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RE-EXCAVATION OF SETI FIRST TOMB, KV17, LUXOR, EGYPT

Ayman HAMED*

Faculty of Petroleum and Mining Engineering, Suez University, Suez, EGYPT

Abstract

This article is discussing technical challenges within engineering works made during re-excavation of the 174 m long tunnel which was cut into bedrock of desert shale known as 'Esna shale'. Recent historical events, during the last decade, explained much of the tunnel deformations and dirt filling inside tunnel space "Debris", caused by multiple water runoff attack to king's valley. The author is also discussing the challenging work under severe financial regime; using non conventional solutions adopted with extraordinary actions in using junk yard equipment. Seti I tomb, is considered as the deepest opening in the valley, not mentioning the risk in re-excavation the tomb, harsh atmospheric conditions inside the tunnel, measured and monitored by author, needed a serious ventilation system to serve workers during removal of dirt. Through that, an interesting mathematical relation between atmospheric variables has been emphasized. Design of steel supporting system serving an inclined deep tunnel with irregular circumference, under strict condition of reversibility, has been performed as a remarkable topic, to solve and apply in such archaeological site. Finally, the article is considered as a scientific pattern for application of geo-engineering in conservation of underground archaeological sites.

Keywords: *Tomb; Seti first; KV 17, conservation, numerical modeling, tunnel.*

Introduction

Seti First tomb (KV17) was discovered in 1917 by Giovanni Battista Belzoni [1], since that time, it is known as the most famous burier in the Valley of the Kings. It contains the most beautiful wall decoration and writings. Deeply at the end of its burying chamber, Belzoni uncovered an entrance leading to an extending tunnel, but he never enters, as it was in bad state

In 1961 Sheikh Ali Abdel Rasoul [2] and his team worked on re-discovery of the tunnel. Dirt has to be removed, firstly, in minimum time and cost. Abdel Rasoul idea not to remove dirt completely from all the cross section; he only excavated an inside hollow; just to fit a man size to get through. His men were accumulating the produced dirt in sacks stiffed on behind and sides of the tunnel, as a wall support. Wooden timbers are also used in squared cross sections to support and maintain the cavity through the depth it reaches. Men of Abdel Rasoul were working in sever conditions of heat and lake of ventilation and much dust.

Later then, many trials have been performed to discover the tunnel, none of them were considered successful, as the secret of the tunnel remained unrevealed for a long time. In November 2007 Dr. Z. Hawass formed a scientific mission to rediscover the tunnel of Seti I.

* Corresponding author: eoam_consult@yahoo.com

The author was the only engineer in this mission. In June 2010 our mission was the first to claim that, the tunnel is completely re-excavated and re-discovered.

The work was aiming to accomplish the following tasks: Removing the dirt to outside of the tomb; supporting the space of the tunnel to be visited safely under the condition of reversible technique; Documentation of tunnel architecture, materials and archaeological findings

Location

Seti I tomb known as KV 17, is one of the most famous buriers at King's Valley (Beban el Molouk) at Luxor, EGYPT. The valley is located at 25° 44" North 32° 36" East. It stands on the west bank of the Nile (Fig. 1).

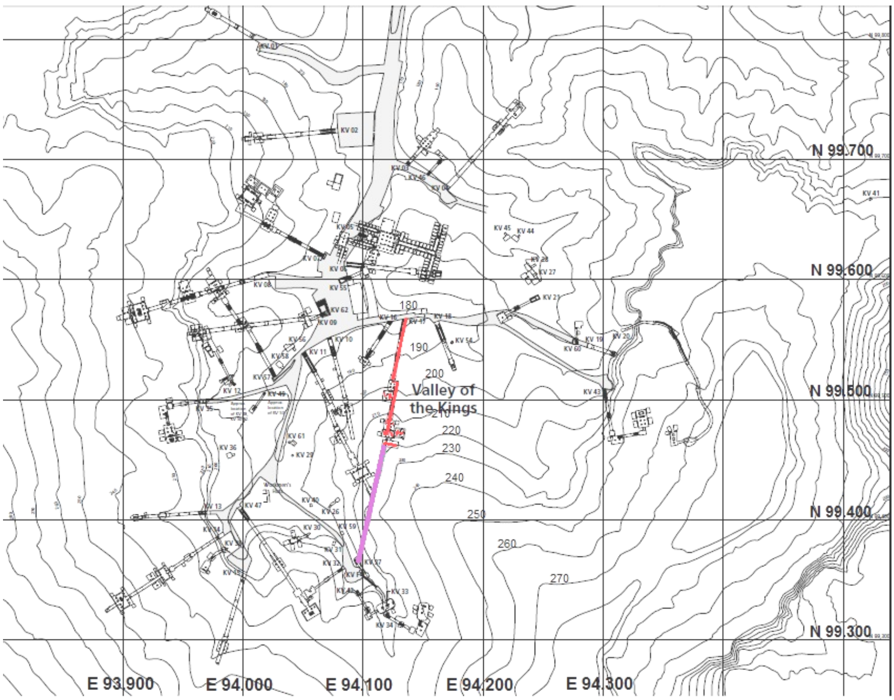

Fig. 1. Topographic map of Valley of the Kings, including Seti I tomb, after Kent R. Weeks (2004).

History of Seti I Tomb Discovery

Donald P. Ryan [4], said that Giovanni Battista Belzoni made perhaps his most acclaimed discoveries during October of 1817. As the first man known to excavate in the Valley of the Kings, Belzoni uncovered five tombs in a short period of just a few days. Most noteworthy was his discovery of the tomb of Seti I (the father of Ramses II), which is arguably one of the most beautiful tombs ever to have been found in Egypt.

Belzoni, G. B. wrote in his book [5, 6] "The sarcophagus was over a staircase in the center of the saloon, which communicated with a subterraneous passage, leading downwards, three hundred feet (~90m) in length. It was nearly filled up by the falling in of the upper part. I measured the distance from the entrance, and also the rocks above, and found that the passage reaches nearly half way through the mountain to the upper part of the valley. I have reason to suppose, that this passage was used to come into the tomb by another entrance; but this could not be after the death of the person who was buried there, for at the bottom of the stairs just under the sarcophagus a wall was built. Some large blocks of stone were placed under the sarcophagus horizontally, level with the pavement of the saloon that no one might perceive any stairs or subterranean passage was there".

Over a period of two years Belzoni and an artist admirably took detailed measurements and recorded Seti's tomb with watercolors and casts, being the first to completely do so in an Egyptian royal tomb. In 1821 Belzoni [7], exhibited his paintings and casts from the tomb of Seti I in a large exhibition held at the Egyptian Hall in Piccadilly, London. The contents of this exhibition were sold the following year.

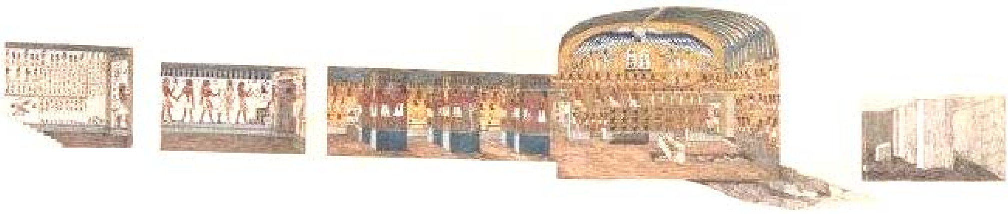

Fig. 2. Sketch of the burrial chamber (k) with entrance of the tunnel (Q), after J. Ricci, 1820 [6]

On the 21st of July 1828, a mission headed by Champollion and assisted by Rosellini, was known as the Franco-Tuscan Expedition, they travelled upstream along the Nile and studied an exhaustive number of monuments and inscriptions. The expedition led to a posthumously-published extensive Monuments de l'Egypte et de la Nubie [8], published in (1845). Unfortunately, Champollion's expedition irreparably damaged KV17, by physically removing two large wall sections with mirror-image scenes. The scenes are now in the collections of the Louvre and the museum of Florence.

M. H. Carter [9], chief inspector in Egyptian Antiquities Service, wrote describing his work achieved during year 1903 to 1904; "in reading through Belzoni's interesting account of his discovery of this tomb in 1817, and his description of its beautifully decorated walls and ceiling, one cannot but think that it must then have been in a perfect condition". He also described his safeguarding work in the tomb of Seti I [10], "When clearing away the rubbish in the tunnel, I found many un-inscribed carefully shaped slabs of stone that had served to form a staircase and sarcophagus slide to the sepulchral chambers (Fig.3.).

Fig. 3. Work made by Howard Carter, in 1902, to save the entrance of the tunnel

These stones were much displaced, and being in want of a good building material for the jambs of the arches, I was compelled to use them for that purpose. For the arches themselves I procured several thousand European red-bricks from "Erment". The wall over the tunnel was lifted up to its former level by means of screw-jacks, thus closing up the cracks in the rock while replacing all fallen fragments which could be reinstated. The arches, of one meter in thickness, were then built with sufficient masonry upon them to hold the wall in place. There being vertical cracks in the thickness of this wall I put two iron clamps on the end to prevent them from opening; to assure the arch against any undue side pressure in the doorway of chamber L (pillared room over the tunnel), I built in with the masonry one of the heavy wooden cross struts that were placed between the two door-jamb. A wooden railing was put round the opening leading to the tunnel to prevent visitors, from falling in.

E.A.Wallis Budget [11], also mentioned that under the sarcophagus is another staircase, which leads to an unfinished passage, its entrance being about 150 feet below the entrance to the first staircase; the total length of the tomb is about 700 feet.

In the year following the opening of the tomb, flood waters from rains entered the lower chambers. Belzoni had filled the shaft in well chamber with debris, but had failed to complete the construction of protective dykes outside the tomb entrance. As a result of the expansion and contraction of the stone and loosening of the plaster, large pieces of the walls and ceiling fell. James Burton completed Belzoni's dykes and cleared well of debris; the tomb has not flooded since. As a part of his conservation work, Carter [9], repaired damage to the walls (1903-1904), but cracks have reappeared and the condition of the walls continues to worsen.

The tomb has also suffered at the hands of vandals who have hacked away at its walls searching for hidden chambers or trying to remove painted relief. Some other reliefs, faded because of the wet squeezes taken by Belzoni [10], others have faded simply as a result of time. The smoke from candles and torches used by early visitors to the tomb has blackened the walls and left soot deposits on the painted reliefs.

Layla I. Eltambory [2], said that in 1961, under the supervision of antiquity authority, Sheikh Ali Abdel Rasoul spent twenty days re-excavating the treasure tunnel of seti I, until he reached a stair way and a masonry façade with gypsum and lime. Unfortunately, the work stopped, without and clear explanation.

Architecture of the tomb

The tomb of Sety I is the longest and deepest of all the tombs in the Valley. It is also the first tomb to be decorated with a complete program of religious texts. KV 17 consists of a total of seven corridors and ten chambers, decorated with painted, raised relief (with the exception of one room). Three sloping corridors, lead to a well chamber and pillared chamber with side chamber. A side descent and two sloping corridors, lead to a second chamber beyond which lies burial chamber. This has a five side chambers, and a long passage at the rear, which is an unusually long descending passage in the floor of the burial chamber.

According to by Kent R. Weeks [3], inclined length of KV 17 tunnel is about 227m; however, horizontal length on plan is about 194m long. Entrance of the tomb is 179.3 m above sea level, the end point reached by Sheikh Ali Abdelrasoul and documented by Kent R. Weeks, is 79m above sea level. Which make the tomb of Seti I the deepest tomb at king's valley (79.3 m). The original floor of the tunnel remained intact steps with a smooth central ramp. The angle of this ancient ramp is varying from 34^{o} at entrance to 36^{o} in deeper section.

Ancient Egyptian used rectangular cross section all along the excavated tomb, even through the extended tunnel, except for burial chamber which is considered as the first vaulted space used in ancient times. Long after, M. H. Carter [9], used vaulted bricks in supporting tunnel entrance during his work in 1903.

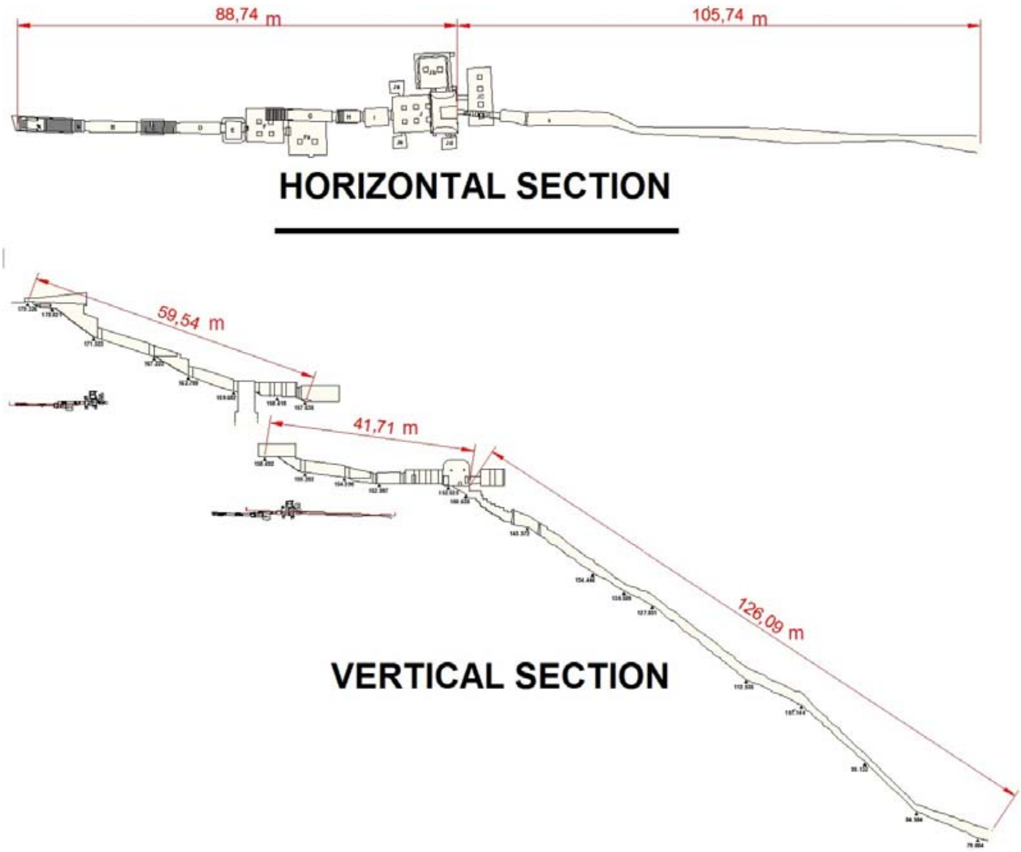

Fig. 4. Horizontal and vertical sections along the tomb of Seti I, after Kent R. Weeks [3]

Methods and Materials

Methods

In December 2007, the mission started excavation, using men labor and annual tools. It was slow and long term operation, although it was effective and fully controllable. To realize the size of the job, the team had to consider the following facts;

- As the tunnel was almost full of debris since discovery and after, it seems that debris (dirt) became pressed and adhered together,
- Two men on front façade should carefully excavate the dirt layer by layer (of about 2cm thick),
- One man on behind should load the dirt in plastic bags of about $0.02m^3$ (25kg),
- A raw of men, spaced by ten meters, queued upward the tunnel, are delivering the dirt bags to each other until the outside entrance of the tomb,
- A six cubic meter of dirt must be removed for each one meter long inside the tunnel.
- Since the dirt are carefully excavated, a man power cannot remove more than one cubic meter per hour work,
- Humans during work, consume more oxygen and produce more heat and humidity, in a closed spaces, this must cause a difficulties in breathing,

- As far as the tunnel goes longer and deeper, number of men increases with decrease in productivity, due to distance,
- Removing the dirt, which became part of stress distribution inside the tunnel, may cause structure instability.

On the light of the above, definite tasks must be achieved as follows:

- Decrease number of labors, by adopting a helping mechanism,
- Increase or at least maintain productivity level,
- Using a reversible supporting system to overcome the stress redistribution inside tunnel walls,
- Using forced ventilation to improve climate condition inside the tunnel.

Materials

Using Universal Distinct Element Code (UDEC software) for numerical modeling to study and calculate the theoretical stress distribution around tunnel cross sections.

Temperature, humidity and barometric pressure have been measured using portable TR-73U data logger average accuracy of measurements is as follows:

- Temperature; ±0.3°C [0 to 50°C]
- Humidity; ±5%RH [at 25°C 50%RH]
- Barometric pressure; ±1.5hPa

Carbone Dioxide has been measured using Telaire 7001 Carbon Dioxide Monitor

- Measurement Range; 0-4,000ppm
- Pressure dependence; 0.13% of reading per mm Hg (Corrected via user input for elevation)
- Sensitivity; ± 1ppm
- Repeatability; ± 20ppm
- Temperature dependence; ± 0.1% of reading per °C; or ± 2ppm per °C; whichever is greater, referenced to 25°C;
- Accuracy; ± 50ppm or 5% of reading, whichever is greater

Man power was used in excavations and manual removal of dirt and sand with the help of other manual tools, such as shovels, buckets and plastic bags.

Hoisting machinery was used to reduce number of movers, which in turn reduce airborne dust for better working condition. Project budget was limited that it gave no ability to purchase required machinery. Junk yard, was an unconventional approach to reconstruct the considered necessary hoisting system. After days of search, an old Decauville used by Howard Carter was found. The system was used during his work in 1893 while excavating out the temple of Deir el Bahri.

H. Carter vessels were made of steel and man powered. However, during assembly and reconstruction of the system, vessels were modified to be made of wood, seeking for lighter weight. Adding of electric wire winches are installed in return of manpower reduction. The winch (gear box) was also reused from junk yard as it was used to serve in restoration of Hatshepsut temple. In April 2009 the first system has been mounted in place (railways, winches, electric drives and vessels). Up to three successive Decauville systems have been installed in the tunnel to cover the complete distance. They connect the deepest point of the tunnel with burying chamber (beginning of tunnel). Men have then to carry dirt up to the external of the tomb. Steel supports are made using local standard shapes of steel 37. The system has been manufactured in-situ by technicians of SCA. A 68 steel frames has been used in total length of 174 m.

Centrifugal fans were used for regular ventilation of the deep points at the tunnel, ϕ 48" fans derived by electric motor of 3hP, which should produce about 13,000m^3/hour.

Results and Discussions

Stress distribution and Tunnel Stability

Tomb of Seti first has been shaped in a rectangular cross section. This is not a common use in modern engineering; where vaults and arches are the best choice. However, when Esna shale is involved, it is quite a challenge to construct inside or even close to such rock layers. Using rectangular cross section inside a shale layer to length exceeding one hundred and twenty meters, this is beyond our present engineering bravery. Seti first tunnel is completely excavated in Esna shale, excluding the entrance and end point. In 2007 when our mission firstly entered the tunnel, falling stones were everywhere; wood timbers were randomly spread over the cavity, mostly during Ali Abdel Rasoul work. Loose dirt (debris) [12], where still exist at sides and floors, which in some places, only keep a place for one crawling person to pass through.

As it is mentioned by H. Ayman [13] a measured average of young's modulus of Theban limestone would be 71.8kPa this would mean a bulk modulus of $K = 71800/[3*(1-2*0.2)] \approx 40$kPa, shear modulus is calculated as $G = 71800/[2*(1+0.2)] \approx 30$kPa.

A two dimensional numerical model has been constructed using geological data mentioned by H. Ayman [13], Rushdi Said [14] and R.A.J. Wüsta [15]. UDEC code [16-20] has been used to simulate two cross sections of the tunnel, one close to the entrance and another close to the end. Both models have exact rock properties and same dimension and square cross section, as the original one, 2m by 2m. The first one was at depth 108m from surface, which happen to be at the top of shale layer, Theban limestone layer is the tunnel cap. Few meters later limestone disappears, only shale remains. This model showed influence of stress redistribution up to the ground surface. Displacement of overburden rock layers is highest value at surface of 3.5cm; however, it didn't exceed 3.1cm at the tunnel top side.

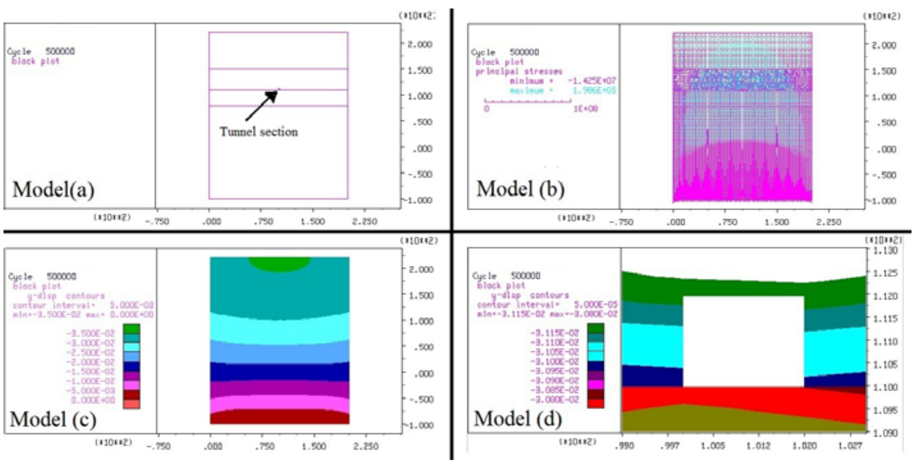

Fig. 5. Numerical simulation of tunnel ideal cross section close to entrance using UDEC code

The second model (deeper cross section), showed that stresses are also influencing rock layers up to ground surface, it is also shows increase in maximum stresses and minimum stresses than in model (1). Nevertheless, the changes in stress values are not radical, which mean that, shale layer contained 2m by 2m cross section tunnel safely, in spite of its varying depth. Overall all depression of rock layers showed 3.5cm settlement, which exactly the same as shallow model, which again confirm that depth of the tunnel in shale layer has almost no influence on rock displacement.

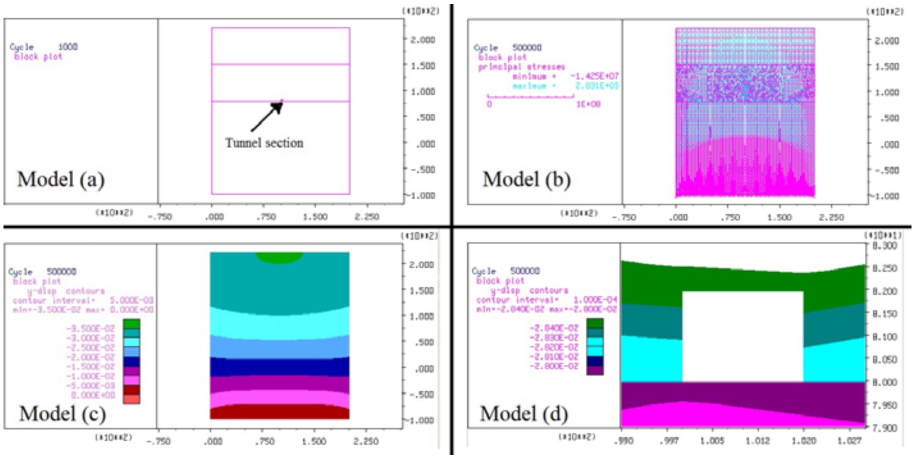

Fig. 6. Numerical simulation of tunnel original cross section at deepest limit using UDEC code

Numerical models of the tunnel, in its original shape, prove that it is mechanically safe, even at the deepest part at shale layer, despite of the bad rock mass quality.

However, confusing question should be raised up by knowing that since 3300 years (age of the tunnel), no major collapse has been reported or recognized in the opening, this is one base facts. Compared to recent time's situation, the tunnel is classified as "critical state". Sooner after Belzoni opened the tunnel in 1817, periodic flash flood accompanied with dirt and different objects washed away inside, to fill the tunnel with water, acting in response with Esna shale producing a destroyed super facial skin of the tunnel.

Amazingly, again no major collapse is recognized or reported, only large quantities of debris and remains of limited fallings from roof and walls are completely filling the tunnel space.

Supporting

The goals of the mission were removing debris left behind water flash, and rediscover the tunnel. During the first few meters a proposed solution by archaeologist has been used, it is composed of brick at sides and steel plates at the top, it was a simple solution which may go a long with nature of the tunnel. However, mason walls may hide many of site evidences and marks enclosed within.

Other solution should be found respecting the following values:

- Reversibility of the system, as it could be completely removed in later times, if needed,
- Keeping visual accessibility of original mother rock excavations (sides, up and ground).
- Respect original axis of the tunnel, as it is came out by archaeological evidences and marks.
- Minimizing inhomogeneous shapes inside space of the tunnel,
- Raising the factor of safety of the supporting system as much as it needs.

Furthermore, a problem of varying width and height along with tunnel axe should be solved, as it complicates a systematic supporting solution. In other words, proposed supports must consider space variations in the three dimensional. The most applicable and proper design would be a set of serial rectangular frames, cubes, with fixed width (respecting the original tunnel width) as well as capability of varying height (to cover collapsed and missing cap). In this special design, vertical stresses should be transferred from weak cap into two inclined berlins parallel to tunnel axe and having the same inclination of the tunnel. The two berlins ride over the mentioned rectangular frames, from their loads are redistributed to tunnel ground. Vertical frames are holed together by side bar to prevent toppling.

Fig. 7. Supports at the first few meters of the tunnel

Considering that the tunnel cross section are naturally reshaped into arch, which mean the natural critical stability of the tunnel. A minimum stresses has been assumed. For practical and economical reasons supporting are designed to overcome further loads.

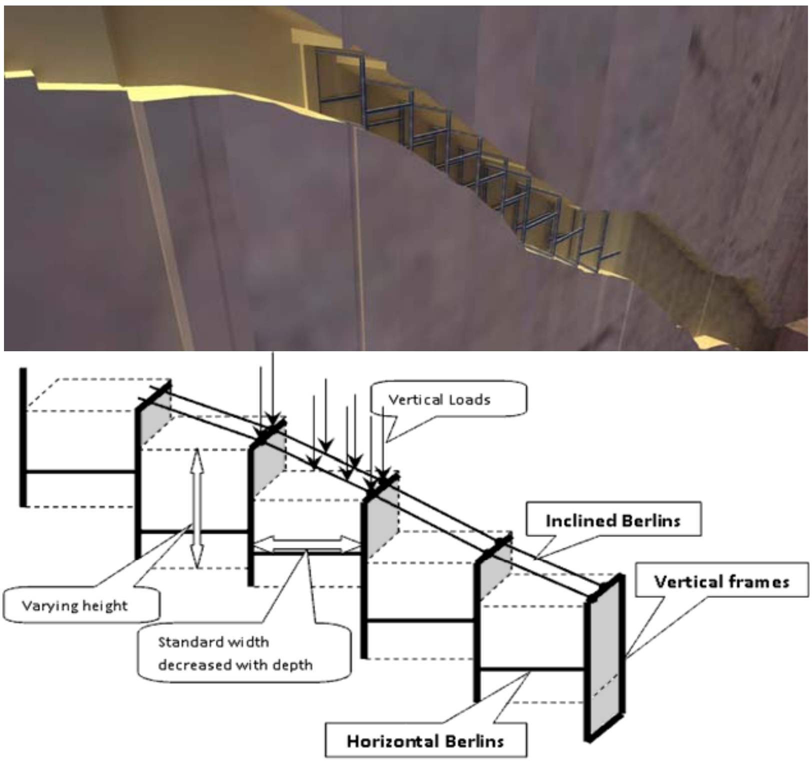

Fig. 8. Digital model of supporting concept detailed with sketch of the supporting design main elements

Variation of Air Quality inside the Tunnel

Seti I tomb and its extending tunnel is deeply penetrating the earth up to 226 m deep, it well be likely to expected lack of natural ventilation. Measurements of atmospheric conditions at entrance of the tomb, in a usual summer day at Luxor, showed, air temperature of 41.5 ^{o}C, absolute air humidity, 9%, air Pressure, 98.18kPa and Carbone Dioxide CO_2, 479ppm (particle per million). Measurement positions are as in. Elevations of measuring points are according to Kent R. Weeks [3].

Air pressure has been measured through the tomb and extending tunnel. Interrelation between elevations and measurement has been plotted and correlated. It is found the air pressure is directly proportional to depth. Mathematical relation is described as a second order polynomial equation with R^2 equal to 0.9972,

$$y = 0.0008x^2 - 0.3327x + 1021.9$$

where (y) is representing air pressure in 10^3kPa (kilopascals) and (x) is elevation (m) at measurement point.

Air temperature measurements begin at tomb entrance with higher value, then gradually dropped down more than ten degrees centigrade tell it reached the entrance of the tunnel at burying chamber. Sharply then, temperature turned over to increase up more than six degrees tell it reached the end of the tunnel.

From above measurements it is clear that entrance of the tomb is affected by external temperature of ambient weather then decayed down with depth of the tomb. However, the case is changed in the tunnel, where temperature is gradually increased during penetrating the depth of the tunnel. Mathematical description of the relation between temperature and elevation shows a third order polynomial equation with R^2 equal to 0.9371, as follows

$$y = 5E\text{-}05x^3 - 0.0167x^2 + 1.7789x - 27.805$$

where (y) is representing air temperature in degree Celsius and (x) is elevation at measurement point.

Although our present research scope is not specifically concerned with ground thermal activities, it was interesting to discuss results of tunnel varying temperature in the scope of ground geothermal. However, it is noticed that until now no studies exist that show the detailed regional distribution of subsurface shallow thermal conditions at study area, Luxor. The above results are going along with most of the publications discussing shallow depth heating, C.A. Swanberg, P. Morgan and F.K Boulos [21] and Burkhard Sanner [22], they mentioned that climatic temperature change over the seasons is reduced to a steady temperature at 10-20 m depth, and with further depth temperatures are increasing according to the geothermal gradient (average 3°C for each 100m of depth). According to present measurements, the first 20-30 meters where affected by the external ambient air temperature, at deeper distance geothermal gradient takes effect according to above equation, with average change of 5°C for only 70 m depth. Another, perspective may take our attention towards shale thermal activity

According to ASHRAE [23], suggested temperatures and air flow rates in different environmental circumstances. The recommended level of indoor humidity is in the range of 30-60%, airflow velocity of 0.15-0.18 m/s and temperature is between 21.0 and 23.0 degrees Celsius.

Concentration of carbon dioxide are also monitored during descending the tunnel, readings are plotted in following curve and mathematically fitted. A second order polynomial equation has been fitted with an R- square value of 0.9806 at mentioned

$$y = -0.0546x^2 + 8.0873x + 803.08$$

where (y) is representing CO_2 concentration in particle per million (ppm) and (x) is elevation at measurement point.

CO_2 in the tunnel is increasing dramatically up to almost three time's normal concentration in air. Compared to external measurements done at the entrance of the tomb, values deep in tunnel are doubled.

It could be explained as many researches in the field of oil and natural gas industry suggests that carbon dioxide emission from shale layers, A.R. Brandt et al. [24] and R.L. Santoro et al. [25], most of them suggested that CO_2 emissions from shale layers are dependent on properties include the fraction organic matter, the mineral makeup of the shale, and the raw shale moisture content.

Carbon dioxide content in fresh air (averaged between sea-level and 10kPa level, i.e., about 30 km altitude) varies between 0.036% (360 ppm) and 0.039% (390 ppm), depending on the location. Due to the health risks associated with carbon dioxide exposure, the U.S. Occupational Safety and Health Administration says that average exposure for healthy adults during an eight-hour work day should not exceed 5,000ppm (0.5%).

Measured values of air humidity shows that it is steadily increase with the depth of the tunnel, mathematical correlation between items can be formulated as follows;

$$y = -8E\text{-}05x^3 + 0.025x^2 - 2.4386x + 140.42$$

R- Square value of the fitted curve is 0.9928. Where (y) is representing air humidity (%), (x) is elevation at measurement point.

Tunnel's wall internal humidity may also be related to depth of the tunnel; however, it is not a steady variation as other atmospheric measurements.

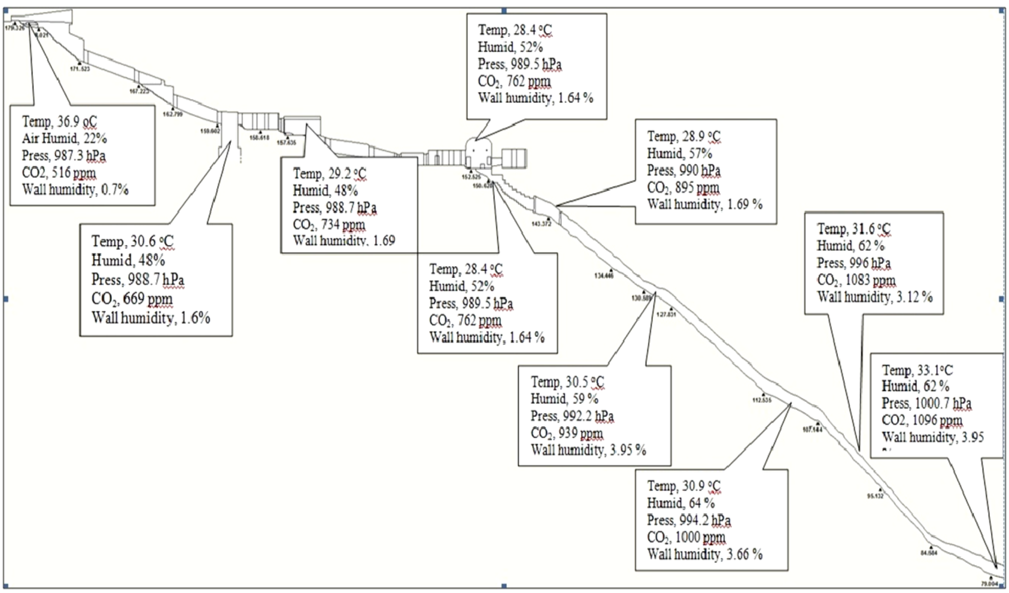

Fig. 9. Location of measuring points for atmospheric conditions detailed by interrelation between measured parameters and depth in tunnel

Comparing the recommended environmental standard values required for human comfort, with measurements inside the tunnel, it became a demand to install and use a forced ventilation system to refresh the air inside the tunnel and dispose the consumed one.

The system is composed of single 10" tube running from outside suction fan down to the bottom. Suction is generated by a double back to back centrifugal fan of one meter diameter; it was reused from the junk yard of SCA.

The adopted system has to overcome the air pressure difference, produced by elevation difference (about 2kPa), friction of air stream inside the 10" tubes is also should be considered.

Conclusions

What is behind the entrance of Seti I tunnel remained a secret for a long time. During our present mission, most of these mysteries have been revealed, as the tunnel has ended with absence of major archaeological artifact. However, working in the tunnel was new evidence on the wide knowledge of ancient Egyptians in using geological data to serve their engineering proposes. It was clear that they were attentive to problems of weak rocks as they used narrow width (~ 2m) while they used wider spans in both limestone layers at the cap and base.

Air condition and quality measurements paid attention to the effect of geothermal gradient inside the tunnel, which can be a point for further research work. Higher concentration of carbon dioxide were also observed and may be linked to gaseous emission of shale .

Finally, it could be declared that performance of archaeological excavations could be greatly improved by using the experience and knowledge of geo-engineering. Quality and cost of work are also dramatically influenced by the assessments and alternatives projected by engineers.

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References

[1] G.B. Belzoni, **Forty-four Plates Illustrative of the Researches and Operations of Belzoni in Egypt and Nubia**, John Murray, London, 1820.

[2] Layla Ibraheim Eltambory, **Alqurnah, Stories from City of Secrets**, 2007.

[3] R.K. Weeks, **Atlas of the Valley of the Kings**, The American University Press, Cairo, 2004, pp. 78-83.

[4] D.P. Ryan, *BA Portrait: Giovanni Battista Belzoni*, **The Biblical Archaeologist** (The American Schools of Oriental Research Stable), **49**(3), 1986, pp. 133-138.

[5] G.B. Belzoni, **Description of the Egyptian Tomb, Discovered by G. Belzoni.,** John Murray, London, 1821.

[6] G.B. Belzoni, **Narratives of the Operations and Recent Discoveries within the Pyramids, Temples, Tombs, and Excavations, in Egypt and Nubia;** and **o**f a **Journey to the Coast of the Red Sea, in search of the ancient Berenice;** and **Another to the Oasis of Jupiter Ammon,** John Murray, London, 1821.

[7] G.B. Belzoni, **Six New Plates Illustrative of the Researches and Operations of Belzoni in Egypt and Nubia**, John Murray, London, 1822.

[8] J.F. Champollion, **Monuments de l'Egypte et de la Nubie**, Firmin Didot Frères, Paris, 1845.

[9] M.H. Carter, *Report of Work Done in Upper Egypt*, **Annales du Service des Aintiquites de L'Egypte (**Le Caire Imprimerie de l'Institut Francais d'Archeologie Orientale), volume VI, 1904, pp. 112-119.

[10] E. of Carnarvon, H. Carter, **Five Years Explorations at Thebes**, Henry Frowde Oxford University Press, London, 1912.

[11] B.E.A. Wallis, **A Guide to the Egyptian Collections in the British Museum**, Harrison and Sons, London, 1909, pp. 174-175.

[12] J. McLane, R.A.J. Wüst, *Flood Hazards and Protection Measures in the Valley of the Kings,* CMR, **6,** 2000, pp. 35-38.

[13] R.A.J. Wust, C. Schluchter, The origin of soluble salts in rocks of the Thebes Mountains, Egypt: The damage potential to ancient Egyptian wall art, Journal of Archaeological Science, 27(12), 2000, pp. 1161-1172.

[14] R. Said, **The Geology of Egypt**. Elsevier Publishing Company, Amsterdam, New York, 1962.

[15] R.A.J. Wüst, J. McLane, *Rock deterioration in the Royal Tomb of Seti I, Valley of the Kings, Luxor, Egypt,* **Engineering Geology, 58**(2), 2000, pp: 163-190.

[16] N. Barton, *The Influence of Joint Properties in Modeling Jointed Rock Masses*, in **Proceedings of the 8th International Congress on Rock Mechanics** (Tokyo, September 1995) Vol. 3, Balkema, Rotterdam, 1997, pp. 1023-1032.

[17] N. Barton, *From Empiricism, Through Theory, to Problem Solving in Rock Engineering,* **News Journal** – **ISRM** (www.isrm.net), **14**, 2011, pp. 60-65.

[18] L. Canelli, A.M . Ferrero, M . Migliazza, A. Segalini, Mechanical *Behavior of Rock Discontinuities under Seismic Conditions,* **Harmonizing Rock Engineering and the Environment** (Editors: Q. Qian and Y. Zhou), CRC Press, London, 2011, pp. 1169-1174.

[19] P. Alfonsi, S. Grelaud, *Determination of Fracture Openings in Rock Masses,* **Continuum and Distinct Element Numerical Modeling in Geo-Engineering** (Proceedings of 1st International FLAC/DEM Symposium, Minneapolis, August 2008), Itasca International Inc., Minneapolis, 2008, Paper No. 04-02.

[20] J. Idris, M. Al-Heib, T. Verdel, *Numerical Modelling of Masonry Joints Degradation in Built Tunnels*, **Tunnelling and Underground Space Technology, 24(6)**, 2009, pp. 617-626.

[21] C.A. Swanberg, P. Morgan, F.K Boulos, *Geothermal Potential of Egypt*, **Journal of Tectonophysics** (Netherlands), **96**, 1983, pp. 77-94.

[22] B. Sanner, *Shallow Geothermal Energy*, **GHC Quaterly Bulletin**, **22**(2), 2001, pp. 19-25.

[23] * * *, Standard 55-2010, *Thermal Environmental Conditions for Human Occupancy* (ANSI approved), **American Society of Heating, Refrigerating and Air-Conditioning Engineers,** ASHRAE, Inc. (www.ashrae.org), 2010.

[24] Brandt, A. R.; Boak, J.; Burnham, A. K., Carbon dioxide emissions from oil shale derived liquid fuels, **Oil Shale: A Solution to the Liquid Fuel Dilemma** (Editor: O. Ogunsola), American Chemical Society, Washington, D.C., 2010; pp 219-248.

[25] R.L. Santoro, R.W. Howarth, A.R. Ingraffea, **Indirect Emissions of Carbon Dioxide from Marcellus Shale Gas Development,** A Technical Report from the Agriculture, Energy, & Environment Program at Cornell University, June 2011, http://www.eeb.cornell.edu/howarth/Marcellus.htm.

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