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Analysis of the Influence of the Ability Standard Variance and the Uniformity of the Sample on the Precision of the Comparison Test

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***Abstract*—According to the case of "2016 year highway engineering test of asphalt penetration and softening point test", we use the mathematical statistical analysis of the ability standard variance and sample uniformity; find the correlation effects of test precision. By comparing the similar data released recently by CNAS, we evaluate the general level in the transportation industry. It validates the rationality of the repeatability and reproducibility of penetration and softening point test, provides reliable validation data for the revision of industry standards.**

Keywords—Ability Standard Variance, Uniformity of the Sample, Precision Degree of the Comparison Test

I. INTRODUCTION

Since 2010, the Transportation Quality Supervision Department has conducted industry-wide test for six consecutive years, covering the fields of bridges, roads, engineering materials and other fields. They examined the overall test detection capability of the industry institutions from a wide range of angles, for different parameters respectively. And they accumulated a wealth of management rules and practical experience in technical operations.[1]

The organization of the industry test has evolved from the exploratory stage to the maturity. From the early, they focused on the organization situation of the comparison activities, sample preparation, verification, distribution and circulation control, data processing and statistics and other processes links[1], then gradually deep into the results precision analysis level. In this paper, the uniformity analysis and data statistic of 2016 asphalt penetration and softening point testing are taken as the object of the argument. Through the same field with the CNAS data horizontal comparison, the overall level of the industry is evaluated objectively.[1]

II. CASE STUDY OVERVIEW

A. Comparison of test size, test projects and statistical analysis methods

The total of 246 institutions participated in the highway engineering test of asphalt penetration and softening point test, of which 99 integrated class A and 57 class B were designated as the participating organizations, and 90 for the voluntary institutions.

Test projects: asphalt 25 ℃ penetration and softening point.

Statistical analysis methods: this comparison test is divided into four groups, and using GB28043-2011[2] algorithm A for statistical analysis, z-score way for conclusion evaluation; data statistics are divided into "small group analysis" that are undertaken separately by designated agency and the "big group analysis" that combined with the designated agencies voluntarily.

B. Comparison of results

The results are published as "satisfaction", "basic satisfaction" and "dissatisfaction". The statistics are in Table I.

III. ANALYSIS OF RELATED INDICATORS

A. Selection of repetition times [3]

GB28043-2011 stipulates that when determining it is necessary to limit the impact of repetitive variation, the number of repetitions of each laboratory in the capability verification should be met:

$$\sigma_r / \sqrt{n} \leq 0.3 \hat{\sigma} \quad (1)$$

where $\hat{\sigma}$ is the repeatable standard deviation determined by the inter-laboratory test before this.

When the above conditions are met, the repeatable standard deviation of the coefficient 0.3 contributes ≤10% to the standard deviation of the ability evaluation.

In this test, the standard deviation of the ability was confirmed by the repeatability limit and the precision test, and then the standard deviation of the ability was determined by the data obtained from the one-round capacity verification program, to find the appropriate number of repetitions in the laboratory. method is used in the capacity verification plan and the repeatability and reproducibility of the method are available, the standard deviation of the ability assessment can be calculated as follows on the basis of this information. It is

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TABLE I. THE STATISIS RESULTS TABEL OF LARGE GROUP TEST

Test items	Total numbers of institutions	Comparison of test results statistics			
		Standard	*Result*	*Number of institutions*	*The proportion*
Softening point	246	|Z|≤2	satisfaction	223	90.7%
		2<|Z|<3	basic satisfaction	11	4.5%
		|Z|≥3	dissatisfaction	12	4.9%
25℃ penetration	246	|Z|≤2	satisfaction	202	83.0%
		2<|Z|<3	basic satisfaction	28	11.4%
		|Z|≥3	dissatisfaction	16	6.5%

known that σ_R is the standard deviation of reproducibility σ_r is the repeatability standard deviation and the inter-laboratory standard deviation is calculated as follows:

$$\sigma_L = \sqrt{\sigma_R^2 - \sigma_R^2} \quad (2)$$

The formula for calculating the standard deviation of capacity is as follows:

$$\hat{\sigma} = \sqrt{\sigma_L^2 + \sigma_R^2 / n} \quad (3)$$

where n is the number of iterations of each laboratory in a round of capacity verification programs.

When the softening point is less than 80℃, the allowable error of the repeatability test is 1℃, the allowable error of the reproducibility test is 4℃, and according to the (3), the standard deviation of the capability is 3.9℃.[2]

The softening point test requires two repeatability tests for every test facility, n = 2.

Substituting into the (2), we can meet the requirements.

B. The standard deviation of the capability is calculated by the data from the one-round capacity verification program

For this asphalt comparison test data, we carried out the mathematical statistics, the standard deviation and mean value of the four groups of softening point and penetration are shown in Table II, for a total of 8 sets.

By using the maximum softening point, of which group 1/ big group's capacity standard deviation is 1.13.Substituting into (2), it can be seen that when the repeatability limit is used, it is not possible to meet the requirements by repeating twice for each the test agency .

C. The repeatability of each laboratory was determined by the relationship between standard deviation of ability and repeatability

GB 28043-2011 stipulates that if the conditions given in $\sigma_r / \sqrt{n} \leq 0.3\hat{\sigma}$ cannot be met, the number of repeated measurements shall be increased or the capacity verification organizer shall be reminded to take account of such conditions.

Taking the softening point group 1 / big group as an example, when the standard deviation of the capability is 1.13 ℃, the repeatability limit of 1 ℃ substituting into the (2) , the number of repeated laboratory should be 14 times.

A prerequisite for applying this method is to assume that the repeatability of the laboratories is approximately similar. If the (2) is not satisfied, the organizer can calculate the repetition times according to the typical values of the repeatable standard deviations. Each participating laboratory should check whether its standard deviation satisfies (2).

In accordance with the requirements of (2), if the number of repeatability is 2, the typical value of repeatability standard deviation should be <0.5.

Therefore, through the repeatability calculation in the uniformity test, it is proved that the repetition number of the laboratory in this comparison experiment basically meets the requirements. If this value is typical of the repeatable standard deviation, the participating laboratories should check their respective reproducibility. In addition, the index is too close to the critical point, indicating that such comparison tests need to consider increasing the number of laboratory repeatability .If the conditions permit, we may require to add penetration test 1 or more repeatability test.

$$S_p = \sqrt{\frac{1}{m}\sum_{i=1}^{m} S_i^2} = 0.5 \quad (4)$$

D. Analysis of Sample Uniformity Test

When the uniformity testing, the first should be compared between the sample standard deviation and precision standard deviation, and to make a pre-judgment; and then compared with the standard deviation of the public recommended value of the experts.

1) According to the precision test, the standard deviation between the samples was compared with the standard deviation of the precision calculation capability: the samples were predicted to be homogeneous. Table IV lists the sample uniformity evaluation results of the second batch.

TABLE II. STATISTICAL TABLES FOR STANDARD DEVIATION AND MEAN VALUE OF SOFTENING POINT AND PENETRATION ABILITY

Softening Point (℃)	**Group 1**		**Group 2**		**Group 3**		**Group 4**	
	Average value	***Standard deviation***	***Average value***	***Standard deviation***	***Average value***	***Standard deviation***	***Average value***	***Standard deviation***
Small group	46.99	0.88	48.351	0.69	46.17	0.69	48.11	0.53
Large group	46.95	1.13	48.422	0.74	46.10	0.80	48.13	0.74
Penetration (0.1mm)	**Group 1**		**Group 2**		**Group 3**		**Group 4**	
	Average value	***Standard deviation***	***Average value***	***Standard deviation***	***Average value***	***Standard deviation***	***Average value***	***Standard deviation***
Small group	68.043	1.69	67.04	1.59	83.84	1.62	66.74	1.60
Large group	68.371	2.31	67.22	1.74	83.79	2.72	66.55	1.65

TABLE III. SOFTNESS POINT UNIFORMITY TEST IN THE TEST VALUE OF THE TABLE

Sample number	**Softening point,℃**		
	Test value 1	***Test value 2***	***Sample Average***
1	48.2	48.7	48.1
2	48.3	47.8	
3	47.2	47.9	
4	47.8	47.7	
5	48.6	48.2	
6	48.5	47.8	
7	48.4	48.0	
8	48.1	49.3	
9	48.1	47.7	
10	47.8	47.7	

2) The standard deviation of the calculated results of the one-round capability test was compared with the standard deviation between the samples: softening point uniformity of the second group of samples in Table IV was taken as an example.

The heterogeneity standard deviation S_s in the softening point uniformity test is 0.216, and the calculation result of the large group satisfies the (2), and there is no need to consider the adverse effect due to the sample heterogeneity. While the small group's statistics do not meet the (2).Therefore, in accordance with the requirements of GB28043-2011, we should consider the impact of heterogeneity, and the standard deviation of the group capacity should be revised. In GB28043-2011 Appendix B, if not meet the (2), the standard deviation of capacity assessment should include the sample standard deviation, with the (5) to amend.

$$\hat{\sigma} = \sqrt{\hat{\sigma}^2 + S_S^2} \tag{5}$$

As a result, the softening point capacity standard deviation of the modified group 2 is：0.72.

IV. AN ANALYSIS OF THE OVERALL CAPABILITY OF THE INDUSTRY

A. The horizontal comparison of detection level in the same field in China

According to the data analysis from the CNAS competency providers, Table V and Table VI are the results of a round of competency verification by a competency provider.

In table V and table VI, the standard deviation of the softening point of the asphalt and the penetration are 0.93 and 2.46.By comparing the data in Table II, the laboratory standard deviation of the industry laboratory A is less than the standard deviation of the ability to verify of the CNAS organization, indicating that the discreteness of the detection ability of class A laboratory is small, the test results are very good consistently. The voluntary agencies have a large number of class B and class C institutions with a significant increase in standard deviation, but still close to the CNAS data, which is much smaller than the standard deviation of the capacity calculated from the precision. This shows that the overall level of the industry institution is at the domestic front.

TABLE IV. GROUP 2 SAMPLE UNIFORMITY EVALUATION RESULTS

Serial number	Parameter	Penetration	Softening point
1	Squared sum between samples SS1	10.822	2.358
2	The square sum of the samples SS2	8.215	1.690
3	Degree of freedom f1	9	9
4	Degree of freedom f2	10	10
5	Mean square between samples MS1	1.202	0.262
6	Mean square between samples MS2	0.822	0.169
7	Statistics F	1.464	1.550
8	Critical value F0.05(9,10)	3.02	3.02
9	Standard deviation of inhomogeneity Ss	0.436	0.216
10	The total average of all sample tests $\bar{\bar{X}}$	67.1	48.3
11	Stable standard deviation of the comparison test S	1.737	0.760
12	0.3σ（Large group）	0.521	0.221
13	0.3σ（Small group）	0.476	0.207

In addition, from the data of large group and small group, we can see that the difference of the two groups' value is less than 5 ‰, after adding voluntary agencies (mostly B, C, etc.), and with the peak of the small group being 1.68 times larger than the peak of the large group. This also shows that the average level of industry testing is fairly stable, discrete results are evenly distributed at the ends of the average, as the Fig 1. shows .

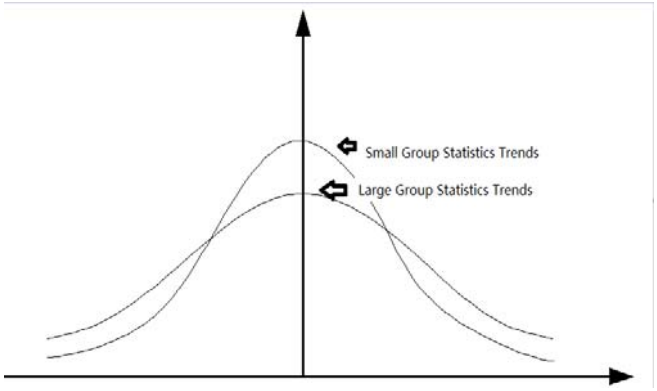

Fig.1. Large group and small group's statistical analysis comparison chart

B. Compared with the standard deviation of precision

1) precisionComparison of penetration test

JTG E20-2011 "Test Regulations for Asphalt and Asphalt Mixture for Highway Engineering" [3]stipulates that when the penetration test result is greater than or equal to 50 (0.1mm), the allowable error of the repeatability test is 4% of the average value, and the reproducibility test of the allowable

TABLE V. SUMMARY TABLE OF STATISTICAL PARAMETERS OF SOFTENING POINT OF ASPHALT (CNAS)

Test items	Number of results	Median values	Standard IQR℃	Steady CV	Maximum value	Minimum value	Extreme value
Softening point(℃)	47	47.7	0.93	1.94	49.6	45.3	4.3

TABLE VI. SUMMARY OF STATISTICAL PARAMETERS OF PENETRATION TEST RESULTS (CNAS)

Test items	Number of results	Median values	Standard IQR	Steady CV	Maximum value	Minimum value	Extreme value
Penetration (0.1mm)	42	66.90	2.46	3.7	71.6	61.1	7.5

TABLE VII. .PENETRATION OF FOUR GROUPS OF RESULTS AND ITS PRECISION CALCULATION OF THE STANDARD DEVIATION OF THE RESULTS OF STATISTICAL TABLES

	Group 1/ Big group	**Group 2/ Big group**	**Group 3/ Big group**	**Group 4/ Big group**
Average value	68.4	67.2	83.8	66.6
Standard deviation	5.0	4.9	6.1	4.9

error is 8% of the average. Group 1, group 2 , group 4 are 70 asphalt, from the large group of data in the table can be seen, according to the meetings value, the standard deviation of the computing power is less half than the standard deviation of the precision ability . Thus, the current detection level of the industry penetration fully meets the standard requirements, and has a high degree of precision.

2) Softening point test comparison situation

When the softening point is less than 80 ℃, the allowable error of the repeatability test is 1℃ and the allowable error of the reproducibility test is 4℃. When the data substituted into the (2), the standard deviation of the calculation of capacity is 3.9 ℃, and taken the standard deviation of 1.13 ℃ of group 1/ large group in Table II as an example, by comparison, far less than the results. We can see that, the industry's current softening point of the detection level fully meet the standard requirements, and has a high degree of precision.

V. RELEVANT INDICATORS REFERENCE TO THE STANDARD SYSTEM REVISION

A. The impact of revisionism

The asphalt penetration and softening point of the ability verification is in accordance with the JTG E20-2011standard for the results of the revision. The treaty has a great impact on standard deviation value. In the statistical calculation process, taken the penetration of the fourth group as an example, the effect of revising is 25% (revised to integer and 2 decimal places), while CNAS is not required to repair according to the traffic industry standard. And also did not show such a situation.

B. Repeatability and reproducibility

According to the results of the current round of capacity verification and the capacity verification report published by CNAS, the standard deviation of the penetration capacity and softening point of the asphalt is quite different from the capacity deviation that calculated by a given repetitive and reproducibility limits in JTG E20-2011 Test Rules for Asphalt and Asphalt Mixture for Highway Engineering. Thus, the relevant technical personnel of the transportation industry should pay attention to whether there is a significant improvement due to the current performance of equipment and other related reasons, resulting in the lower possibility that the test repeatability limits and reproducibility limits.

VI. CONCLUSION

In this paper, according to the results of the asphalt penetration and softening point test in the industry, the determination process of the asphalt penetration and softening point ability verification repeatability and the influence of the standard deviation of the capability on the precision of the test are analyzed. And it also provided revised views for how to refer to the uniformity data correctly, which is helpful for the further analysis of the accuracy of the test results. In particular, the paper also uses the method of mathematical statistics to verify the remarkable achievements of the transportation industry after years of scientific management, and reflects the fact that the industry are among the best in the same field in China objectively.

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