Analysis of the problems existing in the verification and calibration of the Testing System of Single-wheel Sideway Force Coefficient

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Abstract. China’s "Specifications for Design of Highway Asphalt Highway" have strict regulations on the sideway force coefficient of the highway. The testing system of single-wheel sideway force coefficient, as a common equipment for sideway force detection, has more possession in China and is more widely used. At present, the calibration method of the testing system generally uses the comparison method. The verification methods mentioned in the current verification regulations are mainly for static verification and repeatability inspection. Therefore, at this stage, all measurement verification units cannot reasonably evaluate the accuracy of the instrument. In this paper, through related research and data analysis on the verification method of the testing system of single-wheel sideway force coefficient, it is found that there are problems in the process of equipment verification and calibration, and gives the basis for the development of the calibration equipment, which provides a reference for the establishment of metrological verification standards and traceability of the value of dynamic detection equipment in the industry.

1. Introduction
With the development of China's economy, highway transportation has also developed rapidly. In recent years, China's auto production and sales volume, car ownership are growing continuously. At present, the number of deaths from traffic accidents in China has exceeded 60,000 per year for four consecutive years. These figures also reflect the importance of highway traffic safety. Studies have shown[1] that highway anti-skid performance has the greatest impact on highway safety performance and is the driver’s most concerned highway performance. The anti-skid performance of the highway can reflect the braking distance in the case of automobile accidents, so the detection of anti-skid performance has become the key of highway safety detection. The friction coefficient of the highway is an important index for evaluating anti-skid performance[2,3]. In the field of highway transportation, the dynamic friction coefficient mainly reflects the dynamic anti-skid performance index of the highway. Compared with some static friction coefficient detection, the dynamic friction coefficient can better reflect the real anti-skid performance of the highway.

Highway anti-skid performance is an important indicator to ensure highway driving safety and allowable driving speed, and it is also a comprehensive reflection of various technical levels such as
2. Problems in on-site detection of sideway force coefficient

At the present, the detection of the sideway force coefficient of the highway surface mainly uses two equipment of the testing system of single-wheel and twin-wheel sideway force coefficient. The specific test method is carried out according to the method in JTG E60-2008 "Field Test Methods of Subgrade and Highway for Highway Engineering". Because of its reasonable test indexes, objective test conditions, and high test efficiency and accuracy, the testing system of single-wheel sideway force coefficient has become the first choice for testing highway friction coefficients in many countries in the world, it is also the standard method for measuring the friction coefficient of high-grade highways in China. In the actual inspection, the inspector found that there are still some problems in the inspection method and evaluation method of the inspection equipment:

1. At present, when evaluating the highway anti-slip performance of the highway, the sideway force coefficient index is used. However, the texture depth also plays an important role in evaluation. In the actual evaluation, two evaluation indicators should be considered comprehensively to evaluate the highway anti-skid performance.

2. There are many factors influencing the sideway force coefficient. At present, only the correction method of temperature and speed is specified in the standard, and it is an empirical formula obtained through experiments. The tire wear, highway conditions, water film thickness and other factors all have a certain effect on the sideway force coefficient. The influence factors should be considered as comprehensively as possible, and the output value of the sideway force coefficient should be more accurate through further research.

3. At present, the measurement verification of the testing system of sideway force coefficient is mainly to verify the repeatability of the dynamic test results, and the accuracy of the results at the time of dynamics is still unable to be verified, so the on-site testing personnel cannot give a reasonable explanation for the problems displayed by some on-site testing data.

These problems also reflect some actual conditions in the current testing. The main reason for these problems is that the relevant research in China started late. After the testing equipment was successfully developed, it was quickly put into field use due to its efficient and convenient characteristics. Related research is also accompanied by on-site testing, which leads to some actual situations that have not been systematically researched, which also affects the calibration and verification of the equipment, so we need to conduct a more comprehensive and systematic research on the influencing factors, test methods and verification methods of the testing system of single-wheel sideway force coefficient.
3. Verification data analysis and problem presentation

Metrology verification plays a vital role in testing equipment. Only testing equipment that establishes a complete traceability chain and meets China's metrology technical requirements can be put into field use. The verification of the testing system of single-wheel sideway force coefficient is currently performed according to the method in JJG (Traffic) 113-2014 "Testing System of Single-wheel Sideway Force Coefficient". In the verification regulation, the vertical load, sideway force, temperature, test wheel deflection, distance, water film width, and coefficient of variation of the equipment to be tested are required. During the measurement verification test, the static verification test is first performed. Only when the static test results meet the requirements of the verification regulations can be tested dynamically. At present, the traceability of the instrument is also carried out by statically detected force values. In actual applications, the equipment runs dynamically on the highway surface. After a large number of verification tests and data processing, it is found that there are certain problems in the current verification test.

3.1 Data analysis

Figure 1 is the test results of different types of testers that were tested under the same environment on the standard test highway of the Proving Ground for Highway and Traffic Engineering, Ministry of Communications. Figure 2 is the test results of the same type of equipment at different locations during the centralized inspection.

![Figure 1. Comparison of test results of different test equipment](image1)

![Figure 2. Comparison of test results in different locations](image2)

It can be seen from Figure 1 that under the same test environment, the repeatability of each equipment can meet the requirements of the verification regulations, but the test results of the sideway force coefficient between different equipment vary greatly. The equipment has all passed the static test, that is, the test value in the static state meets the requirements of the verification regulations, which shows that the current static verification method cannot accurately trace the source of the test equipment, and there are inaccurate test results in the dynamic test. As can be seen from Figure 1, under the same detection method and the same highway section, the difference between the maximum value and the minimum value of the sideway force coefficient detected by the detection equipment reached 15, and the SFC-IV equipment with the largest average detection result reached 80.58, the smallest GLQ5160TLJ4D equipment has reached 73.04, the average difference is 7.54, this difference is a large number for the sideway force coefficient, which is equivalent to the difference of 70N in the detection of sideway force, which may further directly affect the treatment evaluation of the highway anti-skid performance, taking into account that the equipment itself has mechanical effects as well as speed, temperature, water film width, and other environmental factors have different impacts, these effects will not make the results of the two testing equipment have such a large difference.
It can be concluded from the test data that the static test results are not a good indicator of the accuracy of the device detection, and the dynamic test is not enough to evaluate the repeatability of the equipment. The repeatability only shows that the output value of the testing equipment is relatively stable and the equipment runs more smoothly. However, the accuracy of the dynamic testing results of the equipment is also crucial, so we need to trace the source of the dynamic test results, so that we can more accurately evaluate the excellence of the testing equipment. In addition, in the research of the stability of the test results of the same equipment, it is found that the detection stability of the equipment is good, so it is reasonable for the equipment now required to be verified once a year.

The same equipment has very different test results when testing the side force coefficients of test roads in different locations, which also shows the impact of test road surface on test results. In addition, it can be seen the side force coefficient detection curve in Figure 2 is more volatile than the curve in Figure 1, which shows that through the fluctuation degree of the trend curve of the side force coefficient, the performance of the test pavement such as wear and smoothness can also be obtained indirectly. The smaller the fluctuation of the curve, the better the road surface is, the smoother the road is, and the more uniform the paving. It can be seen that the test road selected in some areas is a section of the local road that is relatively straight and has few vehicles, but the road surface conditions cannot be reached the level of the standard test road, so the detection results of the centralized inspections in the field are less repeatable than those of the Beijing standard test sections, and some of the detection points fluctuate greatly. For example, the test result curve of the test road section in Anhui has a very obvious valley value, indicating that the selected test road may have certain potholes at the location of the test point, or the uneven paving of asphalt has caused this phenomenon. But the road section being tested is currently unable to detect the standard value of its side force coefficient.

3.2 Question raised
Through a large number of verification tests and output data analysis of the testing system of single-wheel side force coefficient, the following problems can be found in the verification tests:

(1) The accuracy of the results obtained by the testing system cannot be verified. The current verification regulations for side force detection are static, and traceability is also carried out through static results. The coefficient of variation calculated by the dynamic test results can only reflect the repeatability of the results. However, it can be seen from the data that the equipment with static test results that meet the requirements of the regulations has a large gap in the data during dynamic testing. This shows that some equipment has the problem of inaccurate detection, static verification can not meet our requirements for dynamic operation of equipment detection, and there is no standard measuring device of testing system in the industry, so it is currently impossible to detect the standard value of the dynamic side force coefficient.

(2) Influencing factors are not properly controlled. In the dynamic test, the change of the ambient temperature is an uncontrollable factor, and it is difficult to guarantee the speed to be stable at 50km/h in the actual verification. The correction method of these two factors is not accurate enough, which will also affect the results. As for the test road, due to the frequent verifications conducted throughout the country, the highway environmental conditions at each test site are different, and it is difficult to be unified.

(3) Some verification methods are not suitable for operation. For example, the total station reading of the test wheel declination angle is difficult to set up because the total station is installed, and the test vehicle needs to be moved away to facilitate the wide field of vision when reading the angle, which is more time-consuming and labor-intensive in actual operation; Testing with a temperature simulator when temperature detection is relatively cumbersome, and it is inconvenient to disassemble the infrared thermometer of the tester, so at present, the standard thermometer is used as the standard in the actual detection, and the temperature of water at different temperatures is tested, and compare the difference.

It can be seen from these problems that the current verification regulations can no longer meet the
actual verification requirements. Therefore, the verification regulations need to be revised for the problems in the verification combined with the problems of on-site testing, and it is necessary to research and develop the calibration device of the testing system of single-wheel sideway force coefficient to solve the problem of traceability of the dynamic measurement results and improve the measurement system in the industry.

3.3 Development basis of calibration equipment

The dynamic test results in the verification of the testing system of single-wheel sideway force coefficient cannot be traced effectively. Therefore, a plan for designing and manufacturing a set of standard calibration devices is proposed to improve and unify the verification methods, and establish the relevant standard specifications of the calibration devices. Since there has not been any relevant research on the testing system of single-wheel sideway force coefficient in China, there are not many materials that can be used for reference. The basis for the development of the calibration device mainly comes from the following aspects:

(1) In order to ensure the accuracy of the calibration equipment detection, it is necessary to refer to the existing detection rules and design specifications related to the lateral force coefficient. The current specifications that can be referred to are: JTG E60“Field Test Methods of Subgrade and Pavement for Highway Engineering”, among which the T 0965 the testing system of single-wheel sideway force coefficient determines the friction coefficient test method in the field operation method of the device and the technical indicators of the test have a very detailed description, and the test speed range is 40-60km/h; section 3.0.7 of the JTG D50-2017 "Specifications for Design of Highway Asphalt Pavement" clearly stipulates that when the completion acceptance of the pavement of expressway, first-class highway and second-class and third-class highway in mountainous and heavy hilly areas, According to the standard value range of the sideway force coefficient (SFC60) delivery inspection corresponding to different average annual rainfall, the rainfall is 500-1000mm, the sideway force coefficient should not be less than 50; the annual rainfall is 250-500mm, the sideway force coefficient should not be less than 45, because the sideway force coefficient represents the anti-skid performance of the highway, the larger the coefficient value is, the better the anti-skid performance is. Therefore, the highway surface that is more prone to wet and slippery in heavy rainfall needs better anti-skid performance. In 7.2 Cement concrete surface of JTG F80-1-2017 "Inspection and Evaluation Quality Standards for Highway Engineering Section 1 Civil Engineering", the sideway force coefficient is also clearly pointed out as one of the actual measurement items, and the corresponding prescribed values are given. For general sections of expressways and first-class highways, the sideway force coefficient is not less than 50, and the special section is not less than 55. It can be seen from the rules and regulations referred to, whether it is the standard value of the lateral force coefficient or the standard test speed, the standards of various industry departments have not been unified, which has caused many cases of improper docking and also affected the measurement verification of equipment. The calibration equipment needs to learn from the regulations in the rules and regulations, and also to solve the problem of non-uniform standards.

(2) At present, the industry has implemented the calibration specifications and verification procedures of the testing system of single-wheel sideway force coefficient in 2014, namely JT/T 921-2014 "Testing System of Single-wheel Sideway Force Coefficient" and JJG(Transportation) 113-2014. " Testing System of Single-wheel Sideway Force Coefficient", these two documents are mainly to guide and standardize the testing system of single-wheel sideway force coefficient for the calibration and verification of such equipment, which includes the six technical indexes of vertical load error, horizontal load error, test wheel deflection angle, distance error, temperature error and variation coefficient of the equipment are required. Among them, the error requirements for vertical load and horizontal load during static test are ±20N, which is 1% error, while for dynamic test, the requirement of the coefficient of variation is not more than 5%. At the same time, it also regulates the test method of specific verification, in which the test speed is 50km/h. Through the regulations and specifications of calibration and verification, it can be seen that there are the six important technical
indicators of detection proposed on the basis of a large number of field tests, but there are still inconsistencies in the detection methods. At present, the traceability of equipment value only stays in the static test stage, so it is necessary to realize the traceability of measurement value in the dynamic process through the calibration equipment, and refer to the relevant error requirements. After the plan is determined, it is verified by testing.

(3) Considering the problems reflected in the verification data, the calibration equipment plan is proposed. According to the conclusions obtained through the verification test, there are three main problems to be solved by the calibration equipment: first is the verification problem of the accuracy of the dynamic test; the second is to solve the problem caused by the centralized verification of the non-standard test highway; the third is best to be able to solve environmental problems such as speed and temperature. The design concept of the calibration equipment is centered on three core problems to be solved.

(4) If the calibration equipment can meet the requirements of load, control speed, and smooth operation, it is necessary to ensure that the material of the calibration equipment has a certain rigidity and is not easily deformed. Second, the components of the equipment cannot be affected by the external environment, and the components of the equipment should be as close as possible to achieve smooth transmission

(5) Through the on-site use of the testing system of single-wheel sideway force coefficient, according to the feedback of the results, we can know more about the influencing factors of the lateral force coefficient, and analyze the results more comprehensively in the uncertainty evaluation, so that the results obtained by the device are more reliable.

4. Conclusion
The testing system of single-wheel sideway force coefficient is one of the widely used highway friction coefficient testing equipment in China, which is both efficient and convenient, but the industry currently lacks a measurement verification equipment for such equipment, which also leads to incomplete verification regulations. It can be seen from the problems found in the field verification that for the testing system of single-wheel sideway force coefficient, the research of the measurement standard equipment is bound to be the most important and urgent task, and after the development of the calibration equipment, a series of tests can be carried out around it to solve some problems in the current verification and test methods, as well as the accuracy of the measurement results. Further, a complete traceability chain can be established to realize the traceability of the equipment.

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