Underground Cemetery Construction in Jerusalem

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ABSTRACT

Underground burial in caves and tunnels was common in biblical times in the land of Israel. Families, especially distinguished ones, owned caves where they buried their deceased relatives for years. During early Christianity in Europe, both Jews and Christians used underground burial sites known as catacombs.

In our days, due to population growth and the high cost of land, together with the extensive preservation of green areas, cemeteries have become a burden and nuisance, particularly for large cities and communities. Many old graveyards are "lifeless islands" in populated areas. In response, some cities have begun to bury their dead at a great distance from the city, while others have started to perform stacked burials, and still others build burial buildings and towers. Some communities have been forced, due to shortage of land, to dig out their deceased after a few years and place their bones elsewhere, in order to regain burial space – a practice that most people find disrespectable.

In 2015, our company designed and started to construct tunnels as an underground cemetery underneath the main cemetery of the holy city of Jerusalem. One must not forget that death is part of the cycle of life; therefore, establishing underground cemeteries in worldwide metropolises will definitely influence our quality of life. The revival of burial in tunnels with new and innovated technologies will benefit us all. We all share the belief that the living, and not the dead, should inherit the earth.

INTRODUCTION

Every year the tunneling business is expanding and collaboration with the International Society of City and Regional Planners (ISOCARP) for the future design of cities and urban communities is in the making. During the last half of this century, billions of people migrated to cities, and it is estimated that by 2030 almost five billion people worldwide will reside in urban communities. Hence, "Underground development will be an important tool in reshaping our urban areas to meet the challenges of the future without destroying their heritage or worsening their surface environment" (Esaki, 2005). In 2013, the OECD (Organization for Economic Co-operation and Development) estimated life expectancy to be around 80 years, meaning that in less than a century we will need to entomb billions of people in cities and urban communities, while trying to retain the deceased's beliefs and customs.

Religion plays a major role in our lives, and many people worldwide still decline to cremate their body after their death; therefore, cemeteries are essential for city inhabitants. Rites and traditions usually call for burials to be near the place of residence, enabling the remaining family members and friends to visit the grave frequently, at least in the first years. This is a challenge that urban designers and architects must confront while trying to solve the problems of future urbanization.

In recent years, population growth, the rising cost of land and the extensive preservation of green areas have made cemeteries a burden and a nuisance, particularly for large cities and communities. Many graveyards that were once on the city's outskirts have become "lifeless islands" in populated areas (Fig. 1), rarely visited by the second and later generations. Cities worldwide face the challenge of allocating less land to maintain current burial practices. In response, some cities have begun to bury their dead at a great distance from the community; others have started to stacked burials, one on top of the other, while still others are constructing buildings and even skyscrapers for the practice of burial (Fig. 2).



Figure 1: Cemetery in the city of Paris, France

Figure 2: Tower cemetery in Santos, Brazil

Another common practice in some places is to ask living relatives of the deceased to pay a property tax for the grave after a few years, in order to avoid the grave being destroyed and the land reused. However, many find this solution disrespectful.

These factors, therefore, present both an opportunity and an inherent challenge. The opportunity lies in better use of environmental resources and existing technology to solve a universal and recurrent need. In addition, the main challenge is how to address this need while respecting sensitive religious, social and cultural practices.

The innovative solution we propose and have already implemented is the use of underground burial. This concept raises many architectural and technical issues, as well as religious questions. On the technical side, there is the need to allocate an appropriate site using a suitable geological survey; next, suitable excavation methods must be chosen; and then all other aspects can be addressed, such as; architecture, ventilation, fire safety, accessibility, waterproofing and finishing materials. The social and religious aspects are no less critical, as any technical solution is unlikely to be adopted unless it is perceived as legitimate and respectful. To better understand the latter,

we briefly describe below the prevailing burial rites. We then describe our proposed solution and how it is currently being implemented.

BURIAL RITES

Underground burial in caves and tunnels was common in biblical times in the Kingdom of Judea, known today as the State of Israel. Families, especially distinguished ones, owned caves where family members were buried and where their bones were later stored in a small niche or sarcophagus. This custom existed for thousands of years. In Europe, during early Christianity and later, underground burial sites were used by both Jews and Christians (Fig. 3). These sites were mainly known as catacombs, the most famous of which are located in Italy, Sicily, Greece, Malta, etc.



Figure 3: Underground burial in tunnels, Rome, Italy

Burial rites and related ceremonies as well as graveyards are considered sacred by many religions. The basic factor common to all of them is the respect one should give to the deceased.

There are many records of death and burial in the Old Testament, but the basic theology behind this sacred matter is defined in only a few places. The first time this matter is mentioned in the book of Genesis is when the Lord expelled Adam and Eve from the Garden of Eden, where it was written in Genesis 3:19: "By the sweat of your face will you earn your food, until you return to the ground, as you were taken from it. For dust you are and to dust you shall return." This living testament is why we return the dead to the ground.

Subsequently, we find a record of burial in an underground structure when Abraham purchased a burial cave for his family. As recorded in Genesis 23:19-20: "*Abraham buried his wife Sarah in the cave of the field of Machpelah, facing Mamre in the land of Canaan. And so the field and the cave in it passed from the Hittites into Abraham's possession as a burial site of his own.*" This cave served Abraham's family for many years. Isaac and Jacob were buried there as well. Some even believe that Adam and Eve were also laid to rest in the same cave many years before.

Lastly, the most mystical reference to burial occurs when the prophet Ezekiel is dreaming of walking in the valley of the shadow of death. As recorded in Ezekiel 37:1-2, 10: "...and set me down in the midst of the valley, and that was full of bones.... and he made me pass by them round about, and lo! they were exceedingly many on the surface of the valley, and lo! they were exceedingly dry.... And I prophesied as He had commanded me, and the spirit came into them, and they lived and stood on their feet, a very great army, exceedingly so..." This testament is probably why many believe in physical resurrection and thus avoid cremation of the body.

In 1963, the Pope lifted the ban on cremation, which, until then, the Roman Catholic Church regarded as blasphemous and highly disrespectful. Nevertheless, the Catholic Church still officially prefers traditional burial, allowing cremation as long as it does not deny the belief in the resurrection of the body. The Eastern Orthodox Church forbids cremation, and even though the Protestant Church is in favor of cremation, the Evangelist Churches, which have millions of members, decline to do so.

Our proposal offers an integrated solution without confronting the issue of traditional burial versus cremation. Underground cemeteries can place the deceased's ashes back into the ground, thus preserving the basic belief of reuniting with the earth.

JERUSALEM AS A PILOT

Jerusalem, which is the capital and the largest city in Israel, must contend with a growing number of burials each year. As a result, authorities responsible for the burial and maintenance of cemeteries have begun to construct multi-level burial structures and now bury people in levels one above the other, on the ground and in burial buildings. In order to avoid long and cumbersome bureaucratic procedures, we decided at first to place burial tunnels underneath an existing cemetery (Fig. 4). We intend to enable both conventional gravesite burial and multi-level burial in these tunnels. In late 2014, we designed and constructed two pilot burial tunnels that will accommodate approx. 800 plots. Each tunnel is 31ft wide, 20ft high and 165ft long (Fig. 5).



Figure 4: Pilot burial tunnel portals, Jerusalem



Figure 5: Pilot tunnel under construction, Jerusalem

This project received extensive favorable publicity in local and international media such as: CNN, BBC, RT, The Washington Post, Tunnel and Tunneling magazine and others. The Jerusalem project of reviving burial in tunnels was nominated for the ITA-Tunneling Award in 2015 and 2017, in the category of "innovative use of underground space". By shortlisting this project, the committee strengthened the importance of this issue. The nomination should raise awareness of the tunneling business community to the potential solution for the development of future urban communities and the potential new market.

The large-scale project of 22,000 graves that we are currently executing evolved from the pilot project and addresses both the technical and religious issues (Fig. 6). The overall plan of the extended project is being created with the client's valuable input, and the scheduled delivery of each section will enable the client to begin using each section as soon as it is completed.



Figure 6: Illustration of underground cemetery complex, Jerusalem

Like all tunneling projects, we investigated the site using a geological survey that included core drills and laboratory study of the findings. The results helped us determine the appropriate alignment and positioning, to avoid as many potential geological obstacles as possible. (Fig. 7)



Figure 7: Geological positioning analysis, Jerusalem

Utilizing NATM (New Austrian Tunneling Method), we prepared a suitable contingency support design for various types of rock mass.

Initially we decided to excavate the tunnels mainly with two large Sandvik MT720 tunneling roadheaders instead of using the drill and blast technique, with the intention of minimizing the disturbance to the cemetery's day-today "business." During the excavation, we did use drill and blast for benching and the shaft pilot hole. The project's final design requirements for ventilation, fire safety and accessibility encouraged us to design a main shaft, measuring 80ft by 92ft with a 180ft depth. The construction of the shaft, located in the center of the cemetery, was done in two stages. The first stage was to excavate a pilot shaft. In the second stage of enlarging the shaft to its final size, the excavated material was extricated through the pilot hole and then disposed of along with the tunnel muck. (Figs. 8)



Figure 8: Shaft enlargement excavation, Jerusalem



Figure 9: Underground cemetery space prior to construction, Jerusalem

In its final operational state, the shaft will include three elevators, staircases, service chambers, plenum shaft, fan room, control room, electrical room and emergency generator, etc. The shaft will also act as a burial "building" that will accommodate more than 3,000 plots in 13 floors. The negative ventilation system based on the suction of air from the underground space will include ducts with motorized dampers governed by a central computerized system.

Since underground burial space is a new concept in the tunneling world, we have thoroughly researched the potential risks we could encounter. Underground cemetery fire safety is a unique field that we developed together with the Israeli Fire and Rescue Services, which used design codes to safely and quickly evacuate visitors and workers to assembly points. State-of-the-art CFD (Computational Fluid Dynamics) computer software that simulates hazardous fire events has already tested the entire area of the underground cemetery (Fig. 10).



Additionally, the space will be divided into sections separated by smoke collection zones, which will allow visitors sufficient time to evacuate in the event of a fire. Due to the minimal use of combustible materials in the underground cemetery, these zones can have a unique, open design that eliminates walls and fire escape doors. Since the space will mostly be covered with shotcrete and natural rock tiles, only fire hydrants – rather than sprinklers – will have to be used.

Figure 10: CFD simulation for smoke event, Jerusalem

Linear heat detectors featuring a fiber optic system will be connected to the site's fire control system, as will the city fire department. The tunnels will include all basic safety measures such as exit signs, emergency lights, fire fighter telephones, extinguishers, a voice evacuation system and more.

In comparison to present ground-level sites, accessibility is going to be improved dramatically. The project will also adopt the most current regulations that will allow the elderly and handicapped to access all parts of the underground space via club cars.

The structural design for cemeteries calls for an "infinite" concrete lifespan. The aim is to minimize future maintenance and thus sustain durability for many years, beyond common practice, even when the space has been abandoned. The various structures will be covered with local Jerusalem limestone rock tiles to comply with the municipal building code. We pay particular attention to maintaining the connection to the ground of each grave even in stacked burials, thus upholding the Biblical ruling, "For dust you are and to dust you shall return." This unique solution can also be suitable for cremated remains.

As described earlier, underground cemeteries were common in ancient times. We are planning to construct a small museum exhibiting ancient burial traditions with displays (i.e., sarcophagi), photos with written explanations, etc. The museum will be situated on the lower floor of the shaft, which is also the main entrance to the cemetery (Fig. 11).



Figure 11: Illustration of the on-site museum, Jerusalem

In response to a request by the client – Jerusalem's main burial society – we established an old/new burial method in addition to existing methods such as stack burial in precast and ground burial. In collaboration with the Finnish company, we developed a machine that excavates holes (burial crypt) in the actual rock, for a solution very similar to the technique used in ancient times, whereby the deceased is laid on the genuine bedrock, observing the important commandment of returning the body to the earth as mentioned in Genesis 3:19.

The first underground cemetery in modern times will inaugurate by November 2019, with one third of its planned capacity. One of our major goals is to make the new underground cemetery a pleasant place to visit. This requires investing in the tunnels' finishing materials so that visitors will sense the serenity and respect, and not feel suffocated or claustrophobic. (Fig. 12)



Figure 12: Illustration of the final underground cemetery, Jerusalem

ART IN TUNNELS

In recent years art is taking place in many forms and places in underground projects. The spot light our project received by the global media groups caught the eye of Yvelle Gabrial a glass artist from Germany which propose a unique large-scale lighted glass sphere. This extra ordinary structure is being placed in several locations in the underground cemetery which will enhance the lighting and the exceptional surrounding ambience. We believe that both the museum and art installed will be an attraction for many tourists visiting the holy city of Jerusalem. (Fig. 13)



Figure 13: lighted glass sphere, Jerusalem

CONCLUSION

The revival of underground cemeteries addresses both the opportunity and the challenges noted above. It provides an environmental solution by preserving precious land. Unlike our precious open spaces and landscapes that are in danger of turning into fields of graves, underground space resources are almost limitless. In addition, this revival restores an ancient tradition of burial in a way that overcomes key sources of resistance to the concept. By combining the old with the new, our proposed renewal of burial in tunnels should be implemented in the underground solutions for future urban planning.

Jerusalem has been a source of wisdom and ingenuity since ancient times. Nowadays, revitalizing the practice of underground burial, which began in Jerusalem, can become a beacon for the planning of future cemeteries. We truly believe that major cities worldwide can benefit enormously from the long - abandoned idea we are restoring today, while utilizing state-of-the-art design and construction tools. Our solution reflects our shared belief that the living, and not the dead, should inherit the land.