A Study for the Construction Method, Site Environment and it’s Usage of Newly Built Underground Architecture in Japan

Kenji Okuyama
Ph.D., Department of Architecture, Faculty of Science and Engineering, MEISEI University, Japan

ABSTRACT

This study is to investigate the underground architecture which newly built in Japan while from 1999 to 2003. I analyze the environments of sites, application purposes, and architectural methodologies of construction. Underground space architectures use and solve to the maximum the difficult conditions given by construction sites to create rich in space, functional, safe, and symbiosis with environment.

1. INTRODUCTION

In recent years architecture making use of underground spaces is being implemented with increasing popularity worldwide. Recent examples are the underground sewage lines of the cities of Paris and Europe, and currently elements such as underground water flow, underground roads, subways, and the implementation of underground power lines are being constructed as city infrastructure. Also, a history of underground dwelling exists in places such as Cappadocia in Turkey and Yao-Dong in China. In modern times, public spaces used by citizens such as the Montreal shopping mall and pedestrian space as well as shopping center and cultural facilities in the Les Halles quarter of Paris exist as examples. More examples of underground spaces with an assortment of applications being constructed worldwide are the underground churches, museums, and concert halls in Stockholm and Finland and the shelters and recreation facilities in the countries of Northern Europe. There is a wealth of research and reporting on past examples of these types of underground constructions. Conversely, in Japan consciousness of architecture using underground spaces has not been as active as in the West. This is because underground spaces have not been used extensively in architectural terms due to the high cost of underground construction and abundant technical problems attributed to reasons such as the cities of Japan being located in plains near coasts or rivers, the soil being weak geologically, and the underground water level being high. Such factors have resulted in comparatively sparse reporting and surveying research on constructions which make use of underground spaces in Japan recently.

Therein, in order to learn how and with what kind of conditions architecture in underground spaces is constructed, I surveyed works employing underground spaces via the monthly magazine “Shinkenchiku” (“New Architecture”). This is a leading international monthly magazine that presents cutting edge architectural works with original design and new technology both in Japan and abroad. From amongst the architectural works presented in this magazine in the 5 years spanning from 1999 to 2003, I especially extracted examples wherein the major application was constructed underground.

My purpose herein is to clarify the architectural factors of the underground space architecture examples from these resources and extract a design resource for underground space architecture in Japan.

2. SURVEY POINTS AND ANALYSIS

The construction cost of underground constructions is approximately 3 times that of the construction cost for constructions above ground. In order to know what sort of factors there are in the construction...
of underground space architecture regardless of that fact, I extracted examples from a 5-year period of constructions that used underground areas from the monthly magazine “Shinkenchiku.” The examples are limited to underground spaces which are spaces for human usage. From these architectural examples, I shall investigate and analyze what kind of environments, sites, and application purposes, as well as what kind of architectural methodologies are used in construction, and I consider the details of such.

2.1 28 examples of architecture using underground spaces

Herein I shall present 28 extracted examples. In order to comprehend, classify, and analyze these examples, I extracted the building names, locations, architectural summaries, designers, builders, building floor spaces, total floor spaces, years completed, cross section compositions, layout maps, and cross section diagrams. However, examples of similar underground space architecture works have been omitted, so that the following serve only as representative examples of their respective construction method characteristics. (Figure-1)

2.2 Applications of the 28 samples

“Shinkenchiku” presents approximately 20 works in each issue. Approximately 1,000 buildings were presented in the 5-year period (60 months) used for this study. From within those examples, ignoring those constructions applied to non-peopled uses such as utility rooms and storage areas, I found 28 constructions using underground spaces. From the number of such constructions presented, it can be said that works which use underground spaces with the main application being for human usage is still very low at 3%.

Regarding the major applications of these 28 buildings, 8 were museums or art museums (28.6%), 8 were assembly halls, presentation areas, or community halls (28.6%), 5 were living spaces or art studios (17.9%), 3 were universities or educational facilities (10.7%), 2 were religious or tribute facilities (7.1%), and 2 were lodging facilities and international meeting spaces (7.1%).

The usage purpose of the samples included museums and art museums which do not necessitate natural light from windows and usage such as the archives of temples and shrines and tribute areas. Also, it became clear that because the volume of large spaces with high ceilings such as music halls and sports spaces within parks must be reduced, building these sorts of constructs underground has been considered.

2.3 The current conditions of construction sites

Looking at the construction locations, or sites, of these samples, 8 were parks or university campuses, 7 were within urban areas, 9 were within forests or natural areas (1 was seaside), and 4 were within historical cities such as Kyoto. The construction conditions of each differ. However, classifying them in general terms results in the following construction factors.

(1) Buildings constructed underground in order to increase the underground portion and decrease the above ground volume due to regulation height limits and cubic capacity limits Eight buildings (28.6%) within parks and university campuses (3 universities)

(2) Buildings constructed underground because sites in the city are spatially limited, highly dense, and land is expensive, in order to use to the maximum cubic capacity, and because consideration must be given to sunshine for previously standing buildings in the area. Seven buildings (25%) in the urban area

(3) Buildings for which the construction location is a park or forest, and which use underground areas in order to comply with consideration to natural environment and height regulations, and buildings for which the construction site is in the mountains or forest and which are built underground in consideration of the scenery and environmental conservation. It should be stated that buildings constructed underground due to consideration towards nature and scenery were evidenced the most in terms of number of cases. Nine buildings (32.1%) within forests and natural areas

(4) Buildings for which the construction site is within temple grounds, and which are built underground due to limited land use and in consideration for historical scenery. Four buildings (14.3%) constructed in historical cities such as Kyoto
Fig. 1. Examples of underground construction.
It was revealed that underground space architecture is constructed in construction sites classified into the 4 categories listed above.

2.4 Categorization of space by the construction method of underground constructions

I categorized underground space constructions by how they incorporated the given site conditions into underground spaces. I compiled these categories into 6 types and named them as listed below.

(a) Burying – the earth is mined and the construction is completely buried with no windows
(b) Digging – a hole is dug into the earth, and the light roof or upper portion of the construction is open
(c) Building basements – constructions that become underground rooms as structural bases of architecture
(d) Mountain peak – constructions completely buried conforming to mountain configuration contour lines
(e) Field burying – constructions buried conforming to a field configuration
(f) Slant cave – constructs embedded into slanted land as cave format architectures

Constructions actually built are planned and built conforming to individual sites, scenery, legal regulations, applications, and functions.

![Construction types and categorisation.](image)

By summing up the construction examples of these 6 construction types, I was able to classify as below.

(a) Four constructions (12, 17, 21, and 24) for which their architectural applications are completely buried underground. Their applications include book storage, cultural asset display and storage, and a tribute to victims of Hiroshima and Nagasaki. Their spaces are limited, and an effect of considering scenery and the surrounding environment.

(b) Four constructions (6, 10, 14, and 20) which possess open cut underground plazas include educational facilities which have been placed underground in order to preserve historical scenery, take on the function of transportation terminals and underground plazas in the limited land of metropolitan areas, and are integrated into surrounding commerce areas and bus stops.

(c) Nine constructions (1, 9, 11, 13, 15, 22, 23, 26, and 28) which are underground spaces used by humans as living spaces which supply the underground function of structural bases for underground architecture. These ignore cases of rooms not used by people such as utility rooms and storage spaces. Four are display rooms, 2 are multi-purpose halls, 2 are studios, and 1 is a living space. Also, 2 university campuses are overlapped.

(d) Five constructions (2, 4, 18, 19, and 27) wherein architecture is inserted into and adapted to the top of sites with hill format inclinations, and which are underground space facilities with consideration given to the scenery and environment. Four are memorial halls, museums, and display spaces set in parks and public spaces, and 1 is a sports and community facility.

(e) Three constructions (5, 7, and 16) wherein a bowl or bowl shaped configuration is created and then underground space architectures are buried within in order to protect scenery and the natural environment. 2 are museums and art museums, and 1 is an international meeting space.

(f) Three constructions (3, 8, and 25) which use an architectural format that employs areas that cut...
perpendicular to the opening portions of earthen cave hole style living spaces in slanted land as terraces or natural illumination. One is a lodging facility, 1 is a community facility, and 1 is a live-in shop.

3. CONSIDERATIONS OF THE CONSTRUCTED UNDERGROUND SPACE ARCHITECTURE

For the 28 samples above, I have charted (Table 1) information for 1: underground space type, 2: site conditions, 3: application of the architecture, and 4: number of underground stories and underground depth. Using the table as a base, I will discuss below by topic items which became clear upon comparing and considering the attributes of underground space architecture.

Table 1. Proposed classification of underground construction.

1) I classified the constructions into 6 underground space types. Within the samples, some examples of constructions are composed of 1 type, and some of 2 types. Within 28 constructions, 15 are composed of 2 types. In Table-1, the main type is indicated with a circle (○), and the sub-type is indicated with a triangle (△). 13 constructions are constructed via 1 type. Within this, the most frequent is c type with 7 constructions, which were constructed as basement floors to constructions built above ground. The next most frequent is type d with 3 constructions, which were constructed in alignment below a mountainous configuration. In the cases of type overlapping, type c is the largest, exceeding 50% with 15 constructions. The next is type b with 8 constructions, and type d with 7 constructions. The least frequent is type e, with 3 constructions. This reveals that the constructions are designed for ease of use and an enriched functionality of underground spaces by combining the assortment of space types.

2) For site condition, I classified the samples into 4 categories, which are in urban areas, forest and natural environment areas, park and university campus interiors, and historical cities such as Kyoto. Six constructions exist as compounds of these. It became apparent that these constructions were
constructed as underground space architecture for factors such as taking into consideration natural ecology, environment, and scenery; taking into consideration the surrounding scenery and environments such as parks, university campuses, and the grounds of temples and shrines; and the maximization of sites with limited space in order to ensure architectural cubic capacity in urban area.

3) For architecture application, museums and art museums were the most frequent at 8 constructions (28.5%). These are architectures for which underground construction does not present any functional problems because the view of natural light and windows is not necessary due to the functions of work display and storage. Also, there are 8 constructions (28.5%) which serve as community facilities (meeting areas, sports areas, halls, etc.). Here as well, if air conditioning facility is established, a lack of necessity for natural light and outside scenery from windows in music halls, tribute spaces, and book storage areas can be listed as a factor for building underground. Also, it was revealed that for profitability in urban sites that have high values commercially, the need to build underground is high for the maximization of cubic capacity when the height is limited due to the height regulations of building codes.

4) For underground room depth and number of stories are the bus terminal and underground citizen's hall in the center of Nagoya City, the deepest construction at 24m underground from the surface level. The next deepest is a book storage area of a Kansai-kan of the National Diet Library at 23m underground. This was built underground in order to maintain a low construction height for its location in a suburb of the historical city of Kyoto, which is also a place with a nice natural environment. Also, an art museum on a site which exists in a nice natural environment within a national park extended 20m underground due to considerations for the natural environment and scenery. Other samples include 16 subterranean constructions from 10m to 20m underground depths. It was revealed that the average depth overall is 12.16m.

4. CONCLUSION

Underground space architectures use and solve to the maximum the difficult conditions given by construction sites to create rich in space, functional, safe, and comfortable spaces. Efficient use of the limited national land including that of Japan, in other words the sparse remaining land in metropolitan areas, and the coexistence of development and the conservation of the natural environment and scenery of expanse of land at the base of the mountain, and mountainous regions in areas rich in nature, outside of urban areas are technologies that can be said to be demanded of underground space architecture.

As mentioned above, I sampled 28 underground space architectures. However, this is only the tip of the iceberg, and there are definitely many more examples of underground space architecture commonly built. Examples that have not been included in this study, for example, the underground city areas and underground parking areas in Japanese metropolitan area transportation terminals, as well as, underground roads have been constructed exceeding 1 million m$^2$ by the year 2000. This is the largest cubic capacity worldwide. In addition, large underground spaces such as the exhibit museum of the Takayama festival and the underground nuclear physics laboratory in Gifu Prefecture exist as well.

As future research tasks, I would like to increase the resource materials, experiment further with the classification and systemization of underground space architecture, and complete a solid basic-resource for future underground space planning and usage.

REFERENCES