

# Usability Design of Concrete Grouting Equipment

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## ABSTRACT

Concrete grouting equipment is often used in engineering construction in industries such as bridge construction and highway construction, and is an indispensable part of engineering equipment. The current research on concrete grouting equipment is mainly focused on technological breakthroughs and innovations, and there are deficiencies in the usability of equipment. This research aims to study the usability design of concrete grouting equipment, through an overview of usability, the development status of concrete grouting equipment, future trends and user interviews to study the usability design of concrete grouting equipment. The usability design elements of concrete grouting equipment are summarized, and the design of concrete grouting equipment is optimized.

**Keywords:** Concrete grouting equipment · usability design · Product optimization

## USABILITY OVERVIEW

Usability originated from human factors engineering. In the international standard ISO9241-11, the definition of usability is as follows: the effectiveness, efficiency and subjective satisfaction of users when a product is used for a specific purpose for a specific user in a specific use environment [1]. Usability design plays an important role in the design of various contemporary products [2]. Usability runs through the entire product cycle. At the beginning of product design, we should consider and invest in usability work, and improve the new

design by testing and evaluating existing products and similar products. Usability is an abstract and complex concept. In order to evaluate the quality of usability, researchers divided usability into multiple dimensions according to their research (Table. 1 shows) [3-5]. Usability is not fixed. Depending on the situation in which a particular user is located, the indicators of usability are also different, which requires specific analysis.

Table 1: Available evaluation indicators



	<b>Index</b>	<b>Shakel (1991)</b>	<b>Nielsen (1993, 2006)</b>	<b>Molich (2000)</b>
Efficient	Operating speed	√	√	
	Operation error frequency	√	√	
	Easy to remember	√	√	√
	Easy to learn	√	√	√
Effectiveness	Adaptability		√	
	Durability		√	
	Reliability		√	√
	Attractive appearance		√	
	Comprehensibility		√	√
	In line with usage habits		√	√
Customer satisfaction	Pleasure		√	
	Comfort		√	

## THE DEVELOPMENT STATUS AND FUTURE TRENDS OF CONCRETE GROUTING EQUIPMENT

Concrete grouting grouting equipment is mainly used in highway, railway and bridge construction industries. It integrates the functions of mixing, grouting, grouting, and grouting, and has the characteristics of convenient mobile construction. Most of the working places are outdoors, which are dusty, dirty, and need to be exposed to the sun and rain. The users of concrete grouting equipment are mainly manual workers, whose work has the characteristics of serious physical exhaustion, long time, and difficult working environment conditions.




At present, domestic research on concrete grouting equipment mainly focuses on technical optimization and innovation. At the same time, it can be seen from the collected cases (Table. 2 shows) that in addition to technical research, domestic concrete grouting equipment also wants to seek breakthroughs in equipment modeling, so that the appearance of the equipment is more integrated and designed. But there are disputes over the availability of the equipment.

Table 2: Domestic concrete grout making equipment

Enterprise	Picture	Features
Chengdu Jerida Construction Machinery Co., Ltd.		In terms of styling, it can be seen that the equipment styling mainly uses polyline elements, which has a certain mechanical feel. However, it forms a strong contrast with the drum above and does not have a sense of wholeness. Moreover, the modules are stacked together, which lacks a sense of rhythm and beauty visually. The color distinguishes the functional modules, but the primary and secondary distinction is not obvious, and the overall look is rather messy.
Henan Yugong Machinery Co., Ltd.		Orange-red and white are used. The equipment divides the functional modules into sections, which is more integrated in terms of appearance. The all-inclusive shell protects the control panel, distribution box, etc., to avoid dust and moisture. But there are problems in terms of usability, and the all-inclusive shell is very inconvenient to use, observe, and maintain.

The current foreign research on concrete grouting equipment is also mainly focused on technological breakthroughs. In addition, foreign countries pay more attention to the detailed design and modular design and product availability of concrete grouting equipment in the design of concrete grouting equipment (Table. 3 shows). Among them, the British MARKHAM concrete grouting equipment uses ergonomics related knowledge in the design to ensure the comfort of the workers and improve their work efficiency.

Table 3: Foreign concrete grout making equipment

Enterprise	Picture	Features
Gertec GmbH		<p>Several major functional modules have primary and secondary color matching, using blue and metal primary colors and embellishment with ochre. Consider the protection of distribution boxes and control panels. Easy to operate, maintain and clean.</p>
ChemGrout		<p>In terms of shape, the module components are scattered, the black protective bracket is more abrupt, and the overall look is unbalanced, with a sense of weightlessness. The color distinguishes the functional modules, with yellow as the main component, and black as the supplement. The control panel and component connections adopt the metal primary color. The equipment has patented fasteners, which can significantly reduce cleaning and disassembly time.</p>
MARKHAM		<p>In terms of styling, the components are modularly distributed to make the components seem to have a certain sense of rhythm. The products are serialized and unified. The functional modules are distinguished by color, the main body is yellow, and the distribution box and the pipe joints are made of metal primary colors and decorated with red as warning signs. The distribution size and overall combined size of the equipment components conform to ergonomics, which saves space and improves the work efficiency of workers. The hoisting point is installed in the center of the machine, which is convenient for transportation and short installation time. And the components can be easily detached from the device for separate use. A protection structure is added to the controller.</p>

Through literature reading and data collection, it can be found that the current development of domestic and foreign concrete grouting equipment is based on technological breakthrough and innovation as the primary goal. In addition, people are beginning to realize that there are problems in the appearance design of concrete grouting equipment and the ergonomics of the equipment, and try to optimize them. Therefore, it is imperative to study the usability

design of concrete grouting equipment.

## ANALYSIS OF DESIGN ELEMENTS FOR USABILITY OF CONCRETE GROUTING EQUIPMENT

### Introduction of Equipment

This paper takes a concrete grouting equipment of China Hubei Huatou Lvzhi Co., Ltd. as an example to analyze the availability design elements of concrete grouting equipment. The equipment can be divided into electric cabinet box, water pump, loading hopper, slurry tank, servo motor, unit base, squeeze pump, slurry storage bucket, mixing motor and water tank.

### Equipment functional partition

In order to better analyze the design elements of the availability of concrete grouting equipment, the author divides the equipment into functional areas, which are mainly divided into processing area, support area, control area, conveying area, and motor (Table. 4 shows).

Table 4: Equipment functional partition

	Functional partition	Corresponding parts
1	Processing Zone	Pulp tank, pulp storage bucket, water tank, loading hopper
2	Support zone	Unit base
3	Control area	Control box
4	Conveyor area	Water pump, squeeze pump, pipeline
5	Motor	Stirring motor, servo motor

### User operation process

Through the observation method, the user's operation process was sorted out and combined with user interviews, the areas of frequent human-computer interaction of the equipment and the problems existing in the current equipment usability were summarized (Table. 5 shows). The preparation work before the user's work is cumbersome, and each important part needs to be inspected to prevent slurry leakage, ensure slurry quality, and ensure worker safety.

Table 5: User behavior before work

Operation process	User behavior	Corresponding parts
Before work (preparatory work)	Check whether the electrical wiring of the equipment is in good condition.	Electrical wiring
	Check and drain the water in the slurry tank, slurry tank, slurry pump and connecting pipe.	Pulp tank, pulp storage tank, control panel, connecting pipe
	Check whether the bearing housings, shaft oil seals, refueling points at each connection, packing, etc. need to be supplemented with lubricating oil in each part of the equipment.	Each connection point, support frame
	Check the position of the oil level in the squeeze pump reducer, and install a pressure gauge.	Pressure gauge, control panel, control box
	Check whether the rotation direction of the squeeze pump motor is in accordance with the direction indicated by the arrow on the casing (used for squeezing, the rotation direction of the motor should be in the direction of the arrow, if it is used for suction, the rotation direction is opposite)	
	Connect the water source and turn on the motor, make the machine and the pipeline full of clean water, run for a while, fully lubricate the screw and screw sleeve (rotor, stator) to avoid burns to the rubber screw sleeve, and check whether the machine and pipeline are blocked or leaked.	

In the work, the user's operation behavior is mainly concentrated in the upper hopper of the concrete grouting equipment and the control panel area (Table. 6 shows).

Table 6: User behavior at work

Operation process	User behavior	Corresponding parts
At work (operating behavior)	Manual feeding.	Upper hopper
	Cover the flap.	Control panel
	Operate the control panel parameters to complete the process of parameter setting, automatic pulping and automatic grouting.	Alarm, emergency stop button
	The operation is abnormal, the alarm sounds, the siren lights up, press the emergency stop button.	

Cleaning and maintenance work after work is also a very important part of the operation link, mainly to extend the service life of the equipment and ensure the safety of the equipment (Table. 7 shows).

Table 7: User behavior after work

Operation process	User behavior	Corresponding parts
After work (clean up and repair)	Add clean water and stir at high speed to clean the residual slurry in the slurry tank.	Upper hopper
	Open the drain valve to drain the remaining liquid in the slurry pump and pipeline.	Control panel
	Open the slurry valve and squeeze pump of the slurry storage tank to discharge the test fluid to avoid hardening that affects the efficiency of the equipment.	
	Cut off the power supply and close the electrical cabinet.	Control box, wire
	The remaining water in the water supply system should be drained in the cold season.	Water tank

According to the user's one-time pulping process, count the areas where the user interacts frequently. Among them, the control panel in the control box interacts with the user most frequently. Because feeding requires manual feeding, users at the feeding hopper often use it. Other parts are mainly involved in pre-operation inspection and post-operation cleaning and maintenance.

### User interview

Interview users who use the original concrete grouting equipment, summarize the specific problems existing in the current equipment in use, and carry out the specific components corresponding to the problems. Through interviews with users, eleven problems faced during

use were put forward. The components corresponding to the decibels are the slurry tank, the upper hopper, the support area, the water tank, the display panel, and the motor. Among them, the problem with the display panel and the upper hopper area is the most obvious.

## OPTIMAL DESIGN

According to the preliminary research and user interviews, it can be known that the problem between the display panel and the upper hopper area is the most obvious. The upper hopper is not very convenient to improve due to current technology and size limitations. Therefore, this research mainly optimizes the design of the display panel of the concrete grouting equipment.

Due to the particularity of the environment in which the concrete grouting equipment is used, it is necessary to experience the sun and rain outdoors. Therefore, the protection of electrical cabinets and control panels of concrete grouting equipment is particularly important. The control panel of the original device is located on the outside of the body, and it will encounter problems such as dampness and glare from the sun (Fig. 1 shows an example). The improved concrete grouting equipment puts the control panel and the electric cabinet in the box, and the box with the door can be opened during use. At the same time, there is a transparent glass window on the outside of the box, you can clearly see the screen data on the control panel. In addition, the screen of the control panel changes from vertical to oblique, and the shaded area formed allows users to clearly see the relevant data of the screen under the scorching sun (Fig. 2 shows an example).



Figure 1. Original concrete grouting equipment





Figure 2. Design optimization of concrete grouting equipment

## REFERENCES

- ISO.9211-11.Guide on Usability[S].1997.
- Wang Hui, Wang Jicheng, Huang Kun, etc. Usability research in the product design process [J]. Machinery, 2005.
- Shackel, B. Ergonomics in Design for Usability [J].Cambridge: Cambridge University Press. 1986.
- Bennet, J. Managing to Meet Usability Requirements: Establishing and Meeting Software Development Goals[J].New Jersey: Prentice-Hall. 1984.
- Nielsen, J. Usability Engineering[J]. New York: AP Professional. 1993.