Study on Optimization of New Type of Seepage Well Structure in Sponge City

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Abstract. The seepage well is an indispensable part of the construction of the sponge city. It has a good "elasticity" for the city to adapt to the environmental changes and respond to natural disasters. In the face of the current decline in the groundwater level and the water logging in the city, it is urgent to study the new type of seepage well under the complex geological conditions. In this paper, the advantages and disadvantages of the current seepage well structure are analyzed, and combined with the hydro-geological conditions in the area of Feng Xi new city of xi’an, three new types of seepage wells are put forward, such as reinforced concrete filter pool + multi glass pipe combined structure seepage well, masonry filter pool + single glass pipe combined structure seepage well and prefabricated reinforced concrete structure seepage well. The advantage, disadvantage and applicability of the well are compared, and case analysis is provided, which provides a basis for the construction of seepage wells in sponge cities.

1. Introduction

Under the background of urbanization, the newly built buildings in China are equivalent to half of the total world buildings. With the acceleration of urbanization, the impervious area of the city is gradually increasing, and the city is evolving into a "hard shell city" constructed by reinforced concrete. Rainwater resources can not be effectively utilized, and urban water circulation system and ecosystem are further deteriorated. Urban waterlogging, on the surface, is due to the urban underground drainage system lagging behind urban construction, but the root cause is that construction have changed the surface runoff and increased the burden of underground pipeline network. The problems of water ecology and water resources shortage and water safety faced by cities are mainly attributed to the backwardness of traditional urban engineering pipeline gray drainage infrastructure, flood control planning and drainage engineering planning, and the weak awareness of rational utilization of rainwater resources. Seepage wells, as an important part of sponge cities, can be greatly alleviated. Urban waterlogging, serious water accumulation and a series of other problems; seepage well seepage drainage mode is to use the total amount of catchment control, the rainwater collected in the downward excavation channel through catchment wells, drainage pipes into seepage wells for temporary water storage, while through seepage wells into the underground permeable layer to play a drainage role.

2. Research Status of Seepage Well

China's Ministry of Housing and Urban-Rural Construction issued in 2014 "Technical Guidelines for Sponge City Construction - Construction of Rainwater System for Low Impact Development" (Trial).
The purpose is to guide the construction of new urbanization in various areas, promote and apply the low impact development and construction model, and realize the utilization of rainwater resources through the combination of various technologies. Constantly promote the development of “sponge city” with natural accumulation, natural infiltration and natural purification. Sponge city is defined as a city that is able to adapt to environmental changes like a sponge and has good flexibility in dealing with natural disasters. That is to say, it absorbs water, purifies water, stores water and recycles the stored water when it is raining, so as to realize the sustainable development of the city [1]. The seepage well as a convenient and efficient advanced process has received wide attention.

At present, the structure of seepage wells in China can be divided into masonry structure, reinforced concrete structure and steel tube structure according to different materials, but they all have certain limitations.

2.1. Masonry Structure Seepage Well
Masonry structure is used as a common structural form for early seepage well, and it is constructed by common brick or sector brick. Masonry structure is easy to use local materials, low cost, and does not need formwork and special construction equipment compared with concrete structure, so it is widely promoted. However, it also has many shortcomings. Compared with reinforced concrete structure, the strength of masonry is lower, so the section size of component is larger and the amount of material is more. The masonry is basically manual, with a large amount of labor. The masonry's tensile and shear strength is very low, its seismic resistance is poor, and the compressive strength of bricks and stones can not be fully exerted, so it is limited in use; masonry structure is liable to cause structural damage after settlement, so with the development of new materials and new technology, seepage wells of masonry structure have already been coagulated by reinforcing bars. The structure of soil is replaced by steel tube structure, so its structure needs to be further improved.

2.2. Seepage of Reinforced Concrete Structure
The infiltration well of cast-in-situ reinforced concrete structure has good integrity, stable structure, large runoff capacity, strong adaptability and good durability compared with masonry structure; but the construction of cast-in-situ concrete structure is relatively complex, which consumes more formwork, has larger self-weight and is prone to settlement compared with masonry structure.

2.3. Steel Bellows Structure Seepage Well
Steel bellows can be divided into spiral bellows, annular bellows and corrugated steel sheets. The structure of steel bellows seepage well is mainly used to reduce the water accumulated by the roadbed of expressway, and has been applied to many Expressway sections with remarkable effect. The construction of steel bellows is convenient, and it is generally passed through. Bottom-hole seepage is difficult in urban drainage construction because of its high cost, low permeability rate, difficulty in filling fillers and uncertain opening rate.

3. New type of Seepage Well Structure
In order to maximize the function of rainwater storage, infiltration and purification in urban areas, promote the utilization of rainwater resources and ecological environment protection, and focus on solving the problems of water environment, water ecology and waterlogging in urban construction, this paper puts forward a proposal on the basis of traditional seepage well structure design, considering comprehensively the hydrogeological conditions of Shaanxi Province. Rainwater drainage and storage system suitable for Shaanxi area and a more economical and effective seepage well structure form are put forward.

Including: reinforced concrete filter + multiple FRP composite seepage well structure, masonry structure filter + single FRP composite seepage well structure and reinforced concrete prefabricated pipe seepage well structure.
3.1. Reinforced Concrete Filter Tank + Multiple Glass Fiber Reinforced Plastic Combined Shaft Structure (as Shown in Figure 1).

The structure of reinforced concrete filter plus multiple FRP composite seepage wells is composed of upper reinforced concrete structure, lower FRP tube and cushion layer at the bottom of concrete. The bearing capacity of reinforced concrete structure is large, but for the area with large flow, the flow confluence area is large, the internal force distribution is complex. The reinforced concrete structure with better integrity can effectively ensure the stability and safety of the structure, and it has good durability, strong adaptability to the environment, and can work normally in extreme environments.

Figure 1. Reinforced concrete filter tank plus several glass fibers reinforced plastic combined shaft structures

3.2. Masonry Structure Filter Material Pool + Single Glass Steel Pipe Combined Seepage Well Structural Form (as Shown in Figure 2).

The masonry structure filter + single FRP composite seepage well structure is composed of masonry structure filter and single FRP pipe. The FRP pipe is drilled down to the sand layer, and the concrete
cushion is set near the upper part of the FRP pipe. The masonry structure is used as the seepage well filter. Compared with the reinforced concrete structure, this structure has light weight and low cost. Therefore, it is economical and applicable in areas with small runoff. However, its structural stability may be affected in a large flow area.

![Diagram of seepage well structure](image)

**Figure 2.** The structure of composite shaft with masonry structure filter material pool and single glass steel pipe.

A new material FRP is used as the seepage pipe. FRP has many advantages: smooth inner wall, strong conveying capacity, no scaling, no rust, good frost resistance, good wear resistance, good corrosion resistance and low water resistance. Below zero 20 degrees Celsius, there will be no frost crack after freezing. As the main material of FRP is composed of unsaturated polyester resin and fiberglass, it can effectively resist the corrosion of acid, alkali, salt and other media, and the erosion of untreated domestic sewage, corrosive soil, chemical wastewater and many chemical liquids. In general, it can keep pipelines for a long time safe operation; FRP pipe does not need to be rust-proof, pollution-proof, insulation and other measures and maintenance, its maintenance cost is low. So FRP pipe can work together with masonry structure and concrete structure, at the same time, it can greatly improve the performance of seepage wells.
3.3. Prefabricated Reinforced Concrete pipe seepage Well Structural form (as Shown in figure 3)

The prefabricated reinforced concrete pipe seepage well structure is composed of a series of prefabricated reinforced concrete pipes per unit height. It seeps through the bottom and bottom wall of the pipe. The reinforced concrete pipe will be placed in the underground sand layer, the prefabricated concrete pipe will be overlapped, and at the same time, the hole will be opened under one meter away from the sand layer to improve its penetration speed. The structure form is shown in the figure.

![Figure 3. schematic diagram of precast reinforced concrete pipe](image)

4. Case Analysis

The construction method of seepage well should be combined with the local geological and hydrological conditions, as well as the technical strength, construction equipment, take corresponding measures, formulate detailed construction plan, and strive for safe and effective completion of construction work.

4.1. Hydrogeological Survey

The project is located in Xianyang Vocational and Technical College. Through two field surveys, it is found that the pilot site in this section is low-lying, with a large amount of water and silt. Therefore, two sites were selected as a pilot to study the applicability and rationality of the optimized structure of the well. Fig. 4.1 and 4.2 are field maps of Pilot 1 and Pilot 2, respectively.

![Figure 4. pilot 1](image)
4.2. Seepage Well Construction Plan
In order to prevent seepage wells from collapse and blockage in the future, glass tube is installed at the lower part of seepage wells, and the depth of caisson is more than 8 meters (the depth reaches the middle sand layer). According to the drainage volume and drainage time in the campus, two wells are planned at the lower part. The upper structure is reinforced concrete sedimentation tank with filter layer or brick sedimentation tank. In order to ensure the normal use of seepage wells in the future, the wellhead located on the bottom plate is covered with steel mesh, and a screen with steel wire spacing of 2 cm is added to the mesh. The matching facilities of climbing ladder well cover are set up at the roof checkpoint to facilitate garbage cleaning and maintenance in the future.

Pilot 1 adopts seepage well structure as shown in Fig. 4. The seepage well is composed of rectangular reinforced concrete pool and double FRP pipe. The wall and bottom of the pool are made of C30 concrete, and the reinforcement is double row 14@150. Pilot 2 adopts the seepage well structure shown in Figure 5. Which is composed of brick masonry well and single FRP pipe, and two seepage wells adopt FRP circular pipe with wall thickness of 15mm, which opens on the wall of the permeable layer, with the opening rate of 1%-3%. The seepage well needs to extend into the middle sand layer, which is more than 0.5m, and the highest groundwater level is 1m. The wellhead is covered with steel mesh, and a layer of wire spacing 2cm is added on the steel mesh.

4.3. Penetration Results
After water test on seepage well structure, the permeability efficiency of seepage well structure is 2.7 *10^-3m/s and 1.24 *10^-3m/s respectively (the test results are affected by groundwater level trend and the location of monitoring points). At present, the permeability rate of existing seepage wells is generally 1 *10^-5m/s. The comparison of the permeability results of three seepage well structures is shown in the table below, which is not from the table. It is difficult to see that the permeability rate of the new seepage well structure is obviously higher than that of the ordinary seepage well structure, and the permeability efficiency is 100 times higher than that of the traditional seepage well, showing good permeability effect.

5. Conclusion
Based on the hydrogeological conditions of Shaanxi Province, through the analysis of the advantages and disadvantages of traditional seepage well structure, this paper puts forward several new seepage well structure forms suitable for Shaanxi Province. The following conclusions are drawn:

1. Seepage wells, as an effective drainage facility in sponge cities, can greatly alleviate a series of problems such as urban waterlogging and serious water accumulation.

2. The structure form of reinforced concrete filter + multiple FRP composite seepage wells should be suitable for the larger area of confluence; the structure form of masonry filter + single FRP composite seepage wells should be suitable for the smaller area of confluence; at the same time, they all have the advantages of convenient replacement of filter materials, fast seepage speed, simple construction and geological conditions. The demand is not high.
(3) Three different types of seepage wells are proposed in this paper, but there are many factors affecting the safety and stability of prefabricated reinforced concrete pipe structures. Further research is needed on the diameter, thickness, depth of seepage wells, size and number of openings.

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Reference

[1] Jiancheng Letter No. 275, Ministry of Housing and Urban-Rural Construction, Circular on the Issue of "Technical Guidelines for Sponge City Construction--Construction of Rainwater System for Low Impact Development (Trial)", Ministry of Housing and Urban-Rural Construction, Republic of China, 2014:4-37.

[2] Zhuxi, Li Shunqun, Feng Yanfang, Wang Yanyang. Application of rainwater seepage wells for construction waste in sponge cities [J]. Journal of Guangxi University (Natural Science Edition), 2017, 42 (04): 1415-1421.

[3] Study on well construction technology and recharge test of seepage wells in thick aerated zone by Liu Pengfei, Liu Shaoyu, Wang Zhe, Zhou Xiaoni --- Taking seepage wells in Hutuo River alluvial fan and Gaochong section as an example [J]. Science and technology and engineering, 2016, 16(01): 36-41.

[4] Liao Xiaohang. Application effect of seepage well technology on Hengda Expressway [J]. Highway Transportation Science and Technology (Applied Technology Edition), 2015, 11 (02): 36-38.

[5] Wang Chengwei, Li Yuanmeng. Application of YTHG steel bellows seepage well in Beijing-Shijiazhuang reconstruction and extension project [J]. Highway Transportation Science and Technology (Applied Technology Edition), 2015, 11 (01): 59-62.

[6] Liao Xiaohang. Application effect of seepage well technology on Hengda Expressway [J]. Road traffic and safety, 2014, 14 (06): 1-5.

[7] Zhang Qingyu. Numerical simulation of sidewall structure of concrete permeation [D]. HeFei University of Technology, 2014.

[8] Wang Si Nan. Main points of seepage well construction [J]. Traffic world (transportation, vehicles), 2013 (08): 169-170.

[9] Wang Yun, Wu Wanping, Ruan Yanbin, Xie Songlin, Fu Wei, He Bin. Influencing factors of unsaturated seepage drainage by regulating and storing seepage wells [J]. Highway, 2013 (02): 20-24.

[10] Yan Hua. Application of seepage well technology in highway drainage works [J]. Traffic standardization, 2012 (06): 54-56.

[11] Li Zhen. Study on drainage scheme and seepage well construction technology of low embankment expressway passage [D]. Changsha University of Technology, 2011.

[12] Tong Xin Bo. The construction technology for the middle and lower excavated channel of the expressway. [J]. traffic standardization, 2010 (19): 124-126.