The Current Situation and Development Suggestion of Highway Instrument and Equipment Measurement Management

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Abstract. The application of automation and intelligent technology in highway instrumentation equipment has gradually become the main factor that affects highway engineering test results. This article summarizes the characteristics of highway instrument and equipment measurement, and analyzes the main problems existing in the current highway professional measurement work from two aspects: measurement service and measurement submission. Suggestions for the development of highway professional metrology in response to the above problems. These suggestions include improving the legal system, exerting the strength of industry technical organizations, striving for more measurement authorizations, improving technical levels, and strengthening talent training.

1. Introduction
As of the end of 2019, my country's total mileage of highways opened to traffic was 5.17 million kilometers, ranking second in the world, and the total mileage of expressways was nearly 150,000 kilometers, ranking first in the world, which strongly supports the sustainable development of my country’s economy. Highway engineering is a public welfare infrastructure, and its engineering quality and service level have received widespread attention from the society. In order to accurately control and evaluate the engineering quality and service level, a large number of special instruments and equipment with highway engineering characteristics are widely used in the transportation industry. It plays an important role in ensuring the quality and safety of projects. In order to effectively serve the test and testing institutions and highway engineering project construction practitioners to carry out the traceability management of equipment and to guide the transportation authorities at all levels to strengthen the supervision and inspection of equipment and equipment, the General Office of the Ministry issued the "Highway Engineering Test and Testing Equipment Service Manual in 2019", including 225 kinds of special test and testing equipment for highways.

There are a large number of test parameters in highway engineering tests, and many professional fields are involved, including basic physical, mechanical, and chemical performance testing of ordinary road construction materials (such as soil, sand, cement, asphalt.), as well as some special materials (such as Asphalt mixtures, protective fences, markings, etc.) and roads, bridges, tunnels and other structures are tested for their road performance and safety performance. Therefore, the types of instruments and equipment used are diverse and the index items are numerous, and their measurement
parameters involve Many basic measurement categories such as length, temperature, mechanics, electromagnetics, etc., and even some special traffic-specific values, such as: deflection, ductility, penetration, pendulum value, flatness, rut depth, structural depth, reverse Reflection coefficient etc. This paper systematically sorts out the characteristics of highway instrument and equipment measurement, analyzes the existing problems of professional instrument and equipment measurement work at this stage, thinks deeply about the countermeasures, and proposes promotion from improving the policy and regulation system, improving the measurement service capacity, and building the traffic measurement talent team. Recommendations for the development of highway instrumentation measurement and the improvement of the accuracy of highway engineering quality inspection results.

2. The characteristics of highway instrument and equipment measurement

2.1. Output multiple values, involving more measurement categories
Some highway instruments and equipment represent multiple values, and their measurement parameters involve multiple professional categories such as length, mechanics, time, temperature, optics, etc. Only by tracing the source of each measurement parameter can the reliability of its comprehensive value be guaranteed. The traceability path of such instruments and equipment is often scattered. For example, a penetrometer, whose measurement parameters include temperature, time, and length, and Marshall stability meter, whose measurement parameters include mechanics, length, and so on.

2.2. The measurement result is the derived quantity calculated from the directly measured quantity
There are some concealed projects and a large number of masonry structures in highway construction projects, and the parameters of their quality evaluation are often not easy to directly measure, or although they can be measured directly, they will cause certain damage to the engineering entity. Therefore, in the evaluation of highway engineering quality and safety, some indirect and non-destructive technical methods will be used to obtain the derived quantities from single or multiple measured values through complex functional relationships, which are used in the evaluation of engineering quality and safety. The accuracy of the measurement value of this kind of equipment is affected by some parameters in the function conversion process. How to correctly handle the conversion relationship in a complex measurement environment, or the relationship between the stability of the parameter and the accuracy of the derived quantity, is the difficulty of the traceability of such instruments and equipment, especially for most non-destructive testing technologies, this difficulty is particularly prominent. For example, a radar thickness gauge, whose direct measurement value is the propagation time of electromagnetic waves in the measured object, needs to be converted to a function of wave speed to derive the required thickness data for engineering quality evaluation. However, the uncertainty of the wave velocity parameter in the derivation process brings great technical difficulty to the accuracy evaluation of the radar thickness gauge. Another example is the nuclear hygrometer, which directly measures the count value of radioactive particles, and derives the density and humidity of the measured object through a certain comparison relationship. This conversion relationship is greatly affected by the particle size, gradation, uniformity, physical state, and chemical composition of the measured material. It is also difficult to find a suitable and feasible technical method to measure the accuracy of its own value [1].

2.3. Non-measurement equipment affects the accuracy of test results
In highway engineering test and inspection projects, some indoor test projects need to be completed with the help of some auxiliary tools during the sample preparation process, or some agreed attribute tools need to be used in the test process. Such tools often have no measurement properties, that is, they do not have the ability to quantify a certain attribute of the measured object. However, such tools have a great influence on the measured measurement results. For example: the accelerated grinder used in the highway engineering aggregate test does not produce a value by itself. It only provides a polishing
effect for the aggregate with a fixed volume, a certain speed and other agreed properties, and then the pendulum friction coefficient is used. The instrument measures the friction coefficient of the aggregate after polishing to evaluate the anti-wear performance of the aggregate. However, if some of the agreed properties of the accelerated polishing machine are not at the same level, it will inevitably cause differences in the polishing effect of the aggregate. Then the polished aggregate will not be evaluated at the same polishing effect level, and the test results will not be comparable. Sex. Similarly, the Los Angeles abrasion testing machine used in the highway engineering aggregate test is the same. It provides a fixed abrasion work for the aggregate, and does not produce a value by itself. The mass loss before and after abrasion is used to evaluate the abrasion resistance of the aggregate. Some agreed attributes also need to be limited to the same level to ensure the comparability of test results. There are many such equipment in highway engineering test and inspection work, such as: standard screens, ring cutters, sand filling drums, compactors, vibrating tables, mixers, test molds, etc., all of which do not produce value by themselves, but are not relevant to the test. For tools and equipment that have a great impact on the results, some of their agreed properties must be tested to ensure the comparability of the test results [2,3].

2.4. The roughness of the test method brings difficulties to the determination of measurement requirements
Compared with industries such as electronics and aviation, highway engineering has relatively rough management methods and various technical requirements, and some test methods used for engineering quality and safety evaluation are also relatively inaccurate. The measurement work of the equipment is to ensure the accuracy of its measurement value, so as to ensure the reliability of the test results. However, the roughness of some test methods on the one hand reduces the significance of the measurement of instruments and equipment, and fails to ensure the reliability of the test results; on the other hand, it also brings certain technical difficulties to the verification/calibration methods of instruments and equipment. For example, the rolling method is used to measure the plastic limit of the soil, and the main measuring equipment used is a balance. The traceability method of the balance is relatively mature, but its accuracy does not guarantee the reliability of the plastic limit test result. The accuracy of the test result largely depends on the rolling method and the empirical judgment of the soil sample state. The test result brings an unquantifiable deviation, and this deviation is an order of magnitude higher than the accuracy of the balance itself. For another example, the instrument and equipment group used to measure the depth of the pavement structure by the sand paving method, only from the perspective of measurement, the geometric size of the sand filling cylinder, the geometric size of the push plate and the flatness of the bottom surface, and the indication error of the measuring scale, etc. It can be accurately measured to ensure that it meets the requirements of the test method. However, it is basically impossible to accurately measure the output value of the instrument and equipment through the simulation test process. Because the paving links in the test process have great variability, the test results of different operators are different, and there are rough and unquantifiable errors, which bring great technical difficulties to the measurement of this type of equipment.

2.5. Need to measure the overall performance of system integration equipment
There are a large number of system integration equipment in highway equipment. A piece of equipment often involves optics, electromagnetics, mechanics and other disciplines. It relies on the collaborative operation of multiple components with different working principles to complete the test and detection of a certain parameter. This type of instrument is often a large-scale equipment with a complex control system that cannot be disassembled. Even if it can be disassembled and each component is measured separately, it cannot guarantee the reliability of the overall performance of the integrated system, which brings a lot of difficulties to the measurement work. In order to play the role of such equipment in ensuring the reliability of test results through measurement work, the accuracy of measurement of its overall performance cannot be avoided. For example, a road surface laser flatness meter, theoretically, the core components of the laser ranging sensor, acceleration sensor,
and distance sensor can all be disassembled and measured separately to ensure the accuracy of each component. However, this is not sufficient for the verification/calibration of the road surface laser smoothness meter. It is also necessary to verify the overall performance of its components when working together under the test working state, and the reliability of its comprehensive output value. Therefore, the overall performance of this type of integrated system equipment is the key to measuring its reliability. It must be considered in the work of its value traceability method to truly ensure the accuracy of its value.

2.6. Calculation software needs to be included in the equipment traceability system
With the advancement of science and technology and the deepening of interdisciplinary applications, a large number of equipment based on automation control has also emerged in highway equipment, which not only improves the test efficiency, but also greatly reduces the human influence on the test results. An essential component of this type of equipment is the onboard software. The onboard software is the control center of the instrument and equipment, and it is also the only medium for the equipment user to interact with the instrument and equipment. It is also a processing system that converts various test signals into the required derived values. The accuracy of the measurement value of this kind of equipment not only depends on the measurement accuracy of each physical component, but is also largely affected by the accuracy of the airborne software algorithm and processing accuracy. Therefore, the measurement of the airborne software must include its value traceability system. For example, the road laser rut meter, its onboard software derives the required rut depth value according to the height value of the road cross section collected by the instrument and according to a certain calculation model. If the onboard software has a slight deviation in the selection of the calculation model, it is very likely that the rut depth calculation result will be wrong, or the deviation will be large. There is no essential difference between the airborne software and other physical test components of the instrument and equipment. It is more important to some extent. Only by incorporating it into the verification/calibration parameters of the instrument and equipment can the integrity of the traceability system be guaranteed.

3. The problem

3.1. The professional metering service network is not yet complete
Based on the requirement in the "Metrics Law of the People's Republic of China" that "measurement verification work should be carried out in the nearest location in accordance with the principle of economic and reasonableness", in order to strengthen the management of the special highway measurement instruments of the Ministry of Transport and the health of the entire system measurement instrument supervision and management system, to ensure the transmission of the measurement value is accurate. The current road instrument and equipment measurement management system follows a two-level layout of national-level professional measurement stations and provincial-level local measurement technology institutions. The National Road and Bridge Engineering Testing Equipment Metrology Station, as a national-level metrology technical institution that undertakes highway professional metrology work in the transportation industry, began preparations for construction on May 30, 2008, and passed the (formerly) National Quality Supervision, Inspection and Quarantine on January 31, 2011. The General Administration of China is authorized as a legal metrological verification agency, and its authorized area is the whole country. Provincial-level local metrology technical institutions are laid out in accordance with the "one province, one station" model, and the authorized areas of provincial-level local metrological technical institutions are within the provincial administrative region. At present, there are only 9 authorized institutions, including: Zhejiang Provincial Transportation Construction Engineering Measurement Center, Guangdong Provincial Highway Water Transportation Engineering Testing Equipment Measurement Station, Guizhou Provincial Highway Water Transportation Engineering Testing Equipment Measurement Inspection Station, Sichuan Provincial Transportation Engineering Testing Equipment Measurement Inspection Station, and other institutions.
Station And so on, the provinces with provincial-level local measurement technology institutions account for less than one-third of the country.

On the whole, provincial-level local metrology technical institutions are still in their infancy, a large number of highway instruments and equipment are still being sent for long-distance inspection, the highway instrument and equipment measurement system is not perfect, and a complete highway professional measurement service network has not been established.

3.2. The professional measurement management system still needs to be built
After the "Measurement Law of the People's Republic of China" was promulgated and implemented in 1986, traffic measurement has undergone construction and development from the "Seventh Five-Year Plan" to the "Eleventh Five-Year Plan". In 1993, the former Legal Department of the Ministry of Communications issued the "Administrative Measures for Professional Metrology Verification Stations of the Ministry of Communications" (Jiao Ti Fa [1993] No. 49) to provide guidance for industry measurement work, but the document has been abolished and no relevant documents have been issued yet.. In 2011, after the establishment of the National Road and Bridge Engineering Testing Equipment Metrology Station, the Ministry of Transport successively issued the "Highway Engineering Test and Testing Instruments and Equipment Metrology Management Catalog", "Highway Engineering Testing and Testing Instruments Verification/Calibration Guidelines", and "Highway Engineering Test and Testing". "Instrument and Equipment Service Manual", "Notice on Implementing 7 Departmental Measurement Standards including Vehicle-mounted Pavement Laser Flatness Meters", "Notice on Implementing 8 Departmental Measurement Standards including Concrete Rebound Tester Verification Device" and other measurement-related documents. These documents are basically concerned with the content of the measurement technology. The overall requirements and layout of the road measurement work, the supervision of the measurement work implementation and the long-term operation mechanism, all lack effective policy support, and the professional measurement management system has not yet been established.. This is not only not conducive to the standardized development of professional measurement management, but in the long run, it is not conducive to the long-term development of professional measurement work [1,4,5].

3.3. Insufficient supply of calibration service capacity
There are 225 types of road instruments and equipment in the "Highway Engineering Test and Testing Instrument and Equipment Service Manual". There are only 97 types of instruments and equipment that have publicly released national or Ministry of Transport metrological verification procedures and calibration specifications, accounting for less than 50%. This shows that the gap in departmental metrological verification procedures is still relatively large. In addition, some published metrology technical specifications have problems such as outdated calibration methods and poor operability. Verification procedures and calibration specifications are the basis for the establishment of measurement standards, and their gaps directly affect the establishment of measurement standards. At present, the national road and bridge engineering testing equipment measurement station has only 15 authorized measurement standards, and the number of authorized measurement standards authorized by the provincial-level local measurement technology institutions is still less than 100. There is a large gap in measurement standards, and it is still far away. Far from being able to meet the measurement needs of highway instruments and equipment, highway engineering test and testing agencies are facing the embarrassing situation of wanting to submit for inspection but nowhere to inspect [6].

3.4. Inadequate understanding of the calibration of instruments and equipment
The measurement work in the transportation industry started late and has not developed rapidly enough. In recent years, the traffic measurement department and the national-level professional measurement station have been committed to the management of equipment and the user's understanding of the work of equipment measurement. Although they have achieved certain results, there are still unsatisfactory places. Some test and testing institutions’ understanding of the
measurement management of instruments and equipment is still stuck: they believe that instruments and equipment in various reviews have traceability requirements. Finding a statutory metrology institution and obtaining a certificate will be all right. Information about equipment and equipment, the introduction of measurement knowledge systems in books, and related training in the industry, did not pay enough attention to it. The managers of some test and testing institutions did not have a good understanding of the calibration and management of equipment. If it fails, it can be used, let alone know which parameters the equipment needs to measure, how long is the measurement period, and how to use the calibration results? Therefore, the investment in the measurement and management of instruments and equipment is not enough. Therefore, in actual work, how to apply the calibration results of the instrument and equipment, how to deal with the problems encountered, the management of the instrument and equipment and the users still feel very at a loss, the understanding is not clear and not in place.

3.5. Insufficient application of measurement results of instruments and equipment
The purpose of instrument measurement is to confirm the verification/calibration results. In fact, it is a comprehensive grasp of the technical status of the instruments and equipment. The confirmed conclusions are not only extremely important for the test and inspection work, but also help to improve the value traceability plan. The management and use of equipment is more scientific and effective. After confirming the measurement results, it can generally be applied to the following 4 aspects: (1) Applying correction values (factors) and calibration curves (2) Evaluating the measurement uncertainty (3) Identifying the state of use of the equipment (4) Improving the value Traceability plan. Regrettably, the relevant personnel of the instrument and equipment rarely think about the application of the measurement results of the instrument and equipment, and there are not a few organizations that do not confirm the measurement results. Therefore, the closed loop of road equipment from measurement to measurement results application has not yet formed, and the vicious circle of investment but no return has been repeated, which to a certain extent hinders the progress of professional measurement work.

4. Development Suggestions

4.1. Improve the industry measurement policy and regulation system
Metrology policies and regulations are not only the basis for the implementation of metrological work, but also the basis for the implementation of metrological work norms. Although a series of laws and regulations have been promulgated at the national level, such as the National Measures for the Management of Professional Metering Stations, the measurement of highway instruments and equipment has its own unique characteristics. It is necessary to further strengthen the construction of policies and systems related to traffic measurement work, and highlight industry measurement management. The characteristics of the industry have established the status of measurement management in the industry. Accelerate the promulgation of policies such as "Measures for the Administration of Transportation Industry", "Measures for the Administration of Measurement Supervision and Administration of the Transportation Industry", and "Accounting Standards for Special Measurement and Verification Expenses for Transportation", improve the system of industry measurement policies and regulations, and better regulate and supervise the orderly measurement of industry, Efficient development [6,7].

4.2. Give full play to the role of industry technical committees
Give full play to the role of the think tank of the National Highway Special Measuring Instruments Metrology Technical Committee and the Traffic Metrology and Testing Branch of the China Metrology and Testing Society, and include the "Traffic Metrology Development" in the "14th Five-Year Development Plan for Transportation Science and Technology", and do a good job of top-level design. Based on the existing metrological strength in the industry, with the full use of various
metrological strengths across the country, the layout of the formulation and revision of metrological technical specifications will be implemented, strict requirements, and the quality of technical specifications will be increased, the quantity will be increased, and the inapplicable technical specifications will be updated in a timely manner. The construction of measurement standards has laid a good foundation.

4.3. Accelerate the acquisition of industry measurement standards authorization
Strengthen the construction of national road and bridge engineering testing equipment metering stations, increase scientific and technological investment in professional metering standard technology research, strive for more professional metering standards authorization, and improve the industry's metering technology level. Establish the sharing of technological achievements for highway instruments and equipment, accelerate the updating and duplication of metrological standards construction technology, strengthen technical support for provincial-level local metrological technical institutions, so that they can quickly become viable, truly capable of performing due diligence, and have coverage as soon as possible. All the calibration capabilities of the instruments and equipment used by highway engineering test and inspection institutions can be verified/calibrated in the true sense of "economical and reasonable, nearby and on-site".

4.4. Improve the level of industry measurement technology
Give full play to the highway industry measurement and calibration service alliance led by the national station and the provincial stations across the country. The institutions within the alliance cooperate with each other, integrate resources, and jointly expand the development space, increase industry technology research and development investment, improve industry competitiveness, and provide the industry with High-quality measurement and calibration services have promoted the rapid development of traffic measurement work and continuously improved the level of industry measurement technology.

4.5. Strengthen the construction of traffic measurement talent team
Professional talents are the stamina for the development of the industry's measurement industry. Strengthen the training and education of measurement personnel in the transportation industry, normalize and systemize the training of measurement personnel, improve the business ability and management level of measurement management and technical personnel, and continuously improve the quality of the measurement team. And measure the quality of work. On the one hand, training should pay attention to the training of basic knowledge of measurement, and on the other hand, it should highlight professionalism, establish a database of industry measurement verification personnel, realize the information management of personnel training, assessment and continuing education, and promote the long-term development of industry measurement work.

5. The conclusion
The measurement work of highway instruments and equipment has not developed rapidly, which is related to the characteristics of the instruments and equipment and the difficulty in the development of measurement work. Although the current problems in the measurement of instruments and equipment have brought undesirable effects on their use, and at the same time have brought safety hazards to the quality of engineering construction, after nearly ten years of development, the industry has basically clarified the measurement of road instruments and equipment development direction. It is recommended that the traffic measurement authorities in the industry, measurement technology institutions, and test and testing institutions work together to advance toward the set goals, so that the measurement work can give full play to the basic role of promoting the improvement of the industry's engineering quality and helping to build a strong transportation country.
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