ISSN: 2414-1895 DOI: 10.6919/ICJE.202201_8(1).0067

Research on MUTM for Unconfined Compressive Strength Test of Cement Stabilized Material

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Abstract

The unconfined compressive strength test is a mandatory experiment for cement stabilized material (CSM) of highway design and construction. Currently, the test can be completed with the cooperation of various equipment such as reaction frame, lifting jack, demoulding device and press machine. In order to improve the testing efficiency and precision, the research team designed an assembly multi-function unitized testing machine (MUTM) that integrated the four devices. The MUTM consists of five parts: Frame System, Reaction frame system, Power system, Function conversion system and Electrical system. The MUTM makes the manufacturing, demoulding and strength testing of the unconfined compressive strength test completed on one test equipment. After testing, the testing efficiency and stability of the equipment are increased by more than 50% and 14%. While meeting the specification requirements, the testing efficiency is significantly improved.

Keywords

Unconfined Compressive Strength, Highway Construction, Unitized Testing Machine.

1. Introduction

With the development of China's economy, the mileage of highway construction has reached a wide range. As the main load-bearing layer of the asphalt pavement, strength of cement stabilized material (CSM) is the significant to the design and construction of the pavement structure [1]. The test process of CSM includes unconfined compressive strength and CBR value under confined conditions. The unconfined compressive strength test of CSM is an important factor to guide highway design and construction. At present, the on-site test of China's highway engineering is based "Test Methods of Materials Stabilized with Inorganic Binders for Highway Engineering". The test facilities are reaction force frame, the lifting jack, and a press machine [2]. Currently the tests process is implemented manually which result high labor intensity and low work efficiency and prone to lead variation of test data. Researchers have tried to replace large specimens with small specimens to reduce labor intensity, but it is still manual operation. Harbin Experimental Instrument Factory invent and manufacture a unitized machine which greatly improved the test conditions, but the automation and the monitoring of state parameters in the test process still need to be improved. Professor Sha Aimin and Dr. Hu Liqun of Chang'an University have developed vibration forming equipment according to the principle of vibration compaction, but due to the large discrepancy with the data obtained from the existing test equipment, they have not been promoted [3]. For CSM pavement base construction, unconfined compressive strength test is indispensable, whether it is mixture ratio design or quality tracking during construction [4-9]. In order to accurately and efficiently complete the test process, the research team develop an multi-function unitized testing machine (MUTM) that integrates manufacturing,

Volume 8 Issue 1, 2022
DOI: 10.6919/ICJE.202201_8(1).0067

demoulding and strength testing. While meeting the Chinese current specification requirements, the testing efficiency is significantly improved.

2. General Design

The structural design of the MUTM is divided into five parts:

(1).Frame system: A frame carrying the whole equipment and platform for installing other components.

(2).Reaction frame system: Load-bearing structure for manufacturing and strength testing.

(3).Power system: A combination includes motors, jacks and limit devices.

(4).Conversion system: A conversion structural between manufacturing, demoulding, and strength testing.

(5).Electrical system: Include electrical control, parameter display device and communication interface program design.

3. Subsystem Design

3.1 Design Principle

Given that the MUTM is widely used in material testing centers and engineering laboratories, the design principle should be simple operation and display accurately of test results. Considering the transportation, the MUTM is designed to be assembled structure. During the process of manufacturing, demoulding and strength testing, MUTM should support data display and control.

3.2 Frame System

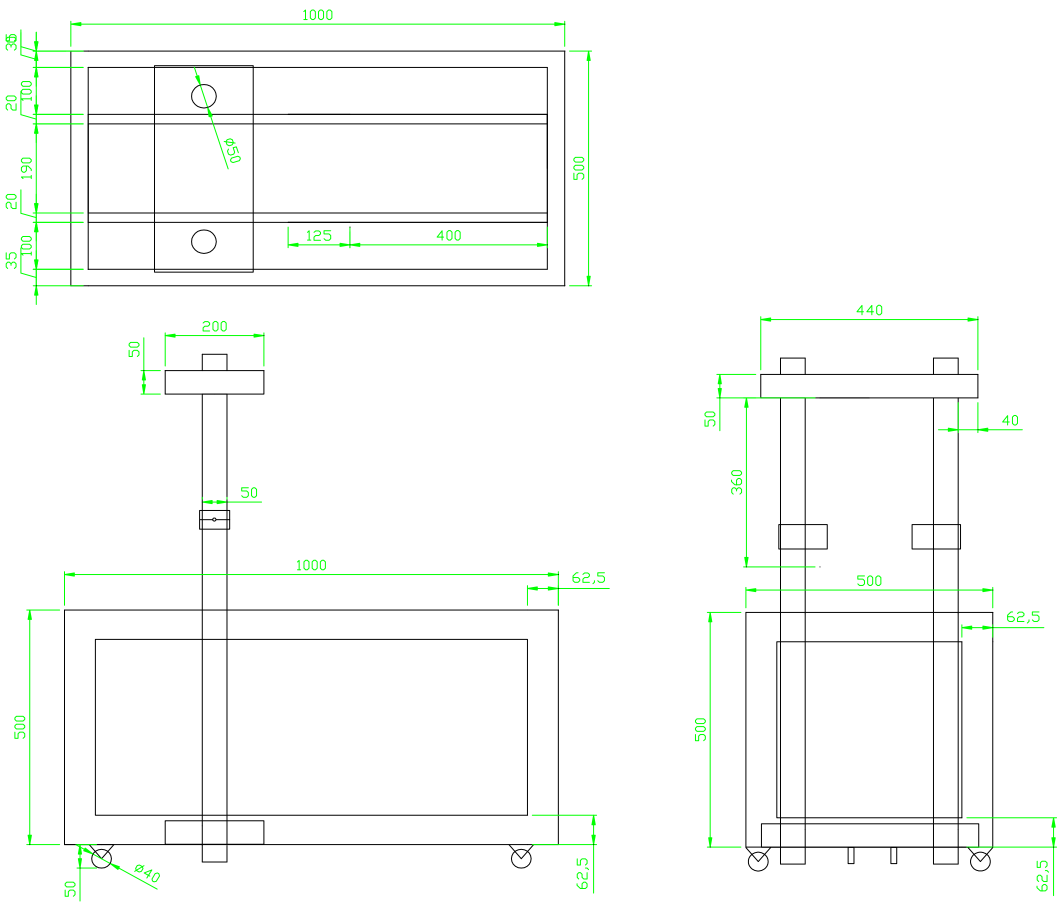

Figure 1. Frame system

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The frame system allows the whole machine to have a space and platform for the structural components. According to the working height of the jack and the volume of the electric motor, the body frame is designed as a rectangular parallelepiped frame welded by channel steel. The frame size is 1000×500×500mm with the channel steel specification of 5# and 50×37×4.5mm. The bottom and four sides of the frame are equipped with removable enclosures for packaging internal equipment and components. For reducing weight, the hoarding is a 1mm steel plate with moderate rigidity, which is fixed on the channel steel frame by nuts. In order to facilitate the movement, a free steering wheel is installed at each of the four corners of the bottom of the frame. The diameter of the wheel is 100mm, and the front two wheels are equipped with brake switches. The design diagram is shown in Figure 1.

3.3 Reaction Frame System

Since the pressure of reaction frame for unconfined compressive strength test reach to 56Mpa, the double column reaction frame structure is adopted through the calculation program. The column is supported by upper and lower bearing plates, which are two cast iron columns with an aperture of 50 mm and a length of 1600mm. The upper bearing plate is 400×240×60mm rectangular high-strength steel plate which is provided with two circular holes sleeved into the column, with a hole diameter of 50mm, so that the bearing plate is connected with the two columns. The lower bearing plate is also a 400×240×60mm rectangular high-strength steel plate, with two round holes sleeved into the column and fixed in the bottom groove of the channel steel frame. The upper surface of the lower bearing plate is provided with a jack limit convex part, which can make the jack accurately in place. In order to prevent the central part of the bottom plate from flexing and deforming due to the concentrated force, four spring retractable channel steel feet are installed on the bottom surface of the bottom plate to ensure sufficient rigidity. To complete the demoulding process, a part that can slide up and down is installed on each of the two uprights, which is fixed by jackscrews, and annular stirrup is added on the lower part of the circular trial mold.

3.4 Power System

The power system is an electric hydraulic jack with a working rated load (cylinder thrust) of 1000KN, a maximum working pressure of 63Mpa, and a maximum stroke of 300mm, which includes a three-phase AC motor with a rated current of 7A. The oil tank of the jack is separated from the hydraulic cylinder, and the oil tank is located at the bottom of the motor. A pressure sensor is installed on the top of the oil tank so the pressure signal is transmitted to the electrical control box.

3.5 Conversion System

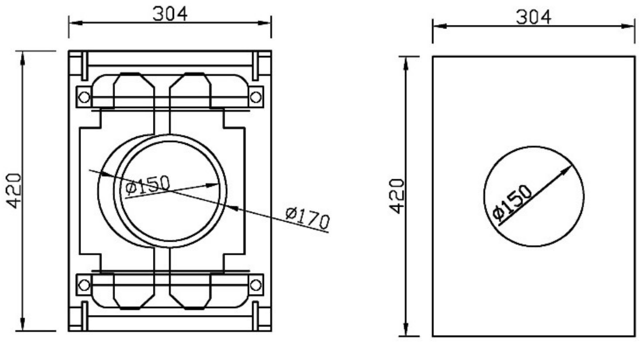

Figure 2. Conversion system

The function conversion system is the core part of this equipment which adopts a track structure to facilitate the production of 150*150mm cylindrical specimens. A flat pulley is placed on the track as a platform for manufacturing, demoulding, and strength testing. The flat pulley adopts a flat welded two axle four-wheel and 200mm × 200mm × 5mm high-strength steel plate, which is designed to support the test mold. The milling part is filled by discs of the same diameter, and the disc fixed by

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two annular plates equipped with a switch handle that can slide along the bottom of the flat plate is on the lower part of the plate. When manufacturing or testing strength, the test piece is lifted by the bottom jack. When demoulding the test piece, the flat pulley is separated from the disc by sliding the chuck, and only the disc rises together with the test piece. In this way, the conversion of different functions is realized. The design conversion system is shown in Figure 2.

3.6 Electrical System

The electrical system is integrated into a control box, which is equipped with power switch and display lamp. The electrical wiring diagram is shown in Figure 3. Where KM1 is the AC contactor, K1 is the intermediate relay, and K2 is the normally closed output point of the control instrument. When the pressure measured by the meter exceeds the set upper limit, K2 will be disconnected, so that the intermediate relay coil will be de-energized. The compute and sensor circuits are shown in Figure 4. The pressure sensor is used for collecting the pressure signal of the jack. The PC software draws the pressure curve, displays the pressure value and its change law, and can form a file output.

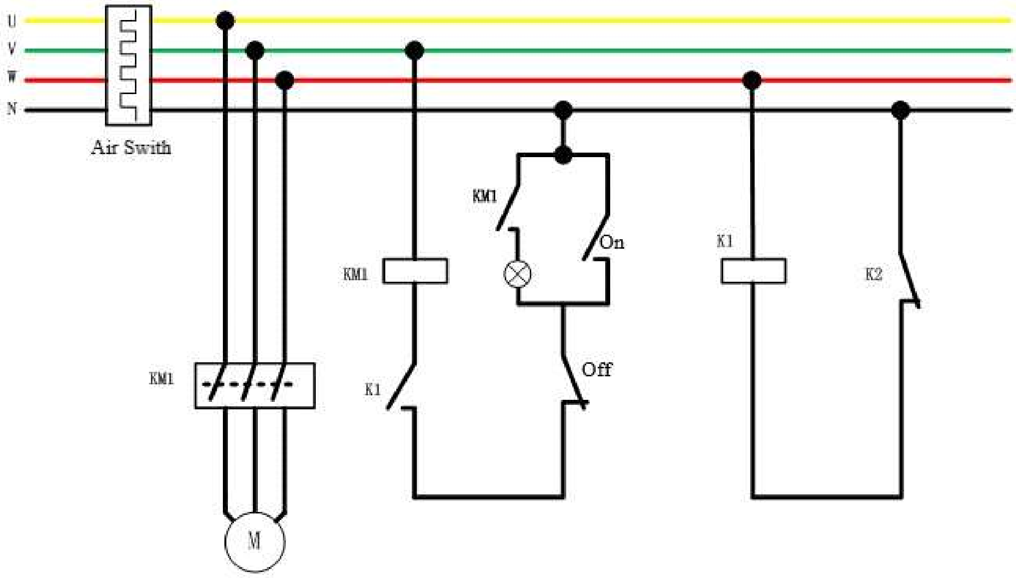

Figure 3. Electrical diagram

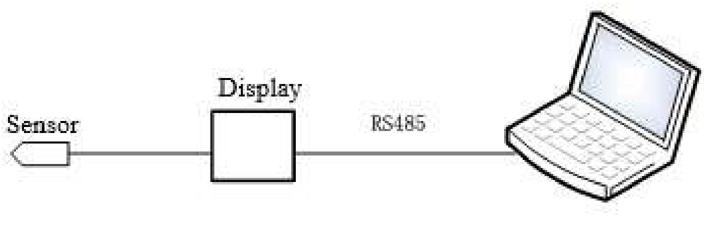

Figure 4. Circuits

4. System Installation and Testing

After the above five systems are installed, the Digital model and physical diagram of the whole machine are shown in Figure 5 and Figure 6. The research team arranged two sets of experiments to verify the practicability and accuracy the equipment. Group A used ordinary jack equipment, while Group B used the MUTM. Each group manufacture 6 test pieces respectively and the work efficiency and reliability of the experimental data are examined by the tester, test results are shown in Table 1. The testing efficiency of the unconfined compressive strength test is increased by more than 50%,

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and the stability is increased by more than 14%. In summary the MUTM can be used in highway design and construction, and the accuracy reach the standards required by specification.

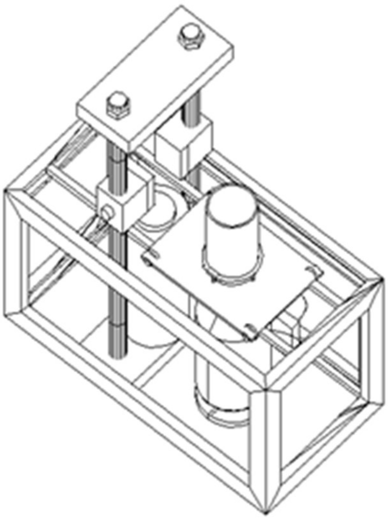

Figure 5. Digital model

Figure 6. MUTM

Table 1. Three Scheme comparing

No.	Load	Jack installing	Compaction	Standing	Demolding	Sum	Totalize
1-1	111	110	247	120	103	691	800
1-2	85	155	146	120	100	606	627
1-3	120	136	928	120	97	1401	1440
1-4	92	122	433	120	106	873	895
1-5	100	107	223	120	105	655	705
1-6	90	105	120	120	127	562	628

Table 2. Three Scheme comparing

No.	Load	Jack installing	Compaction	Standing	Demolding	Sum	Totalize
2-A	67	25	19	39	22	172	288
2-B	60	15	22	19	23	139	292
2-C	77	17	24	20	20	158	310
2-D	90	18	21	16	20	165	349
2-E	65	20	23	18	21	127	280
2-F	56	17	22	17	20	132	297

Table 3. Volatility of experimental data

No.	NO.1	NO.2	NO.3	NO.4	NO.5	NO.6	Mean
MUTM	5.63	5.42	5.22	5.63	5.63	5.77	0.07
Manual	5.91	5.81	5.86	5.78	6.01	6.07	0.08

5. Conclusion

(1) The MUTM realize conversion of manufacturing, demoulding, and strength testing by flat pulley achieving automation of unconfined compressive strength test for CSM.

(2) The MUTM consist of frame system, reaction frame system, power system, conversion system, and electrical system. Simultaneously the weight of the MUTM is reduced by double column structure. The assembled structure realizes convenient to assemble and transport.

(3) The Stability of MUTM increased highway engineering productivity, improved the test environment and created a new test model that is easy to implement.

(4) By contrast test, results of MUTM accord with the Chinese current specification requirements. This MUTM has an improved design, which will optimize structure and digitalize operation.

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