Chinese Industry and Technology of Eco-environment
2025, VOL. 6, NO. 2, 14-18
DOI: 10.47297/wspciateWSP2633-772X03.20250602

Improvement of air quality in underground space

Shenqi Cheng

Anhui jianzhu university,Hefei,Anhui,China,230601

ABSTRACT
Environmental quality challenges in underground space construction With the acceleration of urban expansion, traditional urban planning models are facing unprecedented spatial pressure. The rational utilization of land resources has become a major problem in urban regional development, and it has exposed obvious problems in the development of underground space. In the construction of underground facilities, people generally face many challenges in interacting with underground space. Underground parking lots, commercial areas, pipe galleries and other underground spaces not only have many conveniences, but also constitute a large number of closed environments. Problems such as pollutants emitted by vehicles and harmful gases produced by personnel have become major environmental quality challenges in urban spatial planning. How to properly deal with the air quality problem in underground space has become an important topic in the process of urban planning. For the ventilation system design of underground facilities, it is necessary to establish a scientific and reasonable system to reduce energy consumption while ensuring comfort, which is not only related to the sustainable development of urban space form, but also related to the quality assurance of citizens' living environment.

KEYWORDS
underground space; air quality; ventilation

1 Introduction

With the development of China's economy, people's living standards have improved rapidly, the number of motor vehicles has increased rapidly, and the problem of parking shortage has brought great pressure to cities[1]. In order to make full use of urban space, the problem of parking shortage is solved by building a large number of underground parking lots[2]. They not only assume the functions of living and leisure, but also assume the responsibility of environmental protection and ecological restoration. However, in underground spaces, the concentration of air pollutants increases significantly, causing serious impacts on residents' health and socio-economic activities. In recent years, scholars at home and abroad have begun to pay attention to the improvement of underground air quality, and put forward various control measures. The purpose of this paper is to systematically study the key factors, main pollutants and their treatment methods for improving air quality in underground space, and explore how to furtherimprove the environmental quality of underground space in the future. According to the current situation of air quality assurance, the air quality of underground living space should take into account human health and satisfaction[3], and high-quality underground space should be constructed based on the concept of "people-oriented"[4]. Importance of underground space: Underground space occupies an important position in urban planning because of its unique topographic advantages. The main reason for the deterioration of air quality in underground parking lots is automobile exhaust, which will seriously harm your health.

2 Air pollution in underground car parks

The underground parking lot mainly adopts the complex spatial structure formed by underground parking space and underground passage. The characteristics of this space structure are: strong closure, which can reduce air circulation; At the same time, however, due to the interlacing of multiple underground passages, it is easy for people and vehicles to meet, and the pollution problem is more prominent. The sources of underground parking lots are automobile emissions, human breathing and chemical composition pollution of building materials. The composition of pollutants in automobile exhaust is very complex, mainly including CO, NOx, SO_2,VOC,etc.

People's awareness of environmental protection is getting stronger and stronger, vehicle exhaust emission standards are becoming stricter and stricter, and related technologies continue to innovate. The content of SO_2 in vehicle exhaust has been greatly reduced. According to the relevant literature[5], when the automobile is running at idle speed, the pollutants that endanger human health in the automobile exhaust are mainly CO, NOx and VOC,and the ratio of the three harmful gases is 7: 1.5: 0.2. With the different running conditions of automobiles, the concentrations of CO, HCandNO2inautomobile exhaust also change significantly. According to the emission of automobile exhaust pollutants in underground parking lots, among the above three harmful gases, the emission of CO is far greater than that of the other two, so CO is selected as the research object in this paper. In recent years, air quality has been widely concerned, and air

pollution in underground parking lots also belongs to indoor air pollution. The decline of indoor air quality will lead to a series of adverse reactions and even damage people's health. At the same time, we need to be aware that poor air quality will cause a lot of economic losses. For example, harmful gases in the air can cause respiratory tract infections. The average number of infections in China exceeds one million every year, resulting in losses of several billion yuan[6][7]. Similar situations have occurred abroad. According to a survey by a research institute[8], with people's attention to air quality, how to optimize air quality has become an important research direction of current ventilation design.

3 Ventilation system of existing underground car park

The underground parking lot uses a mechanical ventilation system. Mechanical ventilation system includes air supply system and exhaust system. It is required to form a reasonable ventilation flow field in the garage, reduce the concentration of pollutants through dilution, and ensure that the concentration of pollutants in the garage meets the air quality standards. In most practical situations, the effect of improving indoor air quality only by ventilation dilution is not ideal. Moreover, when the underground parking lot is in a densely populated area, the direct discharge of pollutants into the outdoor space without treatment can easily cause secondary pollution and endanger the health of the surrounding people. The supply air flow is generally less than the exhaust air flow, so as to form negative pressure in the garage and avoid secondary pollution caused by the outflow of harmful gases. At present, commonly used mechanical ventilation systems include: mechanical air supply system plus mechanical exhaust system, natural convection plus mechanical exhaust system, induced ventilation system plus mechanical air supply and exhaust system. The applicability and economy of the above ventilation systems are different, so they need to be reasonably selected according to the actual situation. The mechanical ventilation system is classified according to the installation position of the air supply system and exhaust system of the underground parking lot, mainly including the following types, (1)The air supply system and exhaust system are all installed in the upper part of the underground parking lot. (2)The air supply system is installed at the upper part of the garage; The exhaust system is installed at the lower part (close to the ground).

According to the relevant literature[9], the exhaust gas emitted by automobiles is composed of a variety of harmful gases, some of which have higher density than air, while others have lower density than air. In order to fully discharge the pollutants in the garage, exhaust systems need to be installed in the upper and lower parts of the parking lot, and the ventilation flow of the lower exhaust system is larger than that of the lower exhaust system. First of all, this situation is discussed and analyzed. Most pollutants in automobile exhaust, such as carbon monoxide (CO), nitrogen oxides(NOx) and hydrocarbons(CmHn), are mainly discharged from the exhaust pipeline, which is often at a very high temperature in the working process, and its temperature is generally above several hundred degrees Celsius. High temperature will cause the density of harmful gases to decrease, and under the action of buoyancy, pollutants will further spread from the bottom of the garage to the top of the garage; For pollutants discharged from other locations on the car, such as a small amount of carbon monoxide, nitrogen oxides and hydrocarbons, they will be discharged to the outside world from the fuel system and crankcase. Because these are all working at normal temperature, the temperature of harmful gases is low, and the corresponding density is also high. However, the external emission of these pollutants is often accompanied by the operation of vehicles. The air flow disturbance during operation makes the air and pollutants in the garage fully mix, so pollutants generally do not gather at the bottom of the parking lot; Moreover, the relevant research data show that[10]based on the consideration of investment cost, the underground parking lot is generally low in height and very compact in space, and the layout of mechanical ventilation system is greatly limited. If ventilation systems are arranged in the upper and lower parts of the underground parking lot, it will not only increase the construction difficulty and cause a waste of resources, but also be detrimental to the maintenance work and even affect the normal use of the garage. For the above reasons, it is considered that it is not reasonable to arrange ventilation systems in the upper and lower parts of the underground parking lot at the same time, and it is recommended that all ventilation systems be installed in the upper part of the underground parking lot(3) to induce the use of ventilation systems. In addition to the traditional air supply and exhaust systems, the induced ventilation system also needs to add induced fans to induce the reasonable distribution of airflow in the garage. The induction ventilation system does not need to install air supply and exhaust ducts to save investment costs. Induced ventilation system has become a research hot spot in recent years, and it has been widely used as a new generation ventilation system.

CO release calculation formula

Reference[11]points out that due to the complicated working conditions in the garage in the actual operation process, the number of cars entering and leaving the garage per unit time, the types of cars and the running time of cars in the garage cannot be accurately obtained. In the design process, ventilation flow is often estimated based on some assumptions. At present, the empirical formula method is generally used to calculate the total CO release from automobile exhaust in underground parking lots:

$$G=m*r*q*t$$

Where:

G-Total CO emissions from underground space: mg/s;

m-Number of parking places in underground parking lots:vehicles);

r-the frequency of cars entering and leaving the garage(the ratio of the number of vehicles entering and leaving the garage to the number of parking spaces in one hour);

t-Average running time of cars in underground parking lots: s;

q-CO generation per vehicle per unit time: mg/s.

4 System optimization scheme

As modern underground buildings are equipped with air supply and outlet duct ventilation systems, and they are all above the garage, the height of the old underground garage is limited, and large-scale construction will affect the operation and use of the underground garage. It is not easy to install and transform the duct system, and it takes a lot of manpower and material resources to transform the existing ventilation system. Therefore, on the basis of retaining the original equipment, consider installing intermittent negative pressure air extraction device to improve the air quality inside the garage, which can not only reduce the concentration of harmful gases, but also transfer a large amount of harmful gases to the purification device.

Figure1 workers are installing the ventilation system in underground garage

Traditional ventilation systems usually only care about the air quality inside the garage, regardless of the impact on the external environment, which is obviously inconsistent with the current development trend. Many underground garages in densely populated areas have such problems. When designing ventilation systems, only the air quality inside the garage is considered and the air quality outside is ignored. For underground garages in densely populated areas, due to the high population density around them, the direct discharge of pollutants will cause secondary pollution and endanger the health of the surrounding people. Therefore, consider adding a negative pressure exhaust purification device and arranging a negative pressure exhaust system under the driveway to collect harmful substances into the air storage tank. Carry out air purification treatment to reduce the final emission of harmful gases.

The picture shows the newly installed exhaust duct laid on the road:

When the flow of people in the commercial area decreases, the airflow disturbance in the underground space is weak, and harmful gases will sink under the air due to density reasons. Our newly laid pipeline is at the bottom, which can effectively pump away harmful gases to achieve the effect of reducing harmful gases.

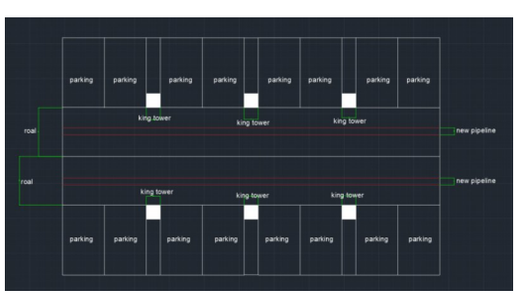

Figure2 pipeline layout diagram

Because the new ventilation duct will be crushed back and forth by vehicles on the road, before construction, the middle part of the original road should be broken, excavated 20cm down, waterproof and moisture-proof materials should be set up on the road after excavation, and then the pipeline should be laid longitudinally above the pipeline to prevent vehicle traffic from being affected. The underground garage has a height limit, and large-tonnage vehicles can't enter, so the strength of the surface material is not high, and a hole is left in the middle for ventilation.

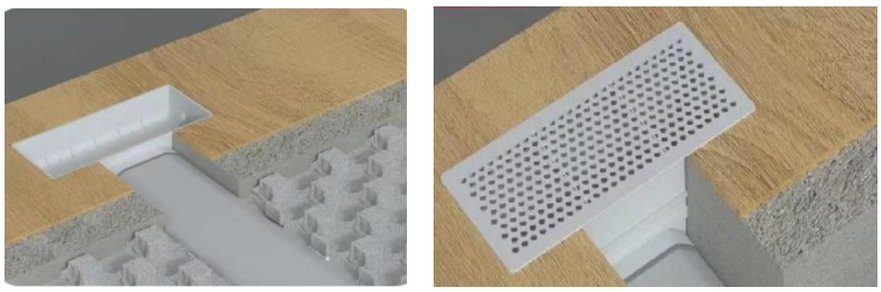

Figure3-4 detail illustration of pipeline

Due to the long longitudinal arrangement distance, the air extraction per unit length in the space will be uneven. The opening position can be controlled by an empty piston, and the negative pressure can be maintained when it reaches a certain amount. Gas detection sensors are installed in each underground area. When the nearest sensor detects harmful gas, the valve can be immediately opened to extract harmful gas, so that the polluted gas in any underground area can be transferred to the purification system. In the purification system, corresponding evolutionary methods can be made for pollutants, such as filtration, dust removal, sterilization, adsorption and catalysis. Can treat harmful substances with high efficiency and energy saving, and can be directly discharged to the outdoor after reaching the discharge standard,

Figure5 schematic diagram of pipeline surface

5 Summary and future expectations

Combined with an engineering example, this paper probes into the function and design principle of ventilation system in underground parking lot, the control and operation strategy of ventilation system. For the design of underground parking lots, good ventilation can not only save energy, but more importantly, ensure the air quality of people's environment. For the subjective feelings of stuffy, hot, humid, ventilated and insufficient lighting in underground space, it can have a good comfort of people's activities.

This paper only involves the optimization scheme, but does not model and simulate the airflow distribution of ventilation flow field in underground garage, establish a reasonable ventilation system control strategy, accurately calculate the outlet flow and control the exhaust flow. The exhaust emission of automobiles in underground parking lot is a dynamic process, and the emission intensity and distribution of pollution sources need to be rationalized. Displacement and discharge time are both uncontrollable factors. The control of underground garage ventilation system is a very complicated process, which is affected by many factors. How to give consideration to air quality, ensure human safety and efficient ventilation to achieve the purpose of energy saving still needs a lot of research.

About the Author

Shenqi Cheng,Anhui jianzhu university,Hefei,Anhui,China,230601,a18189703600@163.com.

References

[1] Wei Mingshan, Automobile and Environment[M].Beijing:Chemical Industry Press.2005,4:1-2.

[22] Guo Feng. Underground architecture and parking psychology[J]. Shanxi Architecture.2008,34(12):42-44.

[3] Xu Yuze, Zhang Li, Yang Yong, etal. Current status of air quality assurance in typical underground living spaces in cities [J]. Clean and Air Conditioning Technology.2019(1):91-95.

[4] Lei Shengxiang, Li Wensheng, Zhou Biao, et al. Quality improvement and evaluation index system of urban networked underground space [J]. Journal of Underground Space and Engineering.2021,17(4):987-1007.

[5] J. C. Ho, HXue, K. L. Tay. A field study on determination of carbon monoxide level and thermal environment in an underground Car park [J]. Building and Environment.2004,39:67-75.Ventilation for Acceptable Indoor Air Quality. ASHRAE Public Review Draft.1989.

[7] Liu Jian, Gong Yi, LianZhiwei. Influencing factors of indoor environmental quality [C]. Proceedingsof the 2000 National Academic Annual Conference on HVAC and Refrigeration.2000.

[8] Lang Siwei, Long Weiding, Feng Ya, etal.Guidance materials for publicity and implementation of energy-saving design standards for public buildings[M]. Beijing: China Construction Industry Press.2005,5:11-15.

[9] China Nonferrous Engineering Design and Research Institute. Code for design of heating, ventilation and air conditioning[M]. Beijing: China Planning Press.2004.

[10] Chen Juan. Discussion on ventilation system of underground garage in civil buildings[J]. HVAC.2005,35:367-368.

[11] Sun Yijian. Concise ventilation and air conditioning design manual[M]. China Construction Industry Press.1997.