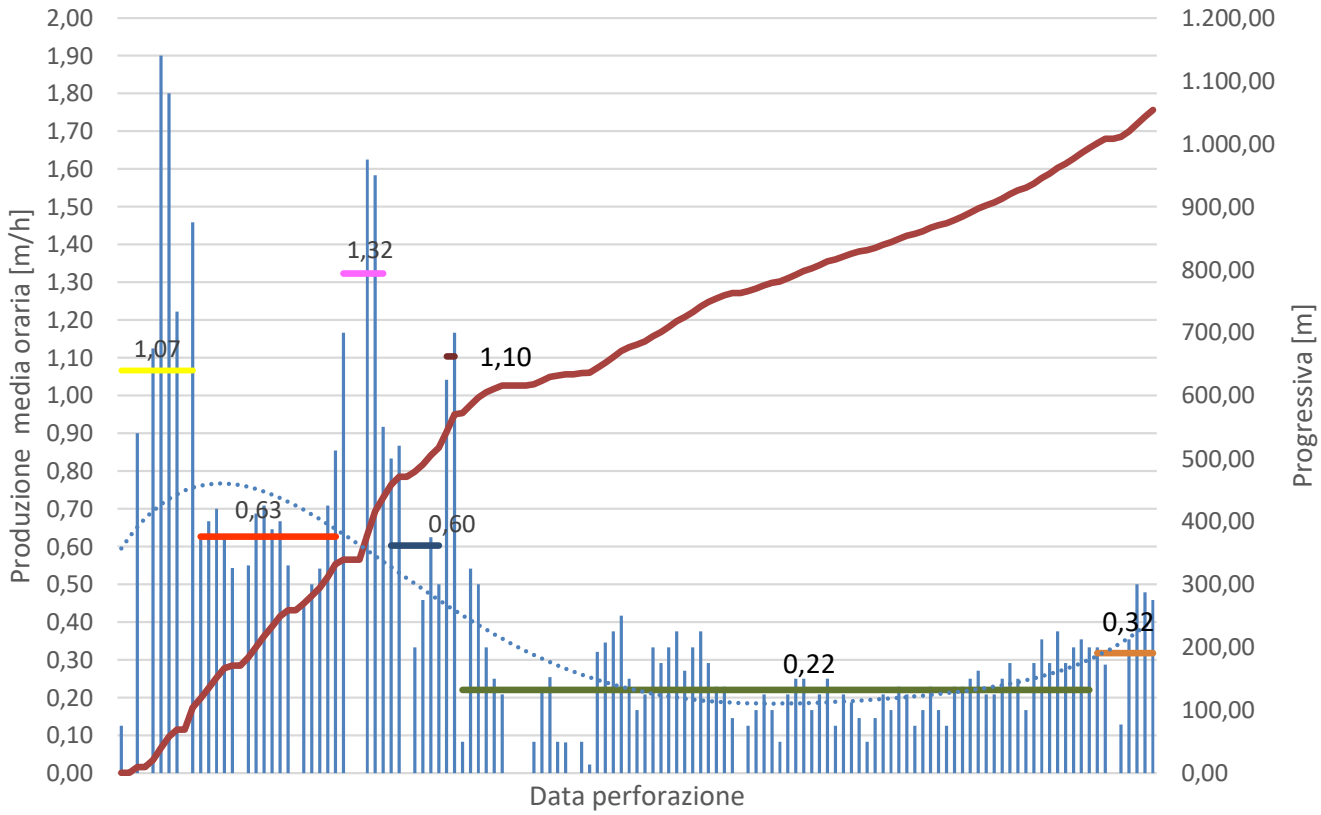
SWELLING BEHAVIOUR

The results of laboratory tests have been displayed in the “Swelling Potential” graphic from the Navfac DM7_01 design manual (Van der Merwe, 1964; William e Donaldson, 1980) were the swelling potential is related to CF (clay fraction) and IP (Plasticity Index).



Project samples showed basically a low potential of swelling while the samples, taken in the segment where the pipes were stuck, are in the part with a very high swelling potential.

- Clay fraction CF = % of particles < 2μm; Activity A = PI / CF



in the critical section were installed

- n.44 lub valves and
- n.47 discharging valves

Drilling in swelling clays increase the water content in the spoil

water content is estimated to be:

- w=55% for the sandy facies;
- w=75% for the clayey facies

additional problems in swelling clay

Tratta	Previsto	Smaltito	Differenza	%
Tratta B-C	7132,00	10927,70	3795,70	53,22%
Tratta D-C	6110,37	12329,96	6219,59	101,79%
Totale	13242,37	23257,66	10015,29	75,63%

In plastic clay with high LL, had as a consequence that the disposed drilled material increased much over extimations !

CONCLUSIONS

This lesson learned shows once more that **NO DIG** technologies are the right solution especially in very critical situations, and sometimes are the unique solution for the execution of important infrastructure works.

Microtunnelling technique, when properly managed, is also able to overcome unforeseen situation.

The implementation of **NO DIG** solutions should always consider the following items:

a) **preliminary geotechnical survey** is of utmost importance and cannot be compromised even if some limitations are present, especially when the recovery of the TBM is not feasible.

b) **detailed risk assesment** at the beginning of the works is the key of the success and based on that a detailed engineering is mandatory; at least for:

- Detailed Design of shaft, pipes and IJS
- Drilling Equipment: TBM set up, jacking frame, pipe brake, launch seal, water circuit
- Technical Procedure: drilling, lubrication, separation

- **Risk assessment and mitigation measures**
- **Detailed Engineering**
- **Management of drilling process**

MT capability to overcome unforeseen situations in challenging projects

Last but not least the recovery of the TBM in the exit pit, …..

F > **E , DRY AND WET**

F > **G (WET)**

D > **C (DRY)**

…and THE END of this presentation.

THANKS FOR THE ATTENTION !