Frontiers in Traffic and Transportation Engineering (2024)
Clausius Scientific Press, Canada

DOI: 10.23977/ftte.2024.040111
ISSN 2616-2334 Vol. 4 Num. 1

Research on Quality Control of Raw Material Testing and Testing in Highway Engineering—Taking the Third Section of Hainan Wanyang Expressway as an Example

Wang Cheng[a], Li Min[b]

China Design Testing Technology Co., Ltd, Nanjing, China
[a]345847278@qq.com, [b]lmyx202210@163.com

Keywords: Highway engineering, Experimental testing, Hainan Wanyang Expressway, Quality Control

Abstract: At present, highway engineering construction is in a stage of rapid development, and there are frequent incidents of rework, scrapping, and even engineering accidents caused by substandard quality issues during the progress of engineering projects. The testing and testing of raw materials in highway engineering is an important basis for evaluating their quality. The testing results not only serve as a judgment standard that affects engineering construction and subsequent maintenance management, but also play an important role in influencing engineering quality control and completion acceptance evaluation. Based on this, this article discusses the factors that affect the testing and testing of raw materials in highway engineering, constructs a model, proposes quality control methods, and proposes countermeasures combined with the example of the testing and testing project in the third section of Hainan Wanyang Expressway, in order to effectively improve the management level and technical ability of highway engineering testing and testing.

1. Introduction

1.1 Research background

According to official data, by 2024, the mileage of highways in China has reached 8613 kilometers. Combined with the national goal of vigorously improving infrastructure construction, this number will continue to rise year by year. The National Highway Network Plan points out that by the end of 2030, a well-designed and widely covered national highway network will be established nationwide. During the golden period of highway construction, quality accidents during the construction process and after completion and use of highway projects are also accumulating year by year, and even casualties have occurred.

The participating personnel obtain real and reliable data through experimental testing results, thereby controlling the quality of engineering construction at a macro level and fundamentally ensuring the level of engineering quality. At the same time, testing data can supervise the quality control of raw materials and semi-finished products, and improve the relevant quality level.

In summary, based on the comprehensive background of highway engineering construction,

identifying the influencing factors of raw material testing and testing in highway engineering, and based on the years of work experience of third-party inspection and testing institutions, combined with literature research, expert review, and investigation by testing personnel, this study investigates the influencing factors of raw material testing and testing in highway engineering, identifies the response degree of the influencing factors, and aims to better control the quality of highway engineering construction, extend the service life of highways, avoid engineering quality accidents, and reduce carbon emissions throughout the entire life cycle.

1.2 Current research status at home and abroad

The French government regulatory authorities will conduct a rigorous qualification review every two years on the private construction project quality supervision enterprises they license. Given the strict and effective institutional management and the prohibition of quality supervision enterprises from participating in any commercial activities related to their interests as economic constraints, France's construction projects have first-class quality and exquisite details[1].

The United States, which is also a developed country, operates a different management model, with the government directly participating in supervision. One type is for the government to directly hire testing personnel, and the other type is for the government to hire long-term personnel engaged in testing from relevant supervisory enterprises. Testing institutions will also obtain relevant testing qualifications from the United States to improve their market competitiveness. Based on the examples of two developed countries, in their engineering quality supervision systems, based on leading economic development, long-term market operation environment, and sound legal system, industry institutions can quickly establish a complete organizational structure, smoothly carry out work, and provide strong support for engineering construction[2].

Compared to developed countries, China's highway and water transportation testing and testing started relatively late and only emerged and developed after 1980. In recent years, with the continuous construction and development of highways, the relevant regulations of the testing and testing industry have also been updated. Nowadays, the data results of testing and testing are important credentials for the quality of engineering projects and the acceptance of completion, occupying a strong position. Tian Zhiyuan and others analyzed and demonstrated the influencing factors and indicators of raw material testing from the perspective of hardware, software, and practitioners[3]. Wang Zhen and others proposed measures to ensure the good development of the testing and testing industry from three aspects: personnel quality, legal construction, and the introduction of compliant experiments[4].

1.3 Research content and methods

(1) To clarify the research background, we will sort out the current situation at home and abroad, organize relevant theories, and clarify the theories of Total Quality Management and 4M1E method for raw material testing and inspection.

(2) We use literature research method to analyze industry problems, identify corresponding causes, and combine expert interview method to analyze them one by one from the perspectives of society, technology, management, and environment. We determine the indicators of influencing factors, select models, conduct data regression analysis to rank the proportion of influencing factors, and conduct in-depth analysis.

(3) Research on quality control of raw material testing through a combination of qualitative and quantitative methods. Based on the example of the inspection project of Hainan Wanyang Expressway, this paper analyzes the current situation of the testing center, points out problems, and proposes countermeasures and suggestions for the four impact indicators.

2. Related concepts and theories

The commonly used raw materials for highway engineering include water, sand and gravel, concrete, asphalt, and so on.

(1) Total Quality Management Theory

The concept of Total Quality Management Theory was born in the United States in the 1960s and entered China in the 1980s. It has already developed into an independent discipline. The Total Quality Management theory focuses on product quality as the core, and adopts a fully participatory enterprise management model to manage the entire process of product production and sales activities. It is divided into four stages, known as the PDCA cycle, as shown in Figure 1.

Figure 1: PDCA cycle diagram.

(2) 4M1E method for highway engineering testing and inspection

4M1E is the abbreviation for Man, Machine, Method, Material, and Environment, as defined in Figure 2.

Figure 2: 4M1E Composition Architecture Diagram.

3. Analysis of influencing factors on testing and testing of raw materials in highway engineering

The influencing factors are multifaceted, and there are still some unavoidable uncontrollable factors in daily experimental work engineering. Based on this, when specifying the influencing factor indicators, this article follows the principles of Scientificity, objectivity, and rigor, in order to improve

credibility and recognition.

3.1 Current research status at home and abroad

This paper comprehensively considers the influencing factors from three aspects: literature review, expert interviews, and employee surveys.

3.1.1 Literature review

(1) By reviewing 24 literature related to the impact of road raw material testing[5-27], it was found that the influencing factors can be roughly divided into 9 categories: temperature and humidity, personnel, instruments and equipment, operating methods, sampling and health preservation, rationality of testing procedures, document recording, and system management. The frequency of influencing factors is shown in Figure 3.

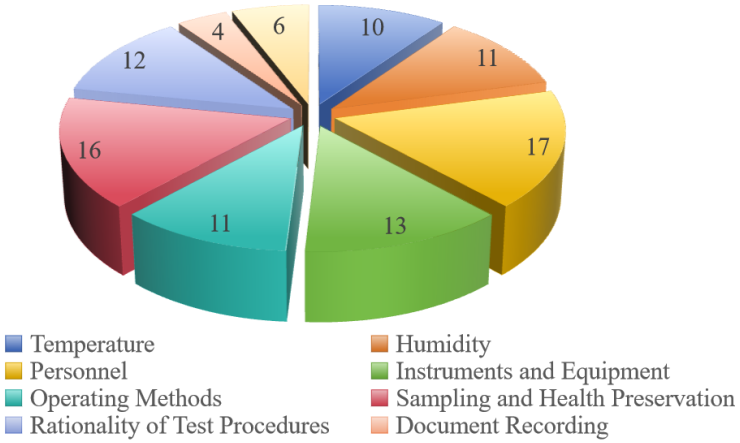

Figure 3: Frequency distribution pie chart.

(2) Testing personnel situation

This survey selected 7 testing engineers and 3 assistants who have been engaged in testing for a long time in the testing center. The basic information is shown in Table 1, Draw as shown in Figure 4.

Table 1: Seven level Terminology and Vague Set.

Number	Education	Years of Employment	Whether to work with a certificate?
1	Master's Degree	17	√
2	Bachelor's Degree	6	√
3	Bachelor's Degree	11	√
4	Associate's Degree	11	√
5	Bachelor's Degree	16	√
6	Associate's Degree	7	√
7	Bachelor's Degree	5	√
8	Associate's Degree	4	√
9	Bachelor's Degree	9	√
10	Bachelor's Degree	10	√

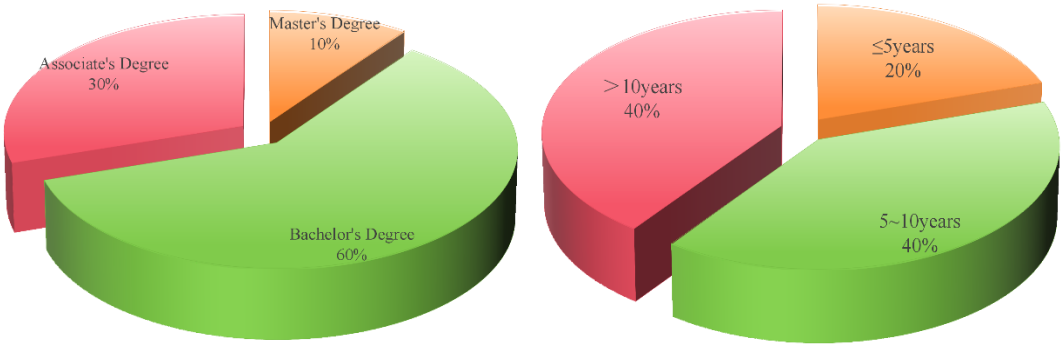

Figure 4: Overview of Personnel in the Experimental Center.

3.2 Determination of influencing factor indicators

Based on literature research, expert interviews, and actual research by testing personnel, this article proposes four influencing factor indicators: society, management, technology, and environment. In the literature research method, the influencing factors that have been evaluated by more than 10 experts and recognized by the experimenters for more than 3 times are classified as Level 1. For more than 7 times, 2 experts are evaluated and recognized by the experimenters for Level 2. For more than 3 times, 1 expert is evaluated and recognized by the experimenters for Level 3. The table of influencing factor indicators is shown in Table *2*.

Table 2: Selection of influencing factor indicators.

First level indicators	Second level indicators	Third level indicators
Factors affecting raw material testing and testing	Social Factors	Personnel
	Technical Factors	Sampling and Health Preservation
		Operating Methods
	Environmental Factor	Temperature
		Humidity
	Management Factors	Rationality of Test Procedures
		Document Recording
		System Management

3.3 Construction of influencing factor model

The accuracy of the results of road test raw material testing is influenced by multiple complex factors, either directly or indirectly, but multiple factors work together to unify the results. Therefore, multiple linear regression analysis is used to construct the model.

Firstly, this study establishes the functional relationship, establishes the basic regression equation of X corresponding to Y, determines the model, and obtains the final regression equation in the fitting software SPSS for credibility verification. Then, the degree of influence is distinguished. Finally, the range of dependent variable changes corresponding to multiple independent variable value intervals is predicted, and the accuracy is given.

Mathematical expression:

$$Y=\beta_0+\beta_1X_1+\beta_2X_2+\ldots+\beta_nX_n+\varepsilon \quad (1)$$

Equation (1) represents the mathematical model of n-variable linear regression. There are n independent variables, and the variation of Y is composed of two parts: X variation and random variable ε. β_0 is the regression constant, β_1... β_n is the regression coefficient.

The multiple linear regression equation is expressed as:

$$E(Y)=\beta_0+\beta_1X_1+\beta_2X_2+\ldots+\beta_nX_n \quad (2)$$

202 sets of independent variable control experiments were conducted on the four indicators of society, management, technology, and environment. SPSS software was used to fit and obtain weights, which were ranked in Table 3.

Table 3: Ranking table of importance of influencing factor indicators.

First level indicators	Second level indicators	Third level indicators
Factors affecting raw material testing and testing	Social Factors(0.094)	Personnel(0.094)
	Technical Factors(0.613)	Sampling and Health Preservation(0.206)
		Operating Methods(0.407)
	Environmental Factor(0.141)	Temperature(0.073)
		Humidity(0.068)
	Management Factors(0.277)	Rationality of Test Procedures(0.113)
		Document Recording(0.092)
		System Management(0.072)

The second level indicators of influencing factors are ranked as follows: technology (0.613)>management (0.277)>environment (0.141)>society (0.094). The third level indicators are ranked as follows: operating methods (0.407)>sampling and health preservation (0.206)>rationality of experimental procedures (0.113)>personnel (0.094)>instrument and equipment (0.092)> temperature (0.073)>institutional management (0.072)>humidity (0.068).

4. Case Analysis of the Third Section Project of Hainan Wanyang Expressway

4.1 Introduction to the Third Section Project of Hainan Wanyang Expressway

The third section of the Wanyang Expressway in Hainan Province is located in Dan zhou City, Hainan Province, with a southeast to northwest direction. The starting point is at K107+299, and the route runs from the east side of the old site of Jiaoyue Village to the southeast foot of Songyang Ridge. The endpoint intersects with the Yangpu Bay Channel South Connection Line of the Ring Expressway (West Line), and the endpoint is at K163+635.127, with a total length of approximately 56.225 kilometers. The design standard is a two-way four lane road with a roadbed width of 26 meters and a design speed of 100 km/h, with an asphalt concrete pavement structure.

4.2 Introduction to the Experimental Center

The testing center of China Design Testing Technology Co., Ltd is responsible for undertaking the raw material testing and testing work of the third section of Hainan Wanyang Expressway project. The testing center is engaged in engineering material and product testing and research. There are a total of 20 testing and testing personnel participating in the Hainan Wanyang Expressway project,

including 3 with senior professional titles and 7 with intermediate professional titles, all holding certificates of testing and testing engineer and assistant testing and testing engineer. The center covers an area of over 1000 square meters and is equipped with over 100 sets of equipment. It has over 200 testing parameters for raw materials such as aggregates, rocks, mortar, and asphalt.

4.3 Realistic characteristics of the experimental center

(1) Relatively loose management

The experimental center is divided into laboratories, with personnel holding certificates on duty. The experimental areas intersect with each other, but daily management is relatively loose. Reports are not mailed in a timely manner, commissioned tests are not conducted in order, and reports are not archived in a timely manner.

(2) The detection process is not recorded in a timely manner

After the samples of the third section of the Wanyang Expressway in Hainan were entrusted to the testing center for testing, there were situations where the test records were not updated in a timely manner during the testing process. At the same time, there were situations where the samples were arranged for testing without being registered in the laboratory in case of emergencies, and the sample number was not updated in a timely manner, resulting in rework of the inspection report.

(3) Lack of experience in analyzing the uncertainty of experimental results

Due to the influence of the experimental environment, equipment, and personnel, the errors in the inspection results of different samples in the same batch may vary. Most laboratories in the testing center and even across the country lack quantitative evaluation of the uncertainty of the inspection results. At the same time, the uncertainty of the data in the testing process can also affect the final detection results. Personnel at each experimental node lack the training mode of analytical experience and related computational abilities.

(4) Delayed archiving and delivery

The process from commissioning to testing, report signing and distribution to archiving is a dynamic one, until the end of the archiving test process. Failure to archive in a timely manner results in the loss of material timeliness, lagging dynamic management, and a large number of projects in the testing center. Failure to timely send test reports to the owner can also delay the process of report archiving to a certain extent. The experimental center is currently implementing an information-based and paper-based information archiving mode, with a significant workload for querying, reporting, and reviewing experimental results.

(5) Lack of experience in inspecting new materials

With the accumulation of experience in highway construction and the research and development of new materials, many high-performance new materials such as noise reducing asphalt are gradually being applied to the field of highway construction. However, the testing center lacks experience in the inspection methods and performance testing of new materials. In addition, there is a lack of motivation for the development of new detection methods, and they still rely on traditional inspection methods, with little effort to seek novelty.

4.4 Quality Control Suggestions for Hainan Wanyang Expressway Project

(1) Strengthen technical management in response to technical factors

In the testing work of the third section of the Wanyang Expressway project in Hainan, each sample tested corresponds to relevant standards and specifications. Participants in the experiment must strictly follow the standard specifications and operate in a standardized manner. The technical leader should regularly arrange inspections and conduct regular training for testing personnel to ensure accurate understanding and strict implementation of corresponding violations.

(2) Gradually promote information management in response to management factors

In response to the increasingly popular information technology application scenarios, the experimental center is gradually establishing a database to maintain information on the characteristics and inspection data of project raw materials, identify key characteristics with big data, and conduct targeted sampling and testing in the subsequent inspection, completion and acceptance stages to improve efficiency and achieve precise management. In addition, applying an information-based data management model will greatly reduce the cost of manual communication and docking of data, improve communication efficiency, effectively supervise the experimental process, and refine responsibility attribution.

(3) Strengthening laboratory environmental management in response to environmental factors

The experimental center strictly controls the testing process, conducts testing operations in accordance with national standards, introduces constant temperature and humidity equipment, strictly regulates laboratory temperature and humidity, strives to objectively and truthfully reflect data, and gradually promotes the construction of standardized laboratories.

(4) Strengthening personnel quality training and management in response to social factors

With the gradual application of new materials and technologies in highway projects, the existing knowledge reserves are insufficient to meet the current new testing technologies. The testing center should regularly organize training and assessment to improve the technical ability and testing skills of testing personnel, ensuring effective control of the quality of inspection work.

5. Conclusion

The conclusion of this paper is as follows:

(1) The influencing factors of raw material testing in highway engineering can be divided into four categories: social factors, management factors, technical factors, and environmental factors. The influencing factor indicators are arranged in descending order as follows: technology, management, environment, and social factors.

(2) Based on the comprehensive evaluation methods, the three-level indicators of influencing factors are arranged in order as follows: operating methods>sampling and health preservation>rationality of experimental procedures>personnel>instruments and equipment>temperature>system management>humidity.

(3) Based on the actual situation of the Hainan Wanyang Expressway Testing and Experimental Center, this study analyzes the problems and points out the shortcomings, and proposes improvement suggestions for each secondary indicator. In order to effectively improve the level of raw material testing and inspection.

References

[1] Xiaobin Chen, Jiasheng Zhang, Xuan Wang. Full-scale field testing on a highway composite pavement dynamic responses [J]. Transportation Geotechnics, 2015, 4: 13-27.

[2] Li Yingyong, Li Guangyi, Ding Kai. The Development and Practice of China Highway Capacity Research[J]. Transportation Research Procedia, 2016, 15: 14-25.

[3] Donghai Liu, Min Lin, Shuai Li. Real-Time Quality Monitoring and Control of Highway Compaction[J]. Automation in Construction, 2016, 62: 114-123.

[4] Douglas Alleman, Arthur Antoine, Mia Schrilla. The Use and Performance of Alternative Contracting Methods on Small Highway Construction Projects[J]. Procedia Engineering, 2016, 145: 908-915.

[5] Danyang Su, Meng Li. Quality control approach for civil engineering construction[J]. Journal of Architectural Research and Development, 2019, 2:17-23.

[6] Wang Daopeng, Fan Jifei, Fu Hanliang, Zhang Bing. Research on Optimization of Big Data Construction Engineering Quality Management Based on RNN-LSTM[J]. Complexity, 2018, 123: 114-116.

[7] Raja Rafidah Raja Muhammad Rooshdi, Muhd Zaimi Abd Majid, Shaza Rina Sahamir. Relative Importance Index of

Sustainable Design and Construction Activities Criteria for Green Highway[J]. Noor Akmal Adillah Ismail.Chemical Engineering Transactions (CET Journal), 2018,12: 12-17.
[8] Faiq M. S, Al-Zwainy, Reem Amer Mezher. Diagnose the Causes of Cost Deviation in Highway Construction Projects by Using Root Cause Analysis Techniques[J]. Arabian Journal for Science and Engineering, 2018, 4: 12-19.
[9] Iñaki Heras, Ernesto Cilleruelo, Jon Iradi. Standardization of management systems in Spanish care homes[J]. Leadership in Health Services, 2008, 11:34-37.
[10] Everett E. Adam. An international study of quality improvement approach and firm performance[J]. International Journal of Operations & Production Management, 1997, 9: 17-21.
[11] Andisheh Alimorad, Ali Moradzadeh, Reza Naderi, Mojtaba Zad Salehi, Afshin Etemadi. Prediction of geological hazardous zones in front of a tunnel face using TSP-203 and artificial neural networks[J]. Tunnelling and Underground Space Technology incorporating Trenchless Technology Research, 2008, 6: 11-17.
[12] Sangbok Lee, Byung Yong Jeong. Comparisons of Traffic Collisions between Expressway and Rural Road in Truck Drivers[J]. Safety and Health at Work, 2015, 6:22-27.
[13] M.A. Rabbani, T. Tsujimoto, M. Mitsuoka, E. Inoue, T. Okayasu. Prediction of the vibration characteristics of half-track tractor considering a three-dimensional dynamic model[J]. Biosystems Engineering, 2011, 2: 33-37.
[14] European. Effects of tractor weight, wheel placement and depth of ploughing on the infestation of perennial weeds in organically farmed cereals[J]. Journal of Agronomy, 2011, 4: 42-49.
[15] Mu-Kwang Kim, Sei-Hyun Lee, Yun Wook Choo, Dong-Soo Kim. Seismic behaviors of earth-core and concrete-faced rock-fill dams by dynamic centrifuge tests[J]. Soil Dynamics and Earthquake Engineering, 2011, 11: 44-47.
[16] Hernán R. Henríquez, Claudio Cuevas, Marcos Rabelo, Alejandro Caicedo. Stabilization of distributed control systems with delay[J]. Systems & Control Letters, 2011, 9:57-66.
[17] Yang Z C ,Xu D X. Intelligent Identification of High Rock-Filled Embankment Constitutive Model Parameters[J]. Advanced Materials Research, 2011, 1154(183-185): 2139-2142.
[18] Daniel X, Wang, Michael D Conerly. Evaluating the power of Minitab's data sub setting lack of fit test in multiple linear regression [J]. Journal of Applied Statistics,2013, 200, 1: 2139-2142.
[19] Fang Wang, Xiaoyu Han. Research on the Optimal Density of Highway Network[J]. Procedia Social and Behavioral Sciences, 2013, 96: 1556-1565.
[20] Yapin WANG, Mengjun WANG. New Idea of Project Management Research on Harmonious Project Management theory. International Conference on Engineering Management and Service Sciences. September (20-22), 2009.
[21] Hyungjoo Choi, Giri Venkiteela, Amedeo Gregori, Husam Najm. Advanced Quality Control Models for Concrete Admixtures[J]. Journal of Materials in Civil Engineering, 2020, 32(2).
[22] Li L X ,Sun G Z ,Fan F Y. Static and Dynamic Test Detection of Steel Tube Truss Arch Bridge[J]. Applied Mechanics and Materials, 2012 , 1802(178-181): 2513-2520.
[23] A. K. Chakraborty, A. K. Raina. Development of rational models for tunnel blast prediction based on a parametric study[J]. Geotechnical and Geological Engineering, 2004, 17:13-20.
[24] M. S. Diederichs. Manuel Rocha Medal Recipient Rock Fracture and Collapse Under Low Confinement Conditions [J]. Rock Mechanics and Rock Engineering, 2003, 22:44-49.
[25] G. V. Basheev, A. M. Efremo. Parameter Calculation for Efficient Allocation of Charge in Borehole During Bench Blasting of Rock [J]. Journal of Mining Scinence, 2003, 46:177-184.
[26] L. G. Wang, G. Tan. A Methodology for Predicting the In Situ Size and Shape Distribution of Rock Blocks[J]. Rock Mechanics and Rock Engineering, 2003, 11:46-52.
[27] N.A.Kassirova. Evaluation of the Efficiency of Methods of Removing External Water Pressure from Underground Structures [J]. Hydrotechnical construction, 2002, 4:21-29.