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Research Article

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Analysis on the influences of underground space development on urban residential environment

Yang Xiaobin, Chen Zhilong and Su Lichang

Research Center of Underground Space, PLA Univ. of Sci. & Tech. Nanjing, China

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ABSTRACT

A residential quarter accommodates substances, life and even the resident's spirit, a place, in and around, where people spend most of their life. It is also the epitome of such urban phenomena as land shortage and its rising price as well as environmental deterioration. Therefore, how to balance efficient land utilization and better living condition is a significant question for urban research. As a limited natural resource, underground space, with its own advantages, can be used in a wide range of areas like transportation, commerce, hazard prevention and environmental protection, boosting the substantial development of cities. This thesis is to study the environment design of underground space within residential quarters in respective terms of psychological environment, air environment, lighting environment as well as sonic environment, with a hope to offer some ideas and suggestions on building a cozy underground space in the quarters.

Key words: residential quarters; underground space; environment; influences

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Despite that buildings with different functions require different levels of environment, any building that witnesses human activity is supposed to meet people's physiological needs and consider its psychological impacts, which is especially the case with those in residential quarters deemed as the center of living. Due to the distinctiveness of underground space and a long time neglect of its improvement, there is the occurrence of "a social recognition that the environment of underground structures is inferior to that of surface structures", exerting impacts on the development of underground space in residential district.

People's perception of environment is formed through various stimulus offered by vision, hearing and smell. To fairly meet people's physiological demands while regarding psychological factors, we need to work out a corresponding environment design which mainly involves control on air quality, humiture, lighting and sound. The key to the sound development of underground space within residential quarters lies in the creation of a standard, beautiful, cozy, safe and healthy underground environment and a subsequent change in the perceived bad image [1].

1. PSYCHOLOGICAL ENVIRONMENT

The internal environment of a building can give rise to a positive or negative psychological response. The characteristics of underground structures and the some consequent negative psychological reactions that have never been fundamentally improved have been inflicting on people prejudices against underground space, some of which have grown into psychological disturbances [2]. For that reason, further development of underground space in living quarters requires, above of all, mitigation or even elimination of those disturbances, that is, to help form a brand new concept of the underground space from the perspective of psychological environment.

1.1 Physiological Environment and Psychological Environment

Physiological environment and psychological environment are both the unity and the opposites; the former can at times be thought of as the latter and they are interdependent. Thought mental activities, psychology reflects objective physical environment. Certain changes of physiological environment may immediately lead to adverse

psychological reactions, while some impacts may take a long time during which certain harms have been done to arouse a psychological response. In terms of lighting, ventilation and air environment, underground space is not so good as surface space, or even stark different from the latter, which may easily result in physiological discomfort and further psychological one. Meanwhile, the closure of underground space or a lack of contact with the outside can make people feel depressed [3]. Underground space thus should maintain unhindered contact with the outside world, which is expected to be the same as that of similar surface buildings when it comes to environment design.

1.2 Psychological Environment Evaluation

(1) Perception of Environment Quality

Perception of Environment Quality refers to the process during which people perceive and evaluate surrounding environment [4]. The mode of the process is that the attributes of environment are formed though people's filters (including the personal preference, cultural and time) into the perceived environment which will influence human behaviors. It can be described by the Lewin Formulation as follows:

$$B = f(P \bullet E) \tag{1}$$

In the formulation, B—behavior， F—function， P—person; E—environment. It shows that the combined or mutual action of human and environment is what decides the human behavior there and then.

(2) Feelings of Residents

The investigation on the basements of some earlier living quarters reveals that residents entering the basements will be more or less brought down by certain mental disturbances which appear even more evidently with the passing time. Those disturbances mainly comprise senses of closure, damp, stuffiness, dimness and even inferiority. The analysis on those factors for psychological disturbance and discomfort of residents shows that the factors, excluding environmental features special for underground space, all have strong bearing with shortage in material and technical conditions and in environment design. For instance, antiaircraft basements constructed in the past usually took into most account aircraft defense in wartime and into little internal environment design. Even later series of transformation out of the need for daily use were provisional measures when there was no other option, which is by no means fundamental solution to the problems [5]. That also serves as the source for most underground structures' being not that satisfactory and for those negative psychological responses. In fact, an attempt to improve residents' physiological environment will readily melt those negative reactions into thin air.

1.3 Improvement of Psychological Environment

One of the major factors for psychological discomfort when in underground is the closure of the space. Researches on the psychology of environment suggest that people's sense of openness of windows when indoor can be expressed as:

$$S_p = CL^{\alpha}R^{\beta}\omega^{\gamma} \tag{2}$$

In the formulation, C is a constant, α=0.2～0.4; $\beta \approx 1$; γ=0.3～0.5. L for lighting is equivalent to 25-1600lx; R for the room in the unit of m^3; ω stands for the window, or exactly the projection ratio of human eye towards the solid angle of window.

According to the investigation, when $S_p \approx 100$, about 50% of respondents feels satisfied, which is also the case with almost 100% when $S_p \approx 200$. It can be concluded from the formulation that R and ω exerts the greatest influences on the sense of openness.

2. AIR ENVIRONMENT

Air quality can have great effect on human's survival, living and activities of all sorts. The air quality of underground structures can be measured with two indicators, namely, air cleanness and degree of comfort.

2.1 Air Cleanness

In those large-scale underground structures under residential quarters, people's requirement for air cleanness can be satisfied by mechanical ventilation which is not only capable of supplying fresh air above the ground to the underground space, but filtering various contaminants contained in the source air via technical means. Nevertheless, mechanical ventilation usually fails to achieve to same effect as that of natural wind, and can have some negative impacts on human. Hence, to realize natural ventilation, some constructions employ vertical ventilating shaft, making use of airflow produced by different air pressure between indoor and outdoor. For half-underground

constructions, ventilation can be realized through high side windows, and it can even be better fulfilled via a sunken courtyard on one side [6].

2.2 Degree of Comfort

Measuring the degree of comfort of indoor air involves temperature, humidity and velocity of airflow, the control of which should be attached great importance when it comes to internal environment design of underground structures. Media surrounding underground structures, stones or soil, are equipped with good thermostability, enabling them to maintain a relatively constant temperature in certain depth underground without being susceptible to air temperature variation. For example, Minneapolis, city in the north of the United States, has a temperature difference of nearly 80 degrees centigrade between the peak of its summer and the bottom of its winter [7]. However, the place in the depth of 8 meters has an annual fluctuation range of less than 5 degrees centigrade.

Tokyo's annual variation of earth temperature in different depths can also been seen from table 1. It shows that, in the depth of 7 meters, the temperature is stable at around 15.5 degrees centigrade throughout a year.

Table 1: Tokyo's annual variation of earth temperature in different depths

Depths\month	1	2	3	4	5	6	7	8	9	10	11	12	average
3 meters underground	16.0	14.6	13.4	12.8	13.1	13.9	15.2	16.7	18.0	18.8	18.5	17.5	15.7
5 meters underground	17.5	16.2	15.7	15.1	14.8	14.7	15.0	15.4	16.0	16.5	17.0	17.0	15.8
7 meters underground	15.6	15.7	15.8	15.8	15.8	15.7	15.6	15.5	15.4	15.4	15.4	15.5	15.6

3. LIGHTING ENVIRONMENT

Generally speaking, underground structures, separated from natural light on the ground, are mainly lit by artificial lighting, but the extent to which natural light is taken in will affect in large measure the environment quality of underground structures. For those structures, the introduction of natural light is not only to meet the needs for illuminance and energy conservation, but more importantly to satisfy psychological desire to perceive such natural signals as sunlight, directions, seasons as well as weather variations.

Natural lighting is no doubt very important for the shaping of underground lighting environment, but artificial one remains a major method when it comes to internal underground space [8]. Artificial lighting has a direct effect on the visual perception given by underground space, the shortage of which will darken the internal environment, confound substances with space and gloom the atmosphere.

The functions of artificial lighting for underground space can be summarized as the following major aspects：

- to layer the space;
- to adjust the space's dimensions;
- to direct the space;
- to intensify the visual perception.

For those underground structures with higher requirements concerning indoor environment, it is expected to increase the use of electric incandescent lamps and decrease the exclusive use of fluorescent lamps with white cold light. Combination of various light sources is feasible when such requirements arise as to ease the monotony of light color or to create a lighting environment blending cold and warm colors. In addition, design of the lighting at the entrance of underground structures merits special attention. In most cases, outdoor in the daytime has an illuminance several to dozens times higher than that of underground under artificial lighting. Since strong lighting contrast will irritate vision of those who entering underground right from outdoor, the reduction of illuminance from outdoor's to underground's ought to follow an appropriate gradient, so as to adapt human vision to the darkening environment. It is the opposite case with nighttime [9]. The light is supposed to be weakening from underground to outdoor so as to prepare the vision for the darker environment on the ground. For those underground structures with special demands for light, local lighting can be adjusted to satisfy those special needs without sacrificing basic ones. To take an example, in an underground garage, the local lighting above the main lane can be properly arranged to serve as guidance to vehicles. Therefore, heed should be paid to that in design out of the purpose to avoid misunderstanding of the flow line of lane and the subsequent inconveniences or even accidents [10].

4. SONIC ENVIRONMENT

4.1 Analysis on the Sonic Environment of Underground Structures

A favorable sonic environment people require during indoor activities can be measured from three aspects: first, whether the sound signals are in an uninterrupted transmission and maintain certain degree of articulation; second, whether the background noise intensity is suitable for work and rest; third, whether the intensity of room noises is controlled under the permissible noise level. The articulation of sound signals is actually prone to the reverberation

time which can be regulated through sound absorption materials and structures with appropriate interior decoration. In that respect, there is no big difference from ground constructions and underground ones [11]. Therefore, the evaluation of the sonic environment of underground structures focuses on background noise and room noise.

Since underground structures, compared with ground structures, have less windows and a larger reflection area as a result, they present a higher sound pressure level than those ground ones in similar type do, usually higher in 3 to 8 decibels. Besides, there is also change in the frequency characteristic of noises. Table 2 demonstrates the result of measuring a ground power plant and an underground one with the same type of turbo generator unit [12].

Table 2: Noise intensity comparison of ground and underground power

Location\SPL\Frequency	125	250	500	1000	2000
ground	91	88	91	92	103
underground	88	92	94	96	103

Having understood major sources of room noise within underground structures, we should endeavor to keep equipments deemed as those sources away from the structures with higher requirements for functions, separate the space under strict rules and set up sound insulation. For such underground constructions as underground club in large-scale residential quarters, the ceilings can be applied with sound absorption so as to reduce the reflection. Meanwhile, carpets and other furnishings capable of absorbing sounds can also be employed to optimize the sonic environment of underground structures.

4.2 Influences on the Sonic Environment of Residential Quarters by Reasonable Development of Underground Space

For those residential housings in a living quarter, noise sources, except for indoor one, mainly originate from the operation of supporting service facilities and motor vehicles, in which case an as significant reduction of those noises will effectively improve the overall sonic environment of the quarter. There was a research, by means of acoustic computation, about the influences on residential housings by the noises of vehicles running on motorways on and under the ground [13].

The sound power level (Lw) of a moving vehicle is about 100dB, and the journey (r) of sound ray 1 covers 16 meters. In light of sound ray 1, the research was carried out to learn about the influences on residential housings by the noises of vehicles running on motorways on and under the ground.

Scheme 1: motorway on the ground

According to the half-free space theory, the noise level when the noises reached residential housings equaled to:

$$Lp_A = L_w + 20\log(\frac{1}{r}) - 8 = 68dB \tag{3}$$

The figure surpasses the permissible value set in the national Noise Criteria in Urban Region.

Scheme 2: Motorway under the ground

The influence of noises within the motorway on the housings is to form a secondary noise source outside the motorway which will cause reflection of noises towards the housings.

According to the room acoustics theory, the sound pressure level in steady state within the motorway, or L_{w1} reaches

$$Lp_o = L_w + 10\log(\frac{Q}{4\pi r^2} + \frac{4}{R}) = 90dB \tag{4}$$

The intensity of secondary noise source L_{w1} equals to…

$$L_{w1} = L_{w0} - NR = 60dB \tag{5}$$

NR stands for the noise reduction of the ceiling.

According to the half-free space theory, the noise level (p) when the noises from secondary source reached residential housings equals to:

$$Lp_B = L_{w1} + 20\log(\frac{1}{r}) - 8 = 28dB \quad (6)$$

The noise from vehicle is 28dB, which merits little attention in comparison with normal ambient noise of 50 to 60dB.

Thus, the system separating man and vehicles in living quarters, together with the underground motorway, will prove to be of great use in expanding area for transportation, increasing safety, and reducing noise pollution from vehicles. Additionally, installing some of supporting facilities under the ground will also help to mitigate their noises and protect the overall sonic environment [14].

CONCLUSION

Underground space is a precious natural resource that can never be restored. The development of the underground space in some residential quarters is stuck with such problems as low level of utilization and failure to optimize overall efficiency owing to the disunion between ground constructions and underground ones. Apart from that, characteristics of underground space and a long time neglect of its improvement has been hindering the development of the space in living districts. The thesis contemplates the planning and environment design of underground space in living quarters, summarizes the forms, models and patterns for developing the space, and expounds the necessity of the planning and its problems and suggestions, principles as well as the spatial layouts it may cover. All of these aim to serve the sound and orderly development of underground space in residential quarters. The environment design of the space is discussed from the aspects of psychological environment, air environment, lighting environment as well as sonic environment, with a hope to offer some ideas and suggestions on building a cozy underground space in the quarters.

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