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Ventilation of greatest road tunnel of Egnatia Highway in normal operation and special cases

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Abstract: - This paper concerns Ventilation of the largest road tunel of Egnatia Highway, either in normal operation or for extraordinary emergencies (such as an accident or fire). This tunnel is located between the River Arachthos and Ioannina is the biggest Twin Tunnel Road, cumulative length of about 9 km., Called "Lorenzo Mavilis" (former Driskos Tunnel). In the normal operation the ventilation achieved through a 38 Jet Fans in total, while the emergency construction of a smoke extraction well consisting of 3 Smoke Extraction Axial Fans and 2 Fire Dampers was required. The smoke extraction well is situated in the middle of the interconnecting gallery, between the two tubes of the tunnel at Ch. 8+250. It is vertical with a circular cross section, of 6.5-6.6m excavation diameter and 185m deep. The operation and use of Jet Fans Impulse create both a system "longitudinal" ventilation of the tunnel, and obtained control of pollutants. The smoke extraction shaft comes into operation only in exceptional cases and created a system of "longitudinal" ventilation by using two of the three axial fans, and the third is a backup.

Keywords: - *Jet Fans , Axial Fans, Ventilation Well, Pilot, Shear zones*

I. INTRODUCTION

The Egnatia Highway is the first high-standard road of Greece and part of one of the most difficult engineering projects. It crosses the northern part of the country from west to east, starting in the port of Igoumenitsa and finishing to Alexandroupolis with the total length 680km. The axis passes through all the geological formations and all geotectonic zones developed in the region of northern Greece. In its final form is a dual carriageway with two traffic lanes per direction, a central reserve and an emergency lane. It includes 177 major (longer than 50m) bridges (40km), 73 twin-bore tunnels of a combined length of 100km single tube, f63 road interchanges, 350 entrance / exit overbridges and underpasses and service roads of 720km. [1]

The largest twin-tube tunnel of Egnatia Highway, with cumulative single tube length at about 9000m is the tunnel of Lorentzos Mavilis (ex Driskos). It is part of the Egnatia Highway from Drosochori to Arachthos River and more specifically from Ch. 6+166.06 until Ch. 10+730, according to the chainage of the left branch. According to the clause 2.9 of the Directive 2004/54/EC “The design, construction and operation of the ventilation system shall take into account: the control of pollutants emitted by road vehicles, under normal and peak traffic flow; the control of pollutants emitted by road vehicles where traffic is stopped due to an incident or an accident; and the control of heat and smoke in the event of a fire”. Finally the design approach for the ventilation system was the mass single-point smoke extraction ones, which facilitates the use of a vertical ventilation shaft. The shaft is connected to the tunnel tubes via a connecting gallery of maximum height 7m and width 6m, while the excavation was performed by the conventional method.

II. VENTILATION / SMOKE EXTRACTION SYSTEM OF LORENTZOS MAVILIS TUNNEL

2. 1 Layout of the ventilation system of the tunnel

The ventilation to control of pollutants emitted by road vehicles, under normal and peak traffic flow of Lorentzos Mavilis tunnel is this one of a typical longitudinal system implemented by the usage of Jet Fans. Apart from those, however, in case of fire a variant of this system namely the Mass Single-Point Smoke Extraction System is mobilized. In this case extraction of pollutants and smoke is implemented through the Smoke Extraction Shaft which includes Jet Fans and Fire Dampers. More specifically, the ventilation system consists of the following equipment:

a) 18 Jet Fans in the left tube – towards Ioannina,

b) 20 Jet Fans in the right tube – towards Arachthos River,

c) 3 Smoke Extraction Axial Fans, of 110m^3/s rate each, located in the Smoke Control Plant Room at the top of the shaft,

d) 2 Fire Dampers in the smoke extraction interconnecting gallery, at the base of the shaft.

With the usage of the Jet Fans, placed in pairs, a 'longitudinal' ventilation system is formed, with one ventilation section (the tunnel tube) in "normal" mode and two, divided by the shaft, sections, for 'emergency' function, as stated above.

Under emergency conditions, only two (2) of the three (3) smoke extraction axial fans are simultaneously operated, whilst the third one is used as a stand-by. The fire damper of the tunnel tube where the fire manifests must be open, while of the other tube it must be shut.

Furthermore, the ventilation system in each tube is checked automatically under "normal" operation (dilution of pollutants) according to the indications of the following instruments:

1. 3 carbon monoxide CO units.
2. 3 visibility units (turbidity).
3. 3 nitrogen oxides NO_x units.
4. 4 units of longitudinal air velocity and airflow direction.
5. A linear fire detection system, consisting of 13 zones (each zone located between the interconnecting galleries). Zone "6" is divided into two sub-zones on either side of the smoke extraction shaft. [2]

III. OPERATING STRATEGY OF THE SMOKE EXTRACTION SYSTEM

3.1 Unidirectional traffic mode

Twin bore Lorentzos Mavilis tunnel is unidirectional one. Moreover, it is divided into two smoke management sections, section 1 and 2. Section 1 extends from the entrance portal up to the smoke extraction shaft and section 2 from the shaft up to the exit portal. Taking into account that the possibility for congestions in this unidirectional rural tunnel can be considered as very low, the firefighting operation can be divided into two cases, depending whether the fire manifests before the smoke shaft or after it, i.e. section 1 or 2 respectively.

In case of fire, jet fans are always recommended to be working in the direction of traffic. Jet fans located near the fire source and up to 100m afar (downstream) are not start operated. In an automatic firefighting operation, jet fans will come into operation one by one at the command of the ventilation control system with a time delay of about 10sec. The first operating jet fan must be directed upstream, as far from the fire source as possible. All the systems of the tunnel which are related to its operation have been designed to provide all necessary information in order to achieve maximum safety. Thus, all devices are consistently addressable, i.e. determined uniquely based on chainage, with the Supervision Control and Data Acquisition (SCADA) having the ability to control each one of them independently depending on the chainage of the fire.

The fire detection system recognizes the chainage where the fire manifested (with accuracy ~ 8m) and sends SCADA the corresponding information. The automatic smoke management operation scenario is posed by the SCADA system only when fire is detected by the linear fire detection cable. The emitted alarm signal of any electrical fire annunciator (panic button) will not automatically put the fire management system into service, thereby to prevent it from unnecessary operation, but a confirmation by a SCADA operator will initially take place, through CCTV cameras and SCADA display screens and then will the operator put the smoke management scenario manually into service, if required.

Before SCADA puts the automatic operation scenario into service it checks whether:

- the inspection elevator of the shaft is in the parking spot and doesn't function,
- there is no personnel in the suction chamber and the interconnecting gallery between the fire dampers,
- the smoke extraction fans and the fire dampers of the fans and of the interconnecting gallery are shut.

Only when the above are met is the automatic operation scenario put into service.

The non-functioning confirmation of the inspection elevator is done by a terminal switch in the elevator parking spot and a non-functioning indication on the local switchboard. The confirmation of the absence of personnel is done by local danger switches (Emergency Stop) and light panels indications that the lighting of the spots is not working. The confirmation that the smoke extraction fans are shut is given by the auxiliary contacts of the power relays on the switchboard and the air velocity measuring station installed in the smoke extraction shaft. The confirmation that the fire dampers are shut is given by terminal switches located on the flaps. In SCADA, safety interlocks have also been foreseen to ensure that smoke extraction fans and fire dampers in the interconnecting gallery will not function if there are personnel present in the suction chamber and the interconnecting smoke extraction gallery or the inspecting elevating device of the shaft is working.

<u>Case N° 1: Fire in Section 1</u>

In this case, the smoke extraction axial fans will suck the smoke and lead it through the vertical shaft in the smoke extraction plant room and finally reject it to the environment. Following the fire detection, two out of three axial fans in the smoke extraction plant room at the top of the shaft will gradually start operating (~ per 30sec). The fire dampers of the two fans, as well as the diaphragm on the shaft orifice, connected to the pertinent tunnel branch, will open in full. In section 1 smoke is led towards the shaft due to suction and the air velocity is measured by velocity gauges of the department (*Map 1*). In section 2, however, the airflow direction must be opposite to traffic direction (from the exit portal towards the shaft), so as to prevent the spread of smoke beyond the shaft exit. In order to achieve the right velocity and the right airflow direction air velocity gauges are used in section 2. The air velocity in this section is regulated by the operation of various jet fans, of the same or opposite direction to the movement of vehicles. Also, the airflow velocity rate should be of about 0.5-1.0m/s.

The airflow in both sections must always be directed towards the orifice of the smoke extraction shaft. Only one fire damper will open; the one of the tube where the fire manifested. The other one will remain shut. The second tube is used as an escape route; therefore, it must be ensured that smoke will not venture into this tube. To achieve this, various Jet Fans located in section 2 of the unaffected (clear) tube will be put into service against the direction of vehicle movement. This will help to stop the existing airflow and will create overpressure, provided that both doors in the vertical escape galleries remain open during the evacuation phase 1 (self-rescue). Furthermore, the airflow velocity of the section must vary in the range of 0.5-1.0m/s during the remaining phases. Thus, some jet fans in this section must operate in the opposite or the same direction as the one of the vehicles, depending on the indications of the air velocity gauges in the particular section.

Based on the above general principles the automatic operation scenario of the smoke extraction system in the event of fire is formed. Therefore, once a fire manifests in section 1, the fire detection panel detects the location of the fire and informs SCADA and this in turn activates the automatic smoke extraction system scenario, which consecutively performs the following actions:

- It terminates the operation of all jet fans in both tubes (zero state).
- Red traffic lights are lit in the fire manifestation tube upstream of the fire, while the variable message signs transmit the appropriate messages in order to halt the traffic upstream of the fire.
- It confirms that: a) the elevator is in the parking spot, b) there is no personnel in the suction chamber or the interconnecting gallery and c) the fire dampers of the interconnecting gallery are shut.
- In the other tube of the tunnel, the entrance of vehicles is interrupted with the use of red traffic lights at the tube portal and the transmission of appropriate messages in the variable message signs.
- In the interconnecting gallery the fire damper opens towards the fire manifestation branch.
- It consecutively sets two axial smoke extraction fans in motion per 30sec, after first giving the command for the corresponding fire dampers of the fans to open.
- In section 1 all jet fans remain inoperative.
- In section 2, according to the corresponding Fire Management Scenario, one or two jet fans are initially set in motion. Thereafter, the air velocity in section 2 is monitored and the jet fans are activated, stopped or reversed in order for the air velocity to vary in the range of 0.5-1.0m/s, oriented always towards the shaft.
- In the other tube of the tunnel, two pairs of jet fans, those closest to the exit portal, are set in motion in the opposite direction of the movement of vehicles.

Once the programmed scenario ends, the system automatically switches to manual mode. The operator monitors the fire area through the CCTV system and the indications of the air velocity gauges, giving instructions for safe tunnel evacuation by the users. Further handling of the fans will be performed by the operator or the firefighters. Through a CCTV system the operator will monitor the progress of the fire extinguishing process done by the fire brigade and will perform the appropriate actions. At the same time, the operator will monitor the other half (part) of the tube where the fire manifested for any smoke diffusion in that area.

Case N° 2: Fire in Section 2

In this case the shaft will not be used for smoke extraction. Smoke will be led towards the exit portal of the tunnel by the aid of longitudinal ventilation. Both fire dampers remain shut and the axial fans in the smoke extraction plant room remain inoperative. In order to lead the smoke outside the tunnel only the jet fans are used in the affected tunnel tube. Also, in the unaffected tube, certain jet fans of section 2 must operate opposite to the normal direction of traffic. This will create an overpressure within the first minutes after the detection of the fire. To avoid smoke recycling in the portals the airflow direction in the second tube must be oriented towards the entrance portal and have a velocity of at least 1m/sec. Based on the above general principles the automatic operation scenario of the smoke extraction system in the event of fire is formed. Therefore, once a fire manifests in section 2, the fire detection panel detects the location of the fire and informs SCADA and this in turn activates the automatic smoke extraction system scenario, which consecutively performs in order of the first three steps of the first case and then follow the below:

- In the unaffected tube, the entrance of vehicles is interrupted by the use of red traffic lights at the portal entrance and the transmission of appropriate messages in the variable message signs.
- In sections 1 and 2 of the affected tube all the available jet fans are successively set in motion, per 10sec, with the same direction of the movement of vehicles, in accordance with the corresponding Fire Management

Scenario. Initially, the furthest fans are set in motion upstream of the fire. The fans close to and 100m downstream of the fire source are not set in motion to avoid possible short circuits in the electric supply systems.

- In the other tube of the tunnel, two pairs of jet fans, those closest to the exit portal, are set in motion in the opposite direction of the movement of vehicles.

Once the programmed scenario ends, the system automatically switches to manual operation and the operator follows the steps described in detail in the previous case. [2]

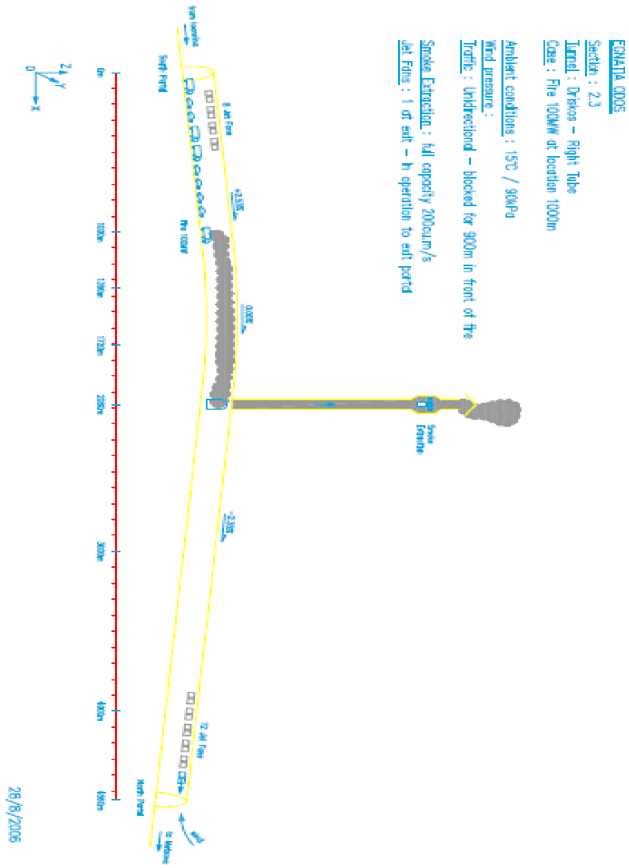
3.2 Bidirectional traffic mode

On rare occasions, one tunnel tube carries two-way traffic while the other one remains closed. A different ventilation strategy must be followed in such an occasion. The objective that must be reached is the stratification of hot smoke inside the tunnel for as long as possible. Therefore, the air velocity must vary in the range of 1-2m/sec, this will help people trapped inside the tunnel to escape on either side of the fire area. During the bidirectional traffic mode the airflow has no specific direction deriving from the vehicle motion (piston effect). In case of fire, the direction of ventilation must always be the same as of the natural airflow, as the reversal airflow should be avoided in any case. If air velocity is equal to zero (apnea) at the time of the fire, the direction of ventilation chosen is the one that will lead the smoke out of the tunnel through the shortest path, i.e. the portals or the smoke extraction shaft. The above conditions are very hard to be predicted and lead to complex and uncertain fire fighting procedures. In order to simplify the procedure in bidirectioanal traffic it is suggested that the dilution of pollutants should be dealt with the standard operation of the smoke extraction system, with suction capacity of about ≈200m^3/s. This creates an inflow of fresh air from the two portals ≈100m^3/s or air velocity ≈1.5m/s, which deals with the dilution of pollutants with ease. When various external factors come up (wind effect in tunnel portals, unequal distribution of traffic inside the tunnel, etc) a balancing of the incoming air loads from the two portal should be conducted with the operation of various jet fans.

After the evacuation of the tunnel by the users some jet fans will be set in motion manually in order to increase the amount of fresh air coming from the portal close to the fire source and create a ‘critical ventilation velocity'. This procedure is similar to the fire management in section 1 for one-way traffic, as developed above, so apply the general observations in paragraph 3.1 (e.g. starting time). Based on the above general principles the automatic operation scenario of the smoke extraction system in the event of fire in section 1 or 2 is formed. The fire detection panel detects the location of the fire and informs SCADA and this in turn activates the automatic smoke extraction system scenario, which consecutively performs the following actions:

- It terminates the operation of all jet fans in both tubes (zero state).
- Red traffic lights are lit in the fire manifestation tube upstream of the fire, while the variable message signs transmit the appropriate messages in order to halt the traffic upstream of the fire.
- The unaffected tube remains closed and has no traffic.
- In the unaffected tube , two pairs of jet fans, those closest to the exit portal, are set in motion in the opposite direction of the movement of vehicles.
- No change is made in the operation mode of the smoke extraction system (smoke extraction fans, fire dampers etc)
- In the tube where the fire manifested, one or two jet fans are initially set in motion according to the corresponding Fire Management Scenario. Thereafter, the air velocity in section 1 and 2 is monitored and the jet fans are activated, stopped or reversed in order for the air velocity in part 1 and 2 to remain stable of about 1.5m/s, oriented always towards the shaft. Once the programmed scenario ends, the system automatically switches to manual mode. The operator monitors the fire area through the CCTV system and the indications of the air velocity gauges, giving instructions for safe tunnel evacuation by the users. Further handling of the fans will be performed by the operator or the firefighters. Through a CCTV system the operator will monitor the progress of the fire extinguishing process done by the fire brigade and will perform the appropriate actions. At the same time, the operator will monitor the other half (part) of the tube where the fire manifested for any smoke diffusion in that area. [2]

Map 1. Ventilation of Lorenzos Mavilis Tunnel – Right Tube



IV. THE CONSTRUCTION OF THE VENTILATION WELL OF THE LORENTZOS MAVILIS TUNNEL

4.1 Construction of the Pilot Borehole

The WELL ends on the roof of the connecting gallery between the two tunnel tubes, while the axis is at the CH. 8+250, according to the chainage of the left tube, while the construction position is 200m southeast of the Ioannina-Trikala National Road (Fig. 1.). The cross-section of the shaft is circular, with excavation diameter from 6.5m to 6.66m and effective radius (the inner side) of the shaft 2.48m (effective cross-section 19.5m^2, maximal excavation cross-section 34.8m^2). Moreover, the upper level is at the height of +894.3m and its basis at the height of +711.3m, namely the entire length is at about 185m. In the study phase of the project for the investigation of the geological and geotechnical conditions was performed the boreholes and according to this, along the well were noticed three main geotechnical units, which are integrated in the Flysh of the Ionian Zone. Concretely, the first unit consists of an interchange of siltstone – sandstone with the dominance of sandstone and representative values GSI:30-40; the second unit with the dominance of siltstone and representative values GSI:20-30 and the third unit consists of the same formation, but with smaller values GSI:13-25. Moreover, several zones of intense fragmentation with high degree of weathering have been detected at a depth of 114m to 134m. The structure of the zone in question is characterized as sludgy clay with angular fragments and fragments of sandstone and siltstone.

In accordance with the geotechnical conditions four categories of excavation and temporary supporting were formed. Also during the sinking of deep wells is the construction of peripheral expansion rings that will be filled with sprayed concrete and steel reinforcement, in order to transfer a part of the vertical forces to the surrounding rock mass of the one part and to constitute retention areas of possible fractures or failures of the supporting shell of the other part, due to time related behavior and associated developing convergence. A total of four rings are made throughout the well at 0.60m radically. Moreover, along the well are constructed nine shear keys (cross-section widening) of the final lining, at distances of 20m in height and on the crowning of the well is constructed a reinforcing ring, consisting of a circular head of 6.06m internal diameter and 9.06m external diameter, of 1,5 m thickness for the creation of a rigid strong structure inside the weathered zone of the area. For the sinking of the Ventilation Well, opened a pilot borehole (the pilot) of 1m final diameter, downwards with standard drilling rigs. This borehole would serve as a conduit for the removal of the excavated material though the connecting gallery. During the drilled of pilot at 35m depth, the' diameter drill rods started to "jam", due to non verticality of the rotating column of drill rods (the axis of the rotational orbit was not vertical) and moreover because of a zone of intense fragmentation where exist. So. for this reason it was decided to fill the hole with grout and then to continue the drilling. During the drilling was noticed some water loss in zones of high fragmentation of the rock mass, at the depths of 36-38.5m, 82-83m, 107-122m & 154-157m, as well as "breach" of the borehole walls. After completion of the drilling a borehole wall collapse (roughly 2 250m^3 volume) have been recorded in the connecting gallery. This happened either due to the unsupported pilot borehole or due to the circulation of underground water through the discontinuities' system. In order to avoid the blockage of the borehole, the pilot borehole was filled with coarse grain size material, And after that the gradual casing of the pilot well took place (Fig.1 .). Simultaneously the coarse grain size material from the connecting gallery and the concreting of the gap between the pipe and the hole was removed. It is noted that despite consecutive attempts, we absolute verticality of the pilot borehole was never achieved. As shown in (Fig. 2.) there was a deviation of about 2m.

Figure 2. Pilot casing.

Figure 3. The extension of the pilot casing into the connecting galery

Excavation of the pre-well and he first 85m depth.

The pilot casing followed the excavating of the crowning of the well, the placement of the steel reinforcement in headband and the excavation of pre-well (the first 6m). The category of excavation and temporary supporting applied for these 6m (according to the Study of Well Construction) is the IV. Also under this category the step excavation was 0.8-1.0m. The elements of the temporary support of the category IV, are: 5m long spiles D25 - S500, with cementitious grout placed per 40 cm in excavation's contour slightly inclined. Shotcrete shell 30cm (10cm reinforced and 20cm plain). Steel frames HEB160 per excavation step, connected with 25mm struts - S500, 2m placed at the contour of the excavation. Two welded steel mesh T188. Self-drilling anchors 250 KN, 8m long, anchoring in full staggered grid 1,25 per step excavation. Consolidation and stabilization grouting of rock mass, depending on the site conditions. [3].

The excavation of the well was evolved without serious problems. To the depth of 85 meters (according to the Well Design) category III of excavation and temporary support class was applied (step of excavation was 1.0 - 1.5m (Fig. 3). [3] The elements of the temporary support of the category III, are the same as elements of category IV, except that the spiles are 3m length instead of 5m, shotcrete shell 25cm instead of 30cm (5cm reinforced) and the Steel sets are HEB140 instead of HEB160.

Figure 3. Excavation depth 60m

4.2 Blockage and Failure of the Pilot

Initial exploratory borehole ΓΦ-1 have disclosed that at 85m depth, a zone of joined rock mass is anticipated. In order to confirm that and to enhance the knowledge of prevailing,conditions exploratory horeholes were executed. This investigation discloses some gaps, as well as weak rock mass and in general the need for additional investigations for the localization and the volume of the already known gaps and the existence of new ones. Such gaps were recorded at the depths 15.5m, 18.7m and 33m from the well bottom (at depth 85m) and at a distance of about 3.7m from the well sidewall. Exploratory boreholes were filled with cement grout aiming at the complete sealing. At the beginning the cement/water ratio was 1:1 (by weight) and at the case of high grout consumption, a grouting ratio 2:1 has to be used. During the grouting works (grouting of 3:1 composition, using at about 300Kgr sand per cement grout cubic meter) pilot walls collapsed resulting in pilot blockage and gradual rise of the water level inside it. The depth of the pilot blockage, as observed by the connecting gallery in its end, is about 15m from the crowning of the connecting gallery, namely about 170m depth, while, as observed using the underwater camera, its blockage depth begins at about 65m depth (namely at about 150m depth), that means pilot blockage from 150m to 170m depth, namely total length of 20m. The works continued with direct water pumping and conducting of three exploratory boreholes of 90m length each one, with sampling at the bottom of the well and filling the holes with cement grout until the absolute sealing.

From the boreholes, a zone of intense jointing and occasional high shearing of the rock mass was disclosed from the depth of 21m until the depth of 41m. While from the depth of 41m and down, the siltstone is "sound", without significant joints only with some occasional discontinuities. Generally, after the completion of the boreholes and the evaluation of the findings, a grouting program down-up (inside the connecting gallery) and up-down (at the well temporary bottom) have been decided. Moreover, in borehole (2A) a piece of the pilot tube at the depth of about 105m, from the well crowning (Fig. *4 & 5*) have been recorded.

Figure 4. Sampling of drilling A2 distinguished (dashed red line) piece of pipe of the pilot.

Figure 5. The piece of tube was found in borehole A2 (the red line shows the cut portion of this).

At the completion of grouting works, 4 sampling boreholes drilled: Π6 & Π7 at the crowning of the existing slope at the northern part of the well and C1 & C2, of 40 and 70 m length respectively, the first one at an angle 60o to the horizontal and the second one vertical to the existing bottom of the well (namely 85m. depth), in order to investigate the extension in height of the disturbed zone and the gaps (above the existing bottom of work) and for execution of grouting in case of such grouting is necessary. From the borehole findings it was estimated that the width of the disturbed zone and the gaps ranges: from about 65m to 140m depth from the crowning of the well and is located at the northern-northeastern part of the well, of max. Thickness: to the North of 15-20m and perpendicular to the North of 10m. The failure of the walls of the initially unsupported pilot borehole arose at the area of the thinly of interchange layered siltstone-sandstone with the dominance of siltstone and existence at the areas with completely weathered siltstone (shear zones). The result was that the initial shear zones turned into disturbed zone and gaps, namely low quality rock mass, that in combination to the presence of intense aquifers and the increased geostatic pressure (due to the depth) constituted the main pilot's failure mechanism, from 105m to 148m depth.

4.3 **Excavation of the well below the 85m depth to the final depth of 185m**

Due to the blockage of the pilot, it was decided to change the methodology of well sinking. So according to the new methodology, the excavation of the well was performed the same way (mechanical means), but the direction of removal of the excavated material was changed. Transport of the excavated material was not made through the pilot, but lifted by a platform (inside a special bucket: 1mx2m) on the roof of the well.

The first 55m, starting from -85, (in accordance with the New Well Design) were excavated in accordance with the Category excavation and temporary supporting V, including among others the implementation of systematic 6-m heavy spiles - forepoles (namely 12 umbrellas). The excavation of the well using the above mentioned category of excavation and temporary supporting and starting from 85, namely was placed first umbrella on the elevation 816.43 or depth of 85.40m and the fifth and last umbrella (12th) at a depth of 134.20m. [4]

The elements of the temporary supporting of the category V, are heavy spiles - forepoles D114,3- S500, cementitious grout with a length of 6m, in contour of excavation, slightly inclined 13o and 2 meters overlap. The beams applied to denser grid in north-northeastern part of the well, where the disturbed zone. Shotcrete shell 40cm (10cm reinforced and 30cm plain). Steel frames HEB180 per excavation step, connected with 25mm struts - S500, 2m placed at the contour of the excavation. Two welded steel mesh T188 – S500. 16 Self-drilling anchors 250 KN, 8m long, anchoring complete the last two steps of advance of each umbrella to avoid entanglement with the overlapping portion of the beams advance. 6 drainage holes 3'' semidiameter PVC 2, 6m long, when applied every three steps of advance, geotextile drains if it necessary.

From the depth of 140**m** until the final **185m**,excavation and temporary supporting works of the well continued by applying the Category of excavation and temporary supporting IV, (as in original Well Excavation and Support Design). Throughout the operations, at a slow but constant rate and applying the method of lifting up the excavated material, the shape of the pilot tube remained circular. But, from the depth of about **148m** the tube began to exhibit distortions and deformations. The shape started becoming elliptical (Fig. 6.) with a tendency to touch upon the walls of the tube as the excavation depth was growing (Fig. 7.).

Figure 6. Deformation of the pilot at the depth of 148m.

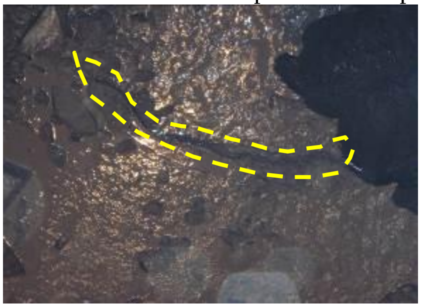


Figure 7. Marking (with broken line) the deformation of the pilot at 154m depth.

This tendency was continued until the complete touching of the casing walls, that means complete blockage of the pilot at the depth of **160m** , while the blockage lasted until the depth of **170.90m**, and then the casing was found fractured or cut (Fig. 8.). The non-verticality of the pilot caused the breaking off of the casing. The breaking mechanism seems to be simple: as excavation products entered into the casing hit the walls of the casing and consequently introduced strain, which in combination with possible joints of pilot casing, result in fracture of the steel tube. This situation has continued to appear until the depth of **172.00m**, while from this depth and below began again gradually to open up, to the depth of **173.00m**, where appeared completely rounded (Fig. 9.).

Figure 8. On the spot image of the broken tube at 170,90m depth.

Figure 9. At the excavation depth of 173m the tube is rounded again.

Then the construction works of the well continued to a depth of 176.40m, as according to the Well Excavation and Support Design while the excavation of last 8.5m had to take place after the concreting of the connecting gallery. Therefore the gallery was constructed and then the excavation of the well continued and was completed successfully with its final depth of 185m, at the ending of the roof of the connecting gallery.

V. CONCLUSION

Ventilation of Lorenzo Mavilis Tunnel under normal operation is achieved with a longitudinal ventilation system, consisting of 38 Axial Fans. In emergency cases, such as an accident or fire ventilation is accomplished through the Ventilation well. The latter consists of 3 Axial Ventilation Fans and 2 Flame Retardant Baffles that only 2 of the 3 Axial Fans will be in simultaneous operation, while the third serves as backup. During construction of the well due to the geotechnical conditions in combination with the possible location of joints of pilot casing, took place pilot's blockage and breaking off of the casing and after the consolidation grouting program, the excavation works of the well continued and completed successfully. In this specific case, the initial design concept for excavation of the well with the removal of excavated material through the pilot, was proven problematic. In general this method is not advisable for weak sheared and water bearing rock masses t but only for healthy rocks with good RQD. In conclusion, in order to avoid unforeseeable developments, when drilling deep wells it is proposed:In cases of "bad geotechnical conditions" the indicated method involves excavation without using a pilot, but transport and removal of materials of excavation from the roof of the well. This method, requires necessary special and relatively expensive equipment for the safe and effective removal of excavated material (special wagons). While using pilot can only be provided to conduct grouting reinforcement and stabilization of rock mass before the excavation of the well.

1. In cases of "good geotechnical conditions" appropriate well excavation method is the one using pilot (cheaper method compared to the above one).

Closing, it is underlined that the well's' excavation method depends on all these factors, and the combination of these factors can give the most suitable method for each case.

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