Proceedings of the 2nd International Conference on Functional Materials and Civil Engineering
DOI: 10.54254/2755-2721/70/20241014

Intelligent underground garage drainage system based on informatized surveying technology

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Abstract. In recent years, with the impact of environmental factors such as global warming, floods and waterlogging disasters have occurred frequently in China. The traditional drainage devices in underground garages have poor water-blocking effects, which can easily result in sewage entering the garage along with vehicles during severe weather or sudden floods. To address the issue of water accumulation outside underground garages, which prevents vehicles from entering, we propose a set of drainage devices for underground garages to complement the shortcomings of existing market products. This device, controlled by an automated intelligent control system, can effectively control each device to achieve automatic water-blocking and drainage operations in underground garages, as well as car washing. During extremely heavy rainfalls, it can completely seal off the garage and enter flood prevention mode to protect vehicles inside from being submerged. Additionally, as the device is semi-underground, it can save a significant amount of above-ground space without affecting surface traffic or existing facilities, demonstrating practicality and having the potential for widespread adoption.

Keywords: Underground garage, Drainage and water-blocking, Intelligent, Flood and waterlogging prevention, Surveying science and technology.

1. Introduction

With the development of society and economy, an increasing number of families own private cars. Residential areas or buildings where people work and live are often equipped with underground garages. However, underground parking lots are generally located in low-lying areas, and after rainfall, there is often persistent water accumulation around them. If this water is not properly drained, it can flood the underground parking lot, causing significant losses to the property owners [1].

The issue of effectively blocking and draining water in underground garages has always been a headache. The existing drainage devices in traditional underground garages have poor water-blocking effects. During severe weather conditions or sudden floods, surface water can easily enter the underground garage along with vehicles. Moreover, traditional underground garage water-blocking devices mostly use manual water-blocking boards or flood prevention sandbags, which, once deployed, prevent vehicles from entering or exiting. Even when faced with minor water accumulation, they hinder

DOI: 10.54254/2755-2721/70/20241014

vehicle access. Additionally, traditional water-blocking devices are cumbersome to disassemble and require substantial manpower, material, and financial resources for drainage, causing significant losses to the national and public interests [2].

Through analysis of the entrance sizes of underground garages in Chinese cities prone to flooding and the required technologies in the existing underground garage drainage and water-blocking market, we have developed a product that can be applied in daily life, efficiently utilize fresh water resources, and provide residents with a higher sense of security. This device aims to solve the technical problems faced by existing underground garages in effectively protecting vehicles and garage structures during floods. It incorporates modern surveying science and technology into its intelligent design and targets the vast market of underground garage drainage and water-blocking. It can efficiently utilize and conserve fresh water resources, contribute to the construction and development of sponge cities in China, and further enhance the happiness, sense of achievement, and security of urban residents. The device model is shown in Figure 1.

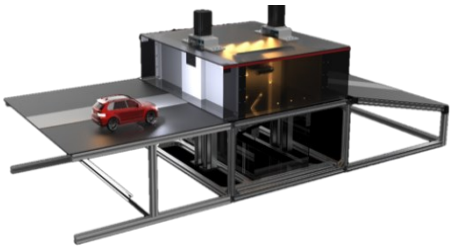

Figure 1. Rendering of the Device

The design of the underground garage floor related to leakage prevention generally consists of a waterproofing membrane, self-waterproofing concrete floor, surface leveling, and slope layer. The drainage system on the ground generally adopts the following two schemes: one is to form a structural drainage trench along the predetermined drainage ditch position by locally lowering the floor along the drainage ditch, but this scheme changes the stress form of the structural floor, making stress concentration prone to occur at high and low points. It also poses difficulties in dealing with pier platforms, foundation beams, and inverted beams, so this scheme has been rarely used in recent years [5]. The other scheme is to construct drainage trenches along the predetermined drainage ditch position during the construction of the building floor, slope the floor towards the drainage trench, and slope the drainage trench towards the collecting well. Due to the influences of the spacing between collecting wells and the two sloping operations of the floor and drainage trench, a very thick floor must be set to meet the surface drainage requirements [6-9]. Compared with these two schemes, this device has the advantages of high water-blocking and drainage efficiency, wide application range, easy construction and promotion, and integration of advanced control and identification systems, thus having certain competitive advantages.

2. Overall Design of the Underground Garage Drainage and Water-Blocking Device

2.1. Mechanical Structure Design of the Device

By organically integrating the mechanical structure with the intelligent recognition control system, our team has designed a set of more secure, flexible, environmentally friendly, and intelligent underground garage drainage and water-blocking device. Through research, the proportion of our designed drainage and water-blocking model to the physical object is 1:7, with a total height of 573mm, total length of 1600mm, and total width of 960mm.

The device includes an interactive panel, a sloped entrance channel, a dual rear water-blocking gate lifting device, vehicle entry and exit channels for the garage, an entrance channel for the drainage and water-blocking device, dual front water-blocking gate lifting devices, water storage and drainage devices, and a floor drain linkage device. The vehicle entry and exit channels for the garage are integrated with

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the water storage and drainage devices, with the vehicle entry and exit channels positioned on the upper part of the water storage and drainage devices. The overall design of the device adopts a dual-channel design, with two stepper motors driving four electromagnetic valves to control the screw rods for asynchronous lifting of the four water-blocking gates. This device utilizes a progressively linked rod structure, which not only reduces energy consumption but also adjusts the closure of the floor drain while lifting the water-blocking gates, enhancing system coordination. The car washing device utilizes a combination of a servo motor and a fine rod screw, coupled with an intelligent electronic control scheme, to use water from the treated water storage device to wash the vehicles entering the garage, achieving efficient and environmentally friendly water reuse.

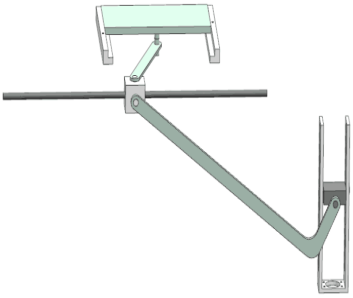

Figure 2. Floor Drain Linkage Device Diagram

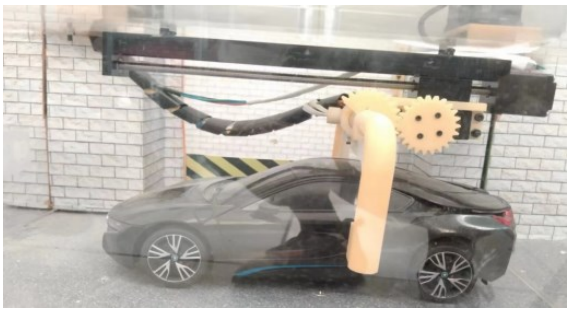

Figure 3. Car Washing Device Diagram

2.2. Intelligent Control Design of the Underground Garage Drainage and Water-Blocking Device

The intelligent control system of this device mainly consists of mature single-chip control systems available on the market, photoelectric sensors, water level sensors, WiFi modules, electromagnetic clutches, etc. The device utilizes various sensors to obtain real-time information on the status of vehicles entering and exiting, and the control system orchestrates the automated operation of the device.

During normal operation, both water-blocking gates of the device are in the open state. At this time, the device channel is indistinguishable from a typical underground garage passage, and it does not affect the normal passage of vehicles. However, in the event of a sudden flood, the device activates its working mode. The dual water-blocking gates rise from underground and close, preventing the flood from entering the underground garage. Meanwhile, the floor drain in the device channel remains open. When a vehicle needs to enter the garage, the first water-blocking gate opens, allowing the vehicle and floodwater to enter the device channel together. At this point, the floor drain in the device channel closes, preventing continuous inflow of floodwater into the water storage tank. Once the sensor detects the vehicle entering the channel, the first water-blocking gate closes again to block the floodwater behind the vehicle. During the closing process of the first water-blocking gate, the floor drain linkage device connects and controls the opening of the floor drain in the channel, allowing the floodwater accompanying the vehicle to drain into the water storage tank below the device. Additionally, a radar water level gauge is installed at the first water-blocking gate to measure the water level in the channel using electromagnetic waves. When all floodwater in the channel has been drained into the water storage tank, the second water-blocking gate opens, allowing vehicles in the channel to safely enter the underground garage. Furthermore, the device is embedded with an inversion model that integrates weather radar data and satellite data. It utilizes the advantages of satellite data to complement the shortcomings of weather radar data. The precipitation data at the entrance of the underground garage is transmitted to the intelligent panel inside the device. When a significant amount of precipitation or even flooding occurs beyond the device's operational range, the device can raise and close all four water-blocking gates, completely sealing off the garage and entering flood prevention mode to protect the vehicles inside. Moreover, the device is equipped with a simple water treatment system, which can treat the collected floodwater in the water storage tank for vehicle cleaning in the garage, greatly conserving fresh water resources. The flowchart of the intelligent control design of the device is shown in Figure 4.

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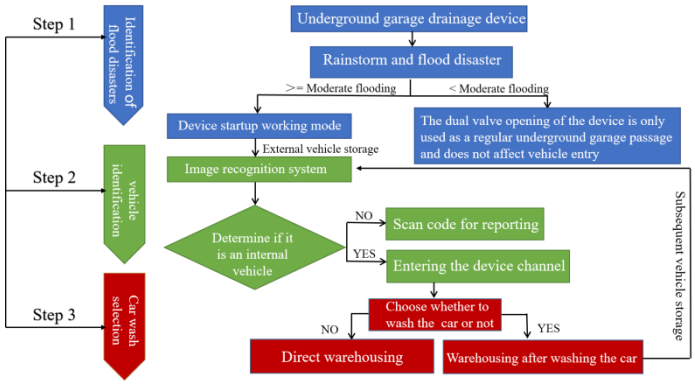

Figure 4. Device Workflow Diagram

The underground parking lot drainage device, in terms of visual vehicle management, mainly utilizes the integration of WiFi module and intelligent panel to provide guidance for vehicle parking. Before the device is officially applied, it is necessary to conduct on-site three-dimensional laser scanning in the underground parking lot to obtain sufficient point cloud data. After processing and coordinate transformation, the three-dimensional coordinate information is unified into the same independent coordinate system. Then, the processed point cloud data is used to extract feature lines and corners, and imported into 3DMAX to complete the three-dimensional modeling of the underground parking lot. Finally, the model data is embedded into the intelligent panel of the underground parking lot drainage device. Due to the attenuation of GNSS signals during propagation, especially when passing through the ground, the signal is severely weakened upon reaching the underground parking lot, making it unsuitable to use GNSS for monitoring and management of vehicle parking in the underground parking lot. This device adopts a Wi-Fi indoor positioning technology-based method for underground parking lot positioning. By setting sampling points in the underground parking lot and collecting Wi-Fi feature information at these points, a corresponding database is established. Based on the MAC information and signal strength collected by the mobile phone at the point to be measured, matching calculations are performed to obtain the position information of the point to be measured, completing the positioning [10]. Through the fusion of the underground parking lot three-dimensional model and positioning information, the device monitors the parking status of vehicles and facilitates human-machine interaction through the intelligent panel of the device, making it convenient for vehicle owners to use and for property management.

3. Functions of the Underground Garage Drainage and Water-Blocking Device

3.1. Water-Blocking and Drainage Function

This device is designed for underground garage entrances of commercial malls, office buildings, and residential buildings in cities prone to internal flooding. During normal operation, it functions as a regular garage passage without affecting the normal entry and exit of vehicles. When the city experiences internal flooding, the device is activated to perform its water-blocking function. When the water level detector detects that the water level in the water storage tank reaches a dangerous level, the self-priming pump starts to discharge water from the tank.

3.2. Panel Interaction Function

An intelligent panel is installed at the entrance of the device for convenient human-machine interaction. It can display in real-time the number of vehicles in the garage, the number of available parking spaces, and the approximate location of available parking spaces for vehicle owners to choose from. The intelligent panel efficiently displays and judges the basic information of vehicles entering and exiting

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the underground garage, facilitating property management. The panel can also serve as a platform for advertising to increase product revenue.

Figure 5. Rendering of the Intelligent Panel at the Device Entrance

3.3. Car Washing Function

This device is equipped with a small-scale water treatment device and car washing equipment, which can perform simple treatment on the floodwater collected in the water storage tank to meet the standard for washing water. By using a pressurization device to pressurize the water to the standard washing pressure, vehicles can be washed when the flood recedes and they exit the garage, achieving efficient and environmentally friendly water reuse.

4. Innovations of the Intelligent Underground Garage Drainage and Water-Blocking Device

(1) The device utilizes a linkage mechanism in the floor drain linkage device, which can adjust the closure of the floor drain while raising and lowering the water-blocking gates, improving system coordination and reducing energy consumption during device operation.

(2) This device innovatively integrates a simple water treatment device and a pressurized car washing device, which can wash vehicles after the flood recedes. While keeping the vehicles clean, it achieves water reuse, thus conserving fresh water resources.

(3) The device ingeniously integrates mechanical devices with intelligent control technology, enabling intelligent management of the garage and automatic water-blocking and drainage, thereby reducing the need for manual intervention.

5. Future Prospects of the Intelligent Underground Garage Drainage and Water-Blocking Device

5.1. Integration with Existing Intelligent License Plate Recognition Systems

In the future, the team can organically integrate mature intelligent license plate recognition systems available in the market with this device. By combining license plate recognition technology with electronic toll collection (ETC) systems, vehicles passing through the gate can be automatically identified and charged without the need to stop. In parking lot management, to improve the efficiency of vehicle entry and exit, unmanned express lanes can be constructed for vehicles that do not need to pay parking fees (such as monthly card holders and vehicles with free access), allowing for card-free and non-stop entry and exit, thereby changing the management mode of parking lots. License plate recognition devices installed at the entrances and exits can record license plate numbers and entry/exit times of vehicles, and combined with automatic gates, achieve automatic vehicle management.

In the future, this device can be applied in underground parking lots to achieve automatic timed charging and automatic calculation of available parking spaces with prompts, realizing automatic parking fee management, saving manpower, and improving efficiency. When applied in smart communities, it can automatically determine whether entering vehicles belong to the community and implement automatic timed charging for non-resident vehicles. In some institutions, this application can also be combined with vehicle dispatching systems to automatically and objectively record the departure of vehicles from the institution.

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5.2. Establishment of a Smart Management Platform for the Device

In the future, the team will integrate various sensors to create an underground garage smart management platform. Through this platform, the automated operation of the device can be orderly controlled, real-time vehicle entry and exit situations and the number of remaining parking spaces in the garage can be displayed, achieving automatic management of the underground garage drainage and water-blocking device. The platform can also perform real-time monitoring of the water level and water quality indicators in the water storage tank to achieve data visualization, intelligent analysis, and automation of related business processes.

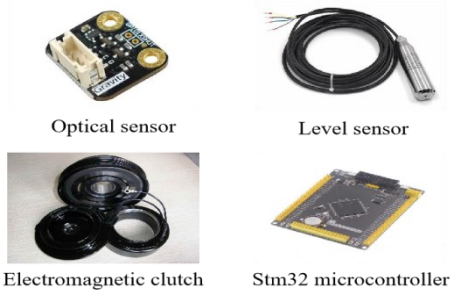

Figure 6. Display of Model Electronic Modules

6. Subsequent Maintenance Work for the Underground Garage Drainage and Water-Blocking Device

This device targets the vast underground garage drainage and water-blocking market, closely related to flood disasters. Therefore, in the subsequent maintenance work of the device, it is necessary to focus on improving deformation monitoring to real-time monitor the structural deformation of the underground garage drainage and water-blocking device to ensure its stability and safety. By monitoring structural deformation, potential safety risks caused by deformation of the underground garage drainage and water-blocking device can be timely alerted, and corresponding measures can be taken for repair or reinforcement to ensure the normal operation and use of the structure. Remote sensing monitoring is not applicable to deformation monitoring in underground garages, so conventional measurement methods or other methods such as foundation monitoring can be used to monitor whether there is ground subsidence, wall inclination, crack changes, etc., in the underground garage. Deformation monitoring of underground garages not only requires regular data collection and analysis of monitoring data but also needs to be continuous. Regular inspection of monitoring equipment and maintenance is required to ensure the accuracy and reliability of monitoring data. In addition, professional personnel are also needed for regular inspection and maintenance of drainage devices. Completing sufficient subsequent maintenance work can extend the service life of the device and ensure the safety of its use.

7. Conclusion

This design can solve the problem of the inability of existing underground garages to effectively protect vehicles in the face of flood disasters, providing residents with a higher sense of security. The device can store part of the urban waterlogging, and the water after treatment can be used to clean vehicles, responding to the construction of the urban drainage and flood control engineering system of "reducing emissions at the source, discharging through pipeline networks, combining storage and discharge, and emergency response to excessive emissions".

The device controls each component device through an automated intelligent control system and integrates traditional and modern surveying science and technology throughout the entire operation process, achieving intelligent management of the underground garage drainage and water-blocking device and automatic water-blocking and drainage. It can protect vehicles in the garage from being submerged, avoiding economic losses to the people and the country, and can contribute to the

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construction and development of sponge cities in China, as well as the digitalization, networking, and intelligent development of urban infrastructure in China.

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