37TH INTERNATIONAL NO-DIG FLORENCE 2019

Fortezza da Basso • FLORENCE (Italy)

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A MICROTUNNEL WITH A VERY LITTLE RADIUS FOR A BIG PIPELINE

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CASE STUDY – MAIN DATA

PROJECT: Gas pipeline “*Metanodotto Cervignano-Mortara*” - SNAM Rete Gas

JOB: Underground crossing of **Milano-Napoli A1 Highway** “Autostrada del Sole” near Melegnano and Lodi (MI)

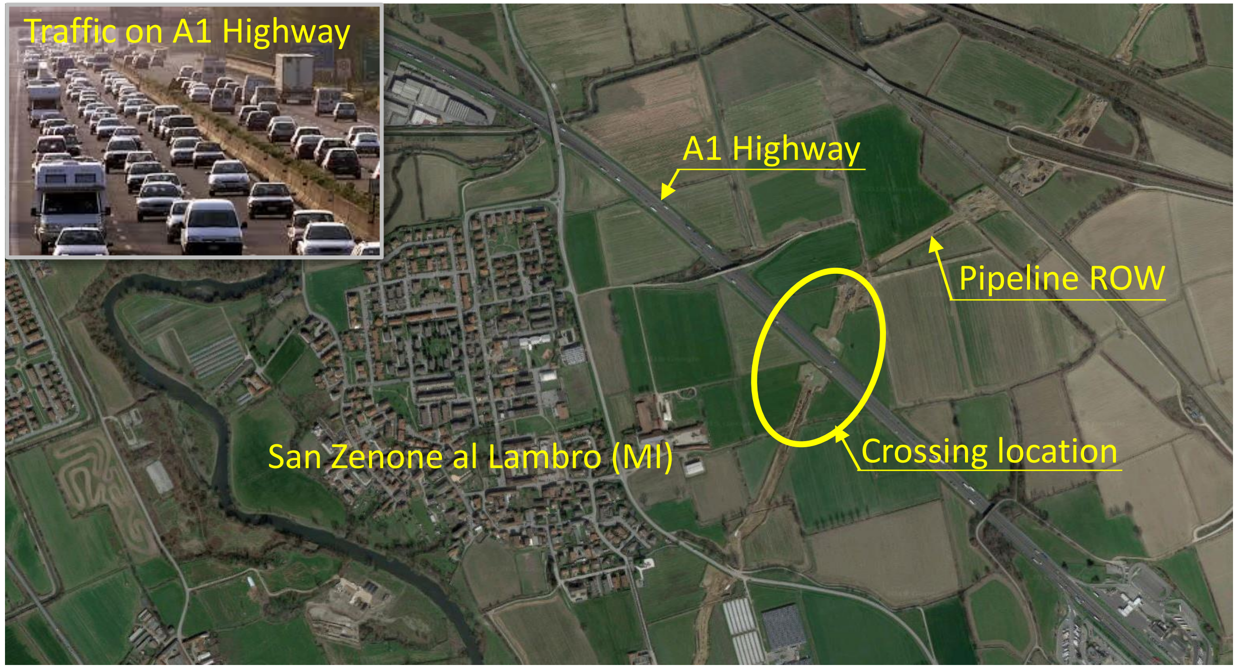
TECHNOLOGY: Microtunnelling (MT)

PIPELINE DATA:

Material:	Steel pipe
Nominal diameter:	**ND = 56”** (1400mm)
Design Pressure:	DP = 75bar

MT PIPE DATA:

Material:	Reinforced concrete
Inner diameter:	ID = 2100 mm
Outer diameter:	OD = 2500 mm
Pipe length:	L = 3000 mm



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ONE CROSSING, ONLY TWO POSSIBLE SOLUTIONS … OR NOT?

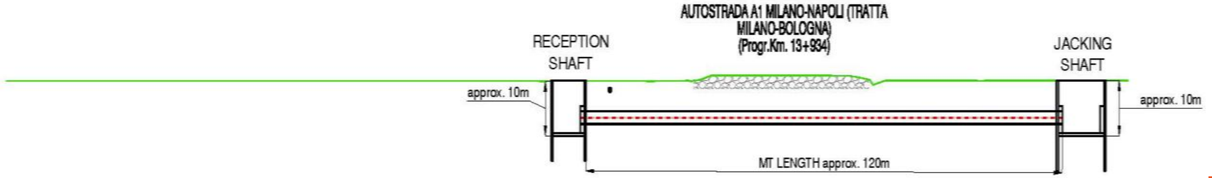
CONSTRAINTS:

	Pipeline minimum curvature radius	R = 1600 m for ND = 56”
	Minimum depth underneath highway	h = 7 m

SOLUTION 1

STRAIGHT MICROTUNNEL PROFILE

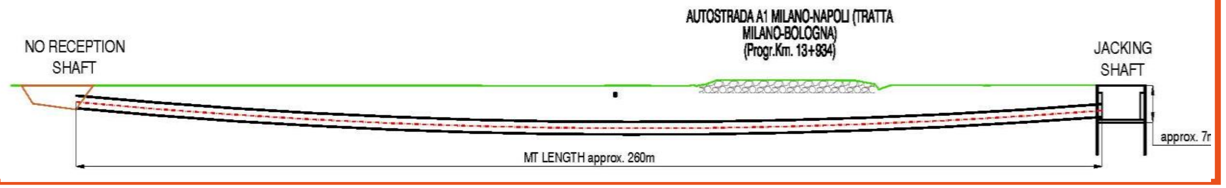
- ⇧ Suitable curvature for pipeline (∞ >>1600m)
- ⇧ Short microtunnel: L = 120 m
- ⇩ Reception shaft needed
- ⇩ Deep jacking and reception shafts (approx. 10m)



SOLUTION 2

LARGE CURVATURE MICROTUNNEL PROFILE: R = 2000 m

- ⇧ Suitable curvature for pipeline (2000m > 1600m)
- ⇧ No reception shaft needed
- ⇧ Relatively shallow jacking shaft (approx. 7m)
- ⇩ Longer microtunnel length: L = 260 m



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ONE CROSSING, ONLY TWO POSSIBLE SOLUTIONS … OR NOT?

CONSTRAINTS: Pipeline minimum curvature radius R = 1600 m for ND = 56”

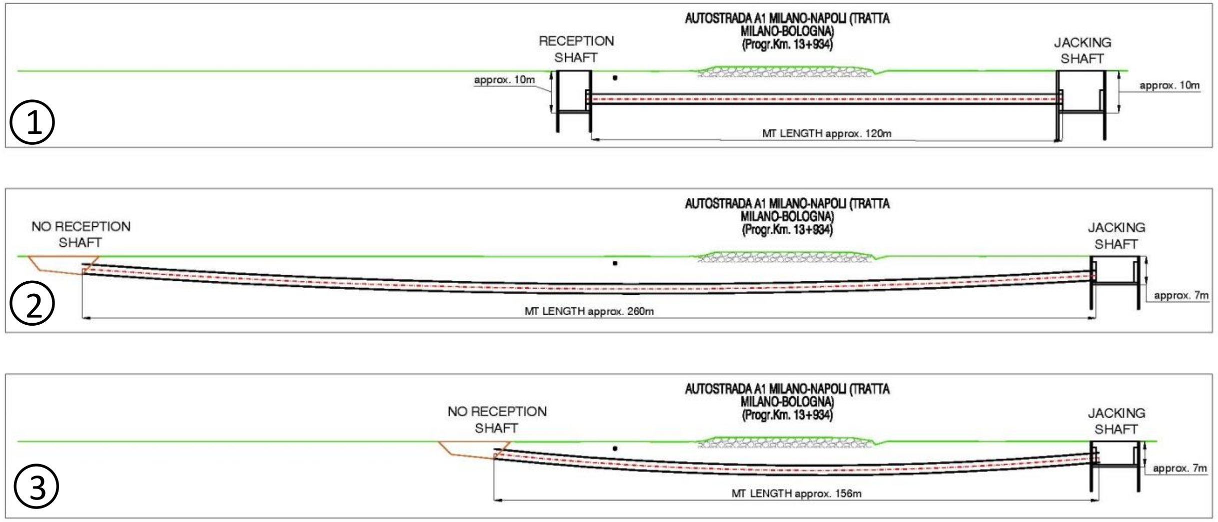
Minimum depth underneath highway h = 7 m

SOLUTION 3

SMALL CURVATURE MICROTUNNEL PROFILE: R = 800 m

- ⬆ Short microtunnel: L = 156 m
- ⬆ No reception shaft needed
- ⬆ Relatively shallow jacking shaft (approx. 7m)
- ⬇ **Too little curvature for gas pipeline (800m << 1600m)**

DEAD END OR CHALLENGING OPPORTUNITY ?



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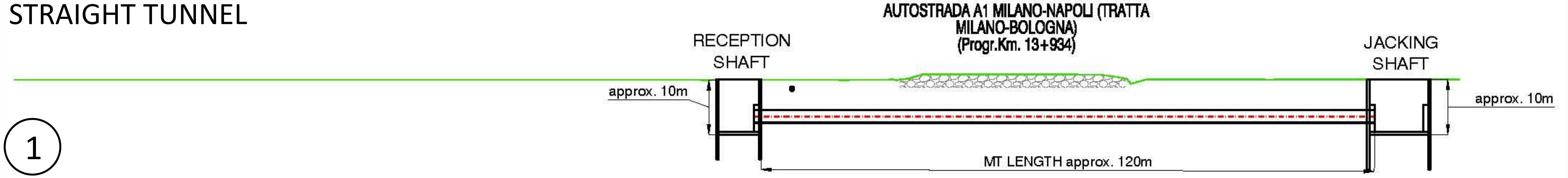
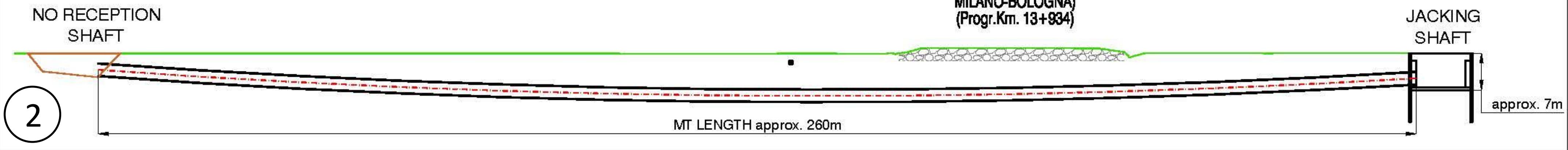
ONE CROSSING, ONLY TWO POSSIBLE SOLUTIONS … OR NOT?

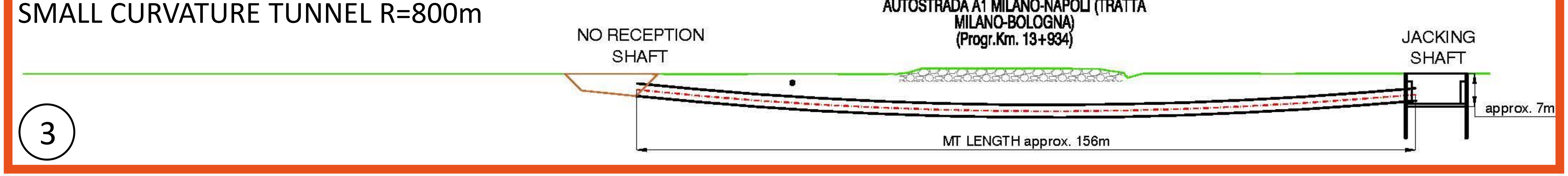
STRAIGHT TUNNEL



LARGE CURVATURE TUNNEL R=2000m



SMALL CURVATURE TUNNEL R=800m



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THINKING OUTSIDE THE BOX

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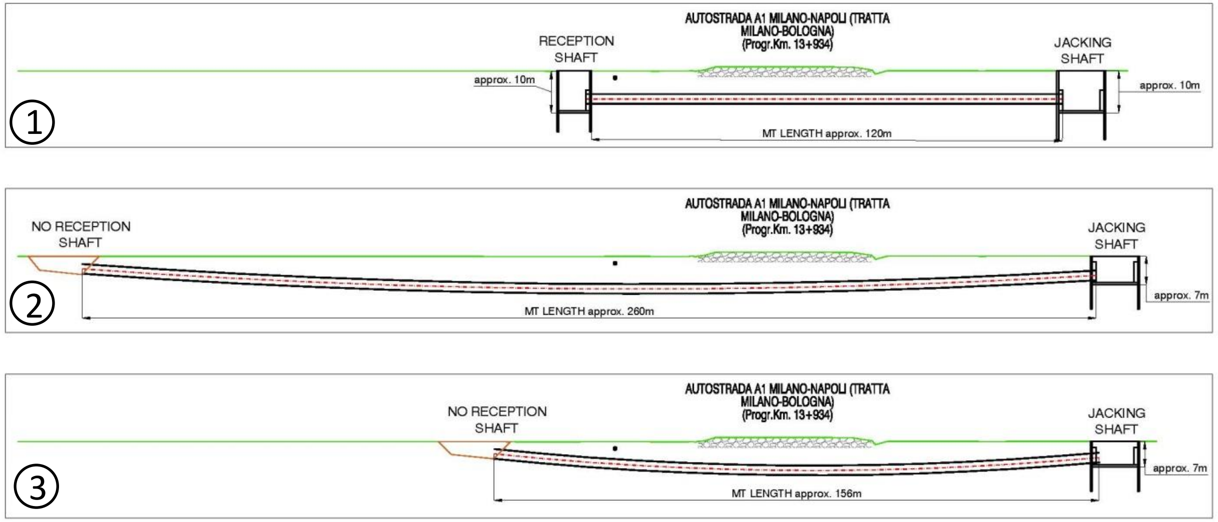

Opportunity to test a new operational procedure and extend applicability

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R=800m BECOMES SUITABLE CURVATURE!

The gas pipeline shall adapt to microtunnel design:

- Preliminary cold-bending of pipeline bars to match the microtunnel curvature
- Final bend radius lower than elastic radius

Opportunity to test a new operational procedure and extend applicability

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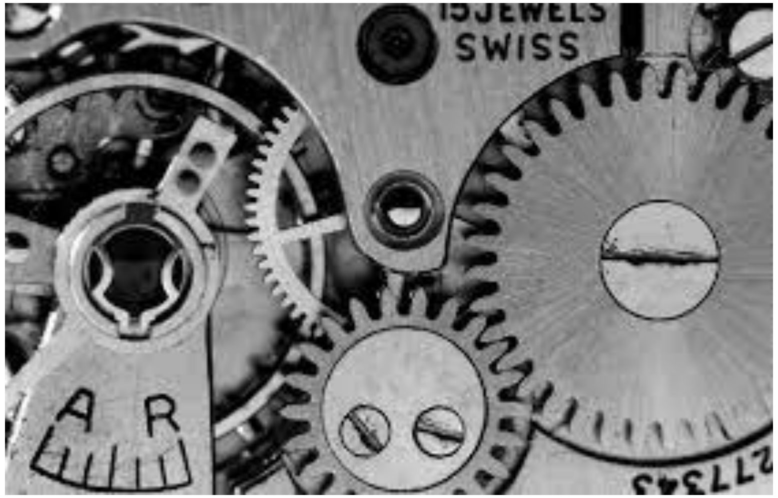
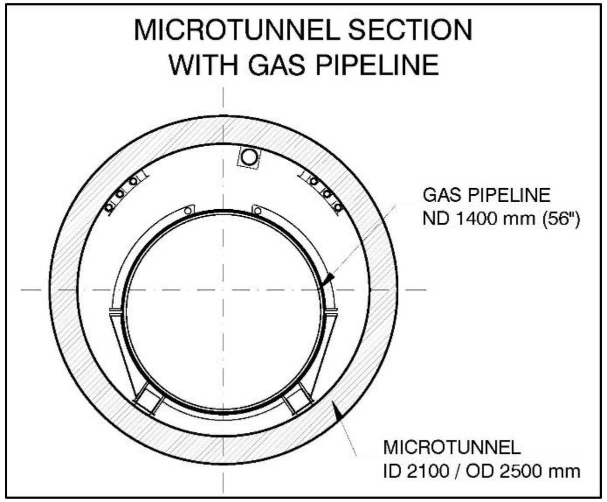
CHALLENGES AND REQUIREMENTS

GAS PIPELINE MECHANICAL WORKS	MICROTUNNELLING WORKS
• High precision in the preliminary bending of the pipeline • Accuracy during assembly works on Site to ensure that MT and pipeline curvatures are aligned	• Limited allowable deviations from design MT axis • Ensuring a smooth profile • Reliable guidance system / High driving accuracy





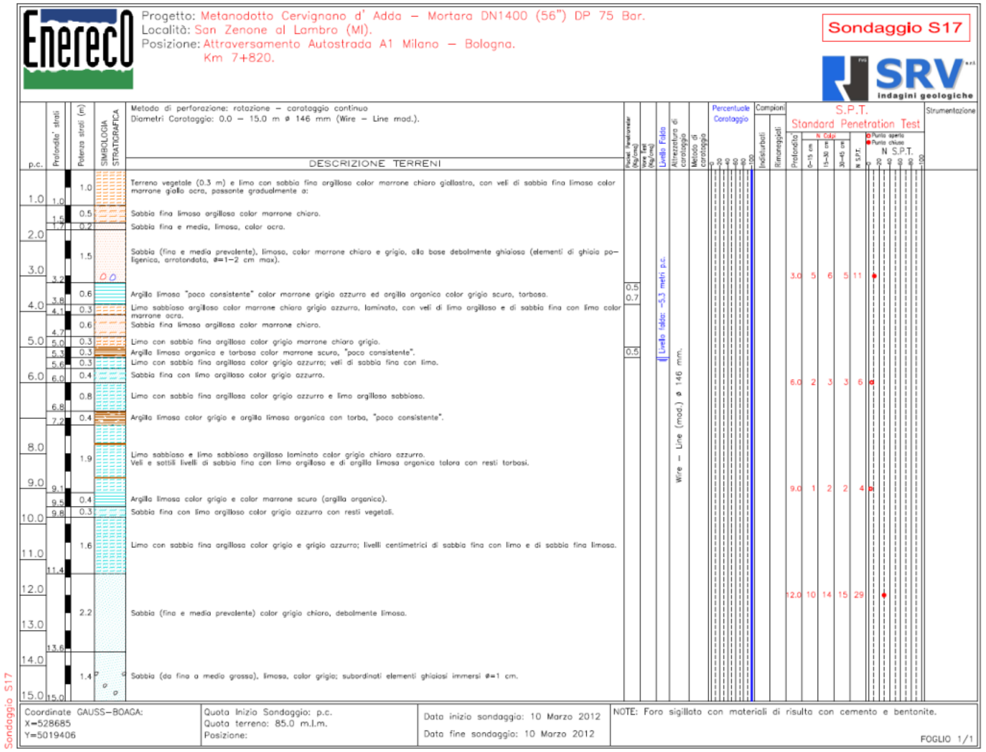
GAINING CONFIDENCE

GEOLOGICAL-GEOTECHNICAL INVESTIGATIONS

- N.1 borehole
- Standard Penetrometric Test (SPT)
- Laboratory analysis on samples

GEOLOGICAL-GEOTECHNICAL CONDITIONS ALONG MT ALIGNMENT

- Lithotypes of the medium and old Alluvium and of the Fluvial Würm
- Frequent alternation of medium-fine **silty sands**, not very stiff **silty clays** and **silts** with fine sands
- Groundwater depth varying in the range 4,5 – 5,3 m below original ground elevation



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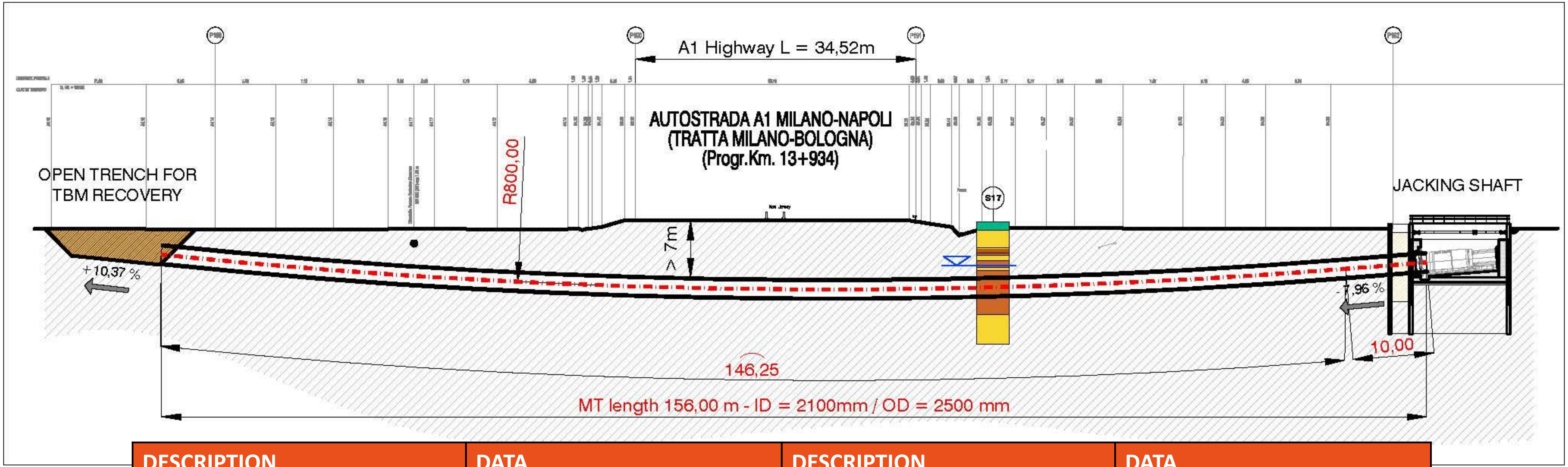
MICROTUNNEL DESIGN



DESCRIPTION	DATA	DESCRIPTION	DATA
MICROTUNNEL LENGTH	156,25 m	PIPE MATERIAL	REINFORCED CONCRETE
MICROTUNNEL PROFILE	CURVILINEAR: Rv = 800 m	PIPE INNER DIAMETER	2100 mm
SOIL CONDITIONS	SAND, SILT, CLAY	PIPE OUTER DIAMETER	2500 mm

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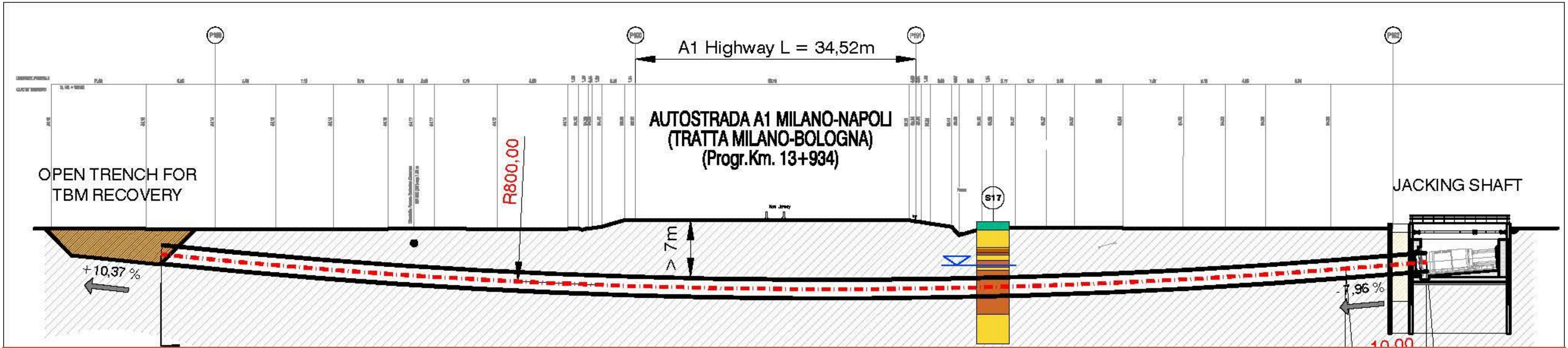

RECEPTION SHAFT

- Open trench excavation to be executed at the end of the drive
- No ground support system required

JACKING SHAFT

- External dimensions: 12,5 m x 7,5 m x H = 6,7 m
- Structure: sheet piles, reinforced concrete foundation slab, concrete jacking and launch walls
- Dewatering only during shaft excavation: well-point

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MICROTUNNELLING OPERATIONS ON SITE

MAIN EQUIPMENT FEATURES

- Closed shield slurry-pressurized TBM by Herrenknecht (AVN2000)
- Mixed terrain cutting head
- VMT-SLS guidance system for curvilinear drives

PRODUCTION DATA

- Working days: **10 days** on single shift
- Average drilling speed: **50-60 mm/min**
- Average pipe jacking time: 60 min approx.
- Jacking force: **600 – 800 kN**
- Cutting head rotation speed: 5-5,5 rpm

MICROTUNNELLING OPERATIONS ON SITE

GUIDANCE SYSTEM RECORDING: MT AXIS DEVIATION

Deviations recorded by the TBM are within the limits provided by ATVA 125 for drains and sewers (gravity flow)

Table 10: **Maximum deviation in [mm] from the target position for drains and sewers**

DN	vertical	horizontal
< 600	± 20	± 25
≥ 600 to ≤ 1000	± 25	± 40
> 1000 to < 1400	± 30	± 100
≥ 1400	± 50	± 200

PIPELINE PULL-IN DESIGN

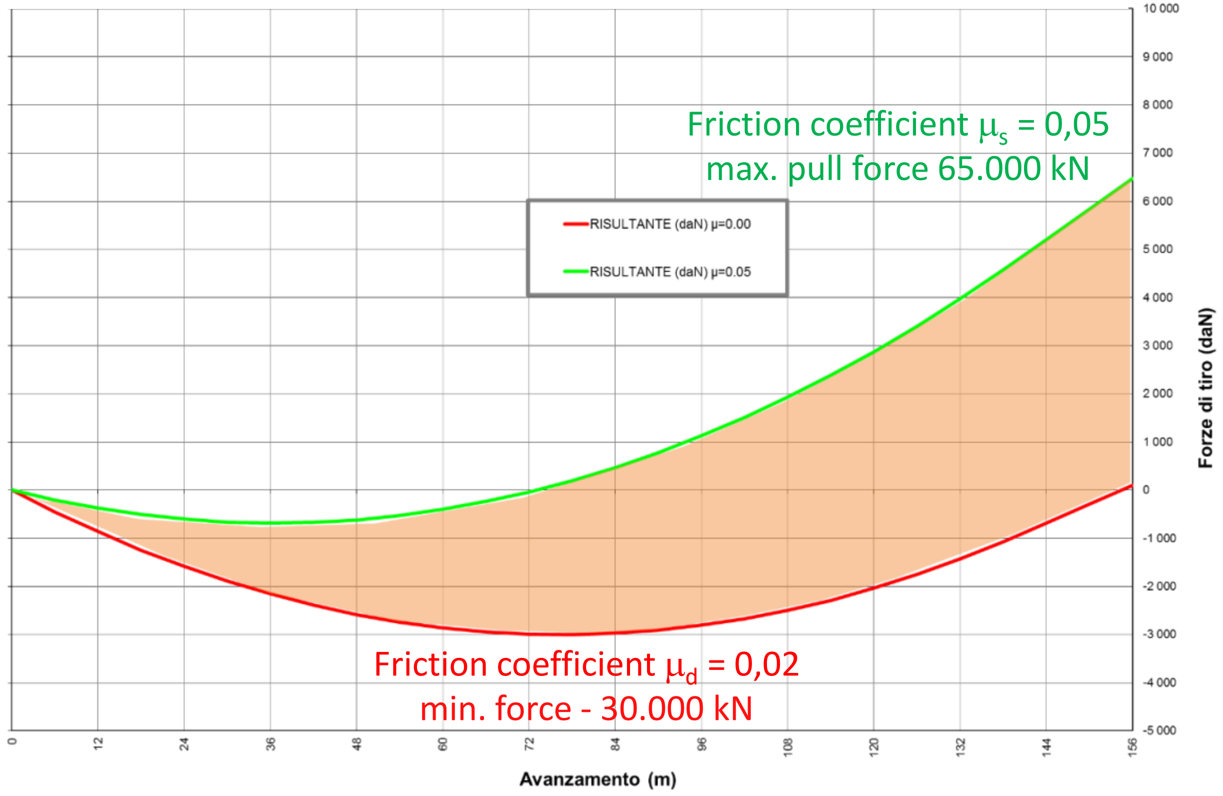
PULL-IN CALCULATION

- Static friction coefficient (pull check):
  μ_s = 0,05 (conservative: 0,04 based on experience/tests)
- Pull force: approx **65.000 N** (approx. 6,5 ton)
- Dynamic friction coefficient (hold-back check):
  μ_d = 0,00 (conservative: 0,02 based on experience/tests)
- Hold-back force: approx. **30.000 N** (approx. 3 ton)

✓ **Pull-in winch for project: 1500 kN (approx. 150 ton)**

✓ **Hold-back system is required**

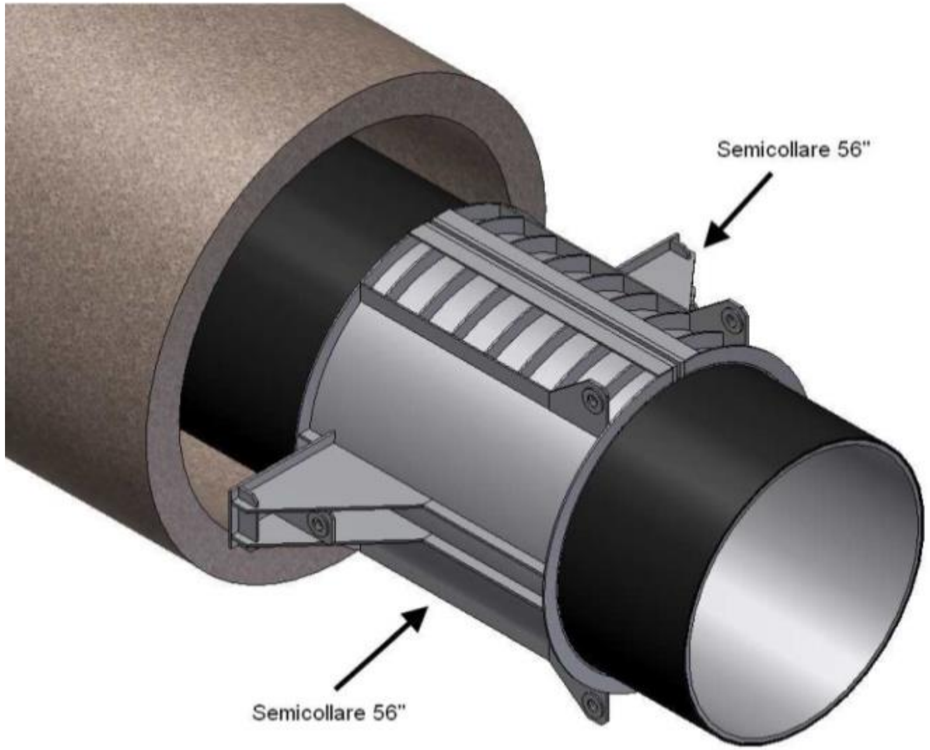
FORCE DURING PULL-IN



PIPELINE PULL-IN CALCULATION

HOLD-BACK SYSTEM

- Blocking system to prevent pipeline sections from advancing when pulling is stopped and to keep the pipeline in position for welding operations
- Blocking system consists of a steel clamp with two side wings to block the pipeline against the MT wall
- Clamp is installed close to the end of each pipeline section to be pulled-in so that it stops in the right place for welding



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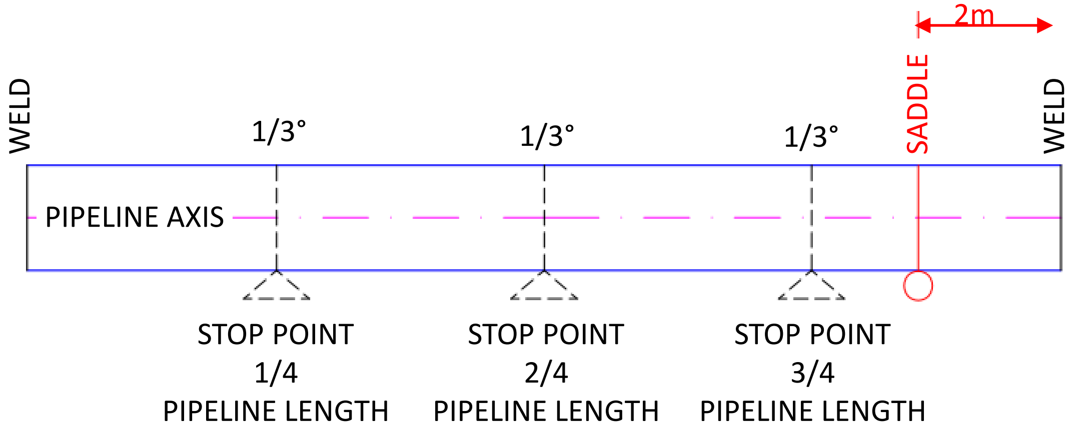
PIPELINE PULL-IN PRELIMINARY OPERATIONS ON SITE

- Detailed as-built microtunnel survey to check curvature
- Preparation of ad-hoc bending plane
- Cold-bending of pipeline bars (3 stop points: 1/3 deg each)
- Cathodic protection and services installation

DESCRIPTION	DATA
PIPELINE MATERIAL	EN L 450 MB STD API 5 l Grade X60
PIPELINE INNER DIAMETER	1378,4 mm
PIPELINE OUTER DIAMETER	1422,0 mm
PIPELINE THICKNESS	21,8 mm
BAR LENGTH	14,5 m
NUMBER OF BARS	no. 10 curved + no. 2 straight



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PIPELINE PULL-IN PRELIMINARY OPERATIONS ON SITE

- Pull-in winch installation in the jacking shaft
- Laying of messenger wire along the microtunnel invert
- Installation of no.1 saddle with rollers every 14,5m to reduce friction
- Welding of pipes two-by-two (double joints) to obtain 30m long sections for pull-in

DESCRIPTION	DATA
BARE PIPE WEIGHT	752.70 kg/m
COATED PIPE WEIGHT	768.89 kg/m
PULL-IN SADDLES TYPE	Gauthier – 210056A
PULL-IN SADDLES WEIGHT	14.5 kg/m
LAURINI WINCH	150 t

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PIPELINE PULL-IN

- Connection of pulling head to the messenger wire in the tunnel and to the first pipeline section
- Pulling of 30m long pipeline section
- Alignment and welding of subsequent 30m long pipeline section

PIPELINE PULL-IN

MONITORING AND CONTROL

- Monitoring and control of pulling stresses with dynamometer
- Monitoring and control of pipeline alignment
  - ➢ Essential to match microtunnel and pipeline curvatures
  - ➢ Use of special pendulum for verticality control
  - ➢ Blocking clamps used to re-align the pipeline in case of need

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MISSION ACCOMPLISHED

CONCLUSIONS

The crossing of the A1 highway, the first microtunnel for a large diameter pipeline built with a reduced radius of curvature ever realized, was successfully completed thanks to **absolute precision** both in **microtunnel execution** and in **pipeline assembly**.

The solution proposed and implemented allowed to construct:

- A microtunnel of extremely reduced length: only 156 m
- A shallow jacking shaft with minimum interference with groundwater
- No reception shaft: only open trench excavation for TBM recovery.

and resulted in:

- Reduced realization times;
- Low realization costs.