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INNOVATIVE TECHNOLOGIES FOR DAMS AND RESERVOIRS TOWARD THE FUTURE GENERATIONS

Proposal of the Rationalization of Dam Construction Quality Control

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ABSTRACT:
The Dam Construction Technology Research Group of the Japan Society of Dam Engineers studied rationalization of the quality control of the dam construction work. We surveyed many cases of quality control of dam construction executed in recent years and conducted a study based on execution data concerning the possibility of rationalizing quality control. Based on the results of this study, we proposed the rationalization of quality control of future dam construction work.

Key words: Quality control, test methods, test frequency, rationalization of quality control, new technologies

1. INTRODUCTION

Dam technologists from industry, government and academia in Japan have established the Japan Society of Dam Engineers, which has conducted a variety of activities including survey research of dam engineering and spreading information to the public. The Construction Technology Research Group of the Japan Society of Dam Engineers has conducted a survey study of the rationalization of quality control test of dam body construction work. This paper summarizes the results of its studies. (Construction Technology Research Group of the Japan Society of Dam Engineers. 2013)

The test items and test frequencies in quality control of present-day dam construction work are often decided based on the construction experience of the precedent dams. So they are almost the same regardless of the dam volume or the construction method or the completion year.

The essential purpose of concrete strength test is to confirm that strength satisfies the standard values. However, it takes time to obtain the results of tests, and in the end, all that is achieved is that it's possible to manage the trends in fluctuation of strength over time following the construction work. And concrete strength test is done intermittently, so continuous control of concrete strength is not performed.

On the other hand, in Japan, Information and Communication Technology (ICT) executions and automatic measurements are often applied to dam construction work. (Yamaguchi. Y, et al. 2012), Their use permits quality control and execution control to be performed continuously and that enhances reliability not possible in the past. (Computerized Construction romotion Committee. 2008)

Based on the above-mentioned situation, we decided to inspect quality control method of the conventional dam construction work. We believe that the time has come to develop and introduce more rational quality control methods of dam construction work.

2. PROBLEMS AND PRESENT STATE OF QUALITY CONTROL

The Research Group first analyzed the state of quality control of dam construction work.

2.1. Problem in the quality control of the concrete dam

We analyzed test items and test frequency at gravity concrete dams, mainly those completed after 1964 (33 dams). The results identified the following items as problems to the quality control of concrete dams.
[1] Regarding test items and test frequency, there are no differences according to construction method (Block method, Roller Compacted Dam Concrete Method (RCD) or Extended Layer Construction Method (ELCM)) or dam volume, or completion year. And at all dams, a constant test frequency was applied from the

start to the end of dam construction work. In the future, appropriate quality control test items and test frequency should be selected according to the materials, the construction method, dam volume. We must return to the original quality control: watching quality variation trends to take improvement measures as needed.
[2] Much attention has been paid to concrete strength test and other laboratory quality control test. In the future, priority should be on quality control integrated throughout the entire execution process: quality control of materials from quarrying to aggregate production, execution control during placing of concrete, and curing management.
[3]When multiple mixes of concrete are used simultaneously, the quality of each mix is separately controlled, resulting in a massive rise in the number of test samples used to control by age. If a certain quantity of data can be obtained to confirm correlation, it will enable rationalization through prioritized control of a representative mix and omission of control of other mixes, which in turn will reduce the number of tests.
[4] In case of scale malfunction or cement adherence to the scales during concrete production, the weight may be shown incorrectly, so it is important to check the scales.

2.2. Problem in the quality control of the embankment dam

We analyzed the test items and test frequency in quality control of core material at embankment dams (21 dams) constructed during and after the 1960s, when construction machinery increased in size and hydraulic control technologies were developed. As a result, as at concrete dams, it was not possible to confirm differences in the test items and test frequency according to dam volume and completion year. Constant test frequency was applied from the start to the end of dam construction works.

The following items were cited as proposed improvements.
[1] The test frequency of the quality control is set by layer units, calendar units, or embankment quantity units. Imbalance of the coarseness and minuteness occurs for the quality control because of a way of the setting of the test frequency. Appropriate test frequency should be reviewed according to the dam volume and construction speed.
[2] At embankment dams, essentially, the material is changed during execution in order to effectively use natural materials. In many cases where material is changed on the way, quality control test is done at the originally decided fixed frequency. When the material is changed on the way, it is necessary to take measures such as increasing the test frequency until quality has stabilized.
Fig. 1 is an example of a history of core material dry density, showing great change in dry density caused by change of material. When material is changed on the way, until stability of quality is confirmed, careful quality control test must be performed.
[3] As methods of on-site density test, in many cases, the joint use of the sand replacement method and Radio Isotope method (RI method) is prescribed. The RI method is simpler and faster than the sand replacement method, and if the correlation of the two can be

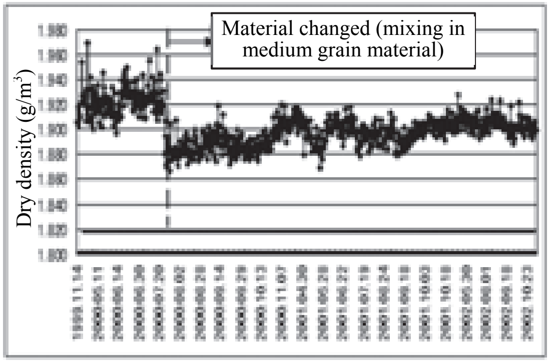


Figure 1. Core material dry density history

confirmed, we should use the RI method mainly and should use the sand replacement method secondarily.
Fig. 2 is an example of the correlation of the sand replacement method with the RI method applied during on-site density test. Relatively good correlation of the two methods is seen, and the RI method obtains smaller values.
In this case we should perform quality control using the RI method mainly. The RI method can perform the

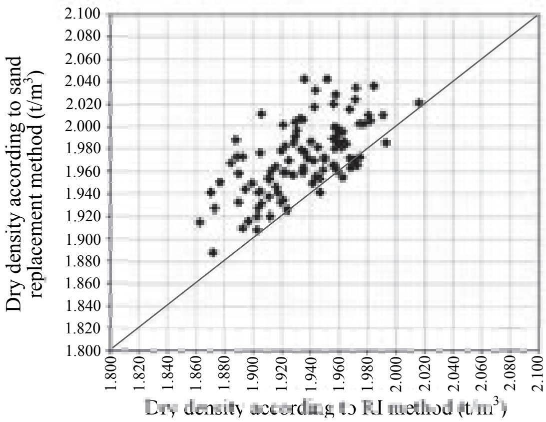


Figure 2. Correlation of sand replacement method and RI method for on-site density test

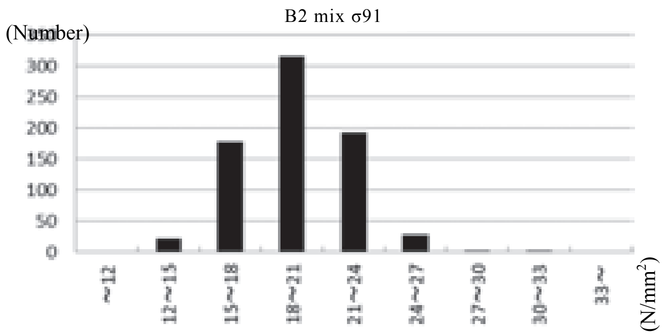
quality control of the safer side and the correlation with sand replacement method is high.
On-site density test data is point data on embankment, so it is not verified that quality is ensured for an entire embankment. The RI method can be tested more easily than the sand replacement method, and quality control should be varied by increasing the RI test frequency. It is necessary to make efforts to introduce new technologies or new testing methods to quality control, by developing new testing methods that permit clarification of area data or continuous data.
[4] To control quality of cores, it is important to ensure density and coefficient of permeability, but it takes time

for the results of these quality control tests to be manifested, and data are organized after execution. When materials are stock-piled, stabilized quality should be ensured by priority execution of quality control before the materials are brought to the dam site.

3. QUALITY CONTROL TEST FREQUENCY

3.1. Case of a concrete dams

Fig. 3 is an example of a 91 day strength histogram of a concrete dam. The histogram shows shape that is almost a normal distribution.



Number	737
Average	19.77
Standard differential	2.54
Coefficient of variation (%)	12.9
Maximum	31.9
Minimum	13.1

Figure 3. Example of results of concrete strength test (Dam A)

Next, we analyzed the impacts on statistical results of average values, maximum values, minimum values, standard differential, and coefficient of variation in a case where the test frequency was lowered at a constant percentage.

Fig. 4 shows the results of analysis of change of the standard differential and coefficient of variation in the case where test frequency was reduced regularly by 1/2, 1/3, and 1/4 at placing period (first phase, intermediate phase, final phase) at 5 concrete dams.

The results were almost identical even if the data declined along with the standard differential and coefficient of variation. At dams other than dam B, in the final phase, both the standard differential and coefficient of variation clearly tended to decline, indicating that the quality had stabilized.

We similarly analyzed the average, maximum, and minimum values, but even in the results showing decline of the data, the trends were almost identical. This shows that test frequency can be reduced while quality has stabilized.

From the above test results, the following proposals are made concerning rationalization of quality control of concrete dam construction work.
[1] For quality control of concrete, further increase of testing frequency or setting harsh control standard values when the material quality is not stabilized will be studied. When the test results have stabilized, revision will be done by reducing test frequency or adopting a simple test method.
[2] Quality control of concrete materials will be considered seriously. In particular, if material is changed midway, testing frequency will be reviewed according to the state of progress or state of execution on the site, doing supplementary testing etc.
[3] When, during concrete strength testing, confirmatory testing by mix or by age has confirmed that strength dispersion is small and there is correlation, then we should revise the reduction of the number of test specimens by mix or by age.
[4] The use of Global positioning system (GPS) or other ICT technology will be encouraged and areal or continuous control will be done to ensure reliability or traceability of execution.

3.2. Case of embankment dams

Fig. 5 shows the histogram distribution in a case where quality control data is methodically reduced to 1/2 for dry density, degree of compaction (sand replacement method, RI method) or coefficient of permeability of an embankment dam, and the results of analysis of statistical quantities such as maximum value, minimum value, average value, standard differential, and coefficient of variance.

This result is identical to the distribution shape of the original histogram, showing that the statistical values are also almost equal.

From the above test results, the following proposals are made concerning rationalization of quality control of embankment dam construction work.
[1] Frequency of quality control should be divided into early execution and stable period.
[2] Intensively incorporating the RI method or other simple test method. Using GPS or other ICT method to control roller compaction frequency or placing thickness, and performing areal and continuous control to increase the reliability of execution. (Ministry of Land, Infrastructure, Transport and Tourism. 2012)
[3] Fig. 6 is a flow chart of the embankment dam quality control test rationalization proposal. It is almost identical to the concrete dam case.

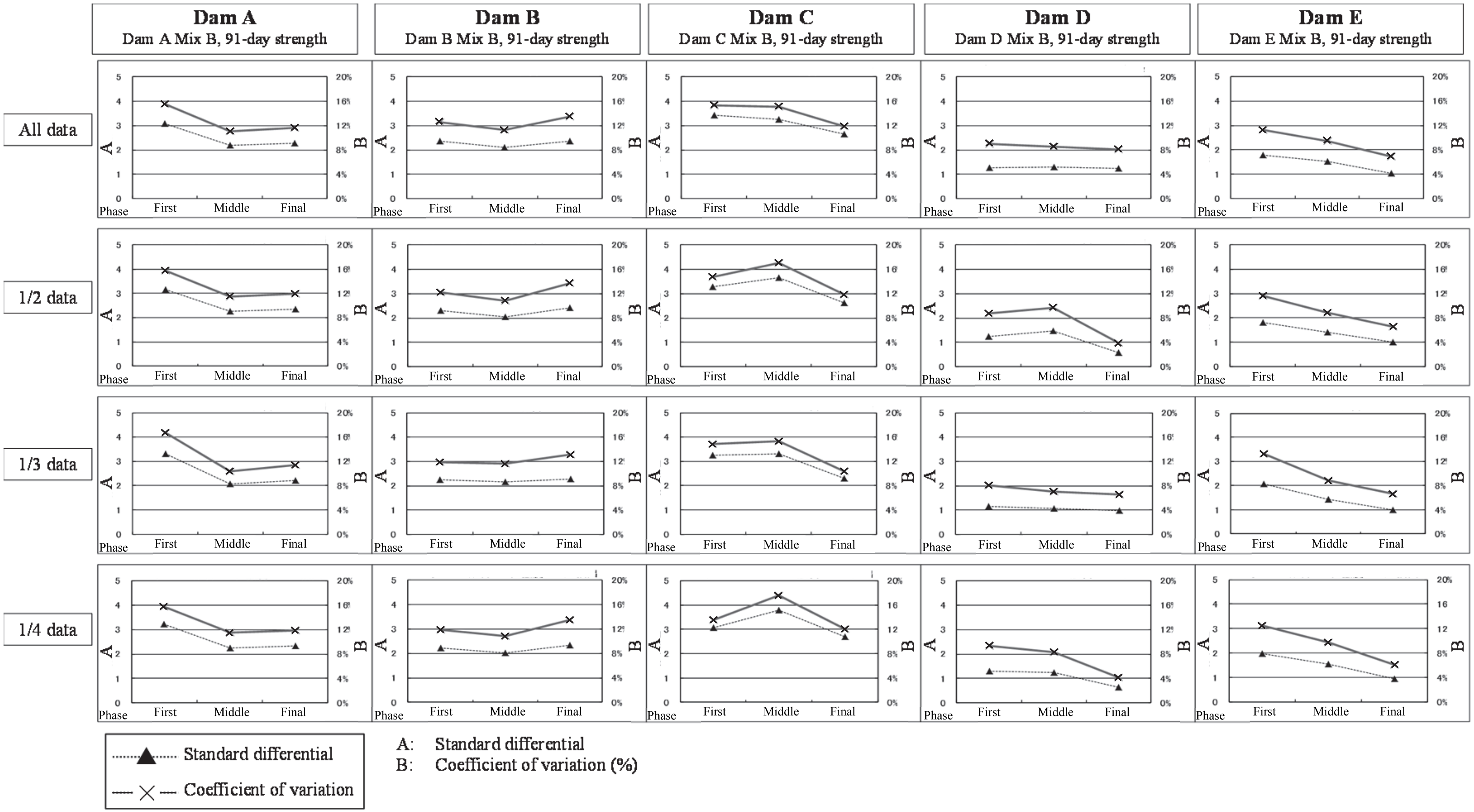
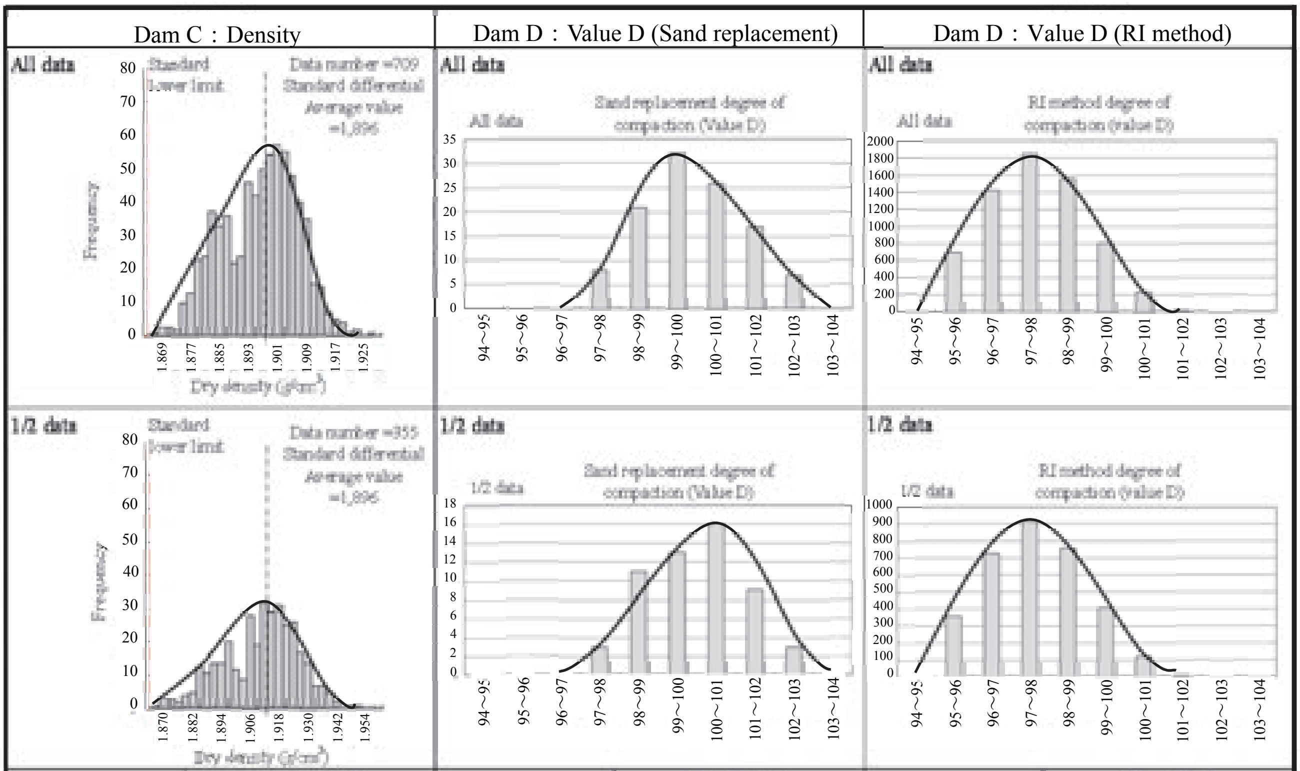


Figure 4. Comparison of the statistic in case of all data and reduced data



Item	Dry density (On-site density test, sand replacement)		Item	Compaction (On-site density test, sand replacement)		Item	Compaction (On-site density test, RI method)	
	All data	1/2 data		All data	1/2 data		All data	1/2 data
Sample number	709	355	Sample number	111	55	Sample number	6,586	3,293
Max. value (t/m^3)	1.927	1.922	Max. value (t/m^3)	102.9	102.8	Max. value (t/m^3)	101.9	101.6
Min. value (t/m^3)	1.866	1.866	Min. value (t/m^3)	67.2	97.7	Min. value (t/m^3)	95	93.5
Average value (t/m^3)	1.896	1.896	Average value (t/m^3)	99.9	100	Average value (t/m^3)	97.6	97.5
Standard differential	0.011	0.01	Standard differential	1.3	1.3	Standard differential	1.3	1.4
Coefficient of variance	0.006	0.005	Coefficient of variance	0.013	0.013	Coefficient of variance	0.013	0.014

Figure 5. Comparison of histogram distribution shape with statistical quantities for case where 1/2 of test frequency is thinned

4. CONCLUSIONS

Judging from the above, proposals to rationalize quality control of concrete dams and embankment dams can be summarized as follows.

1] It is necessary to perform dynamic quality control: constantly monitoring data fluctuation trends and when the necessary quality cannot be confirmed, quickly making improvements at the material procurement, production, storage, or execution stages.

2] It is necessary to perform “continuous revision of quality control”: instead of following uniform quality control items, testing and measurement frequency from the start of execution to its completion, changing quality control frequency and priorities while observing quality fluctuation trends.

3] It is necessary to rationalize quality control of dam construction work by introducing new technologies and new testing methods that can clarify continuous data instead of fragmentary point data while using ICT.

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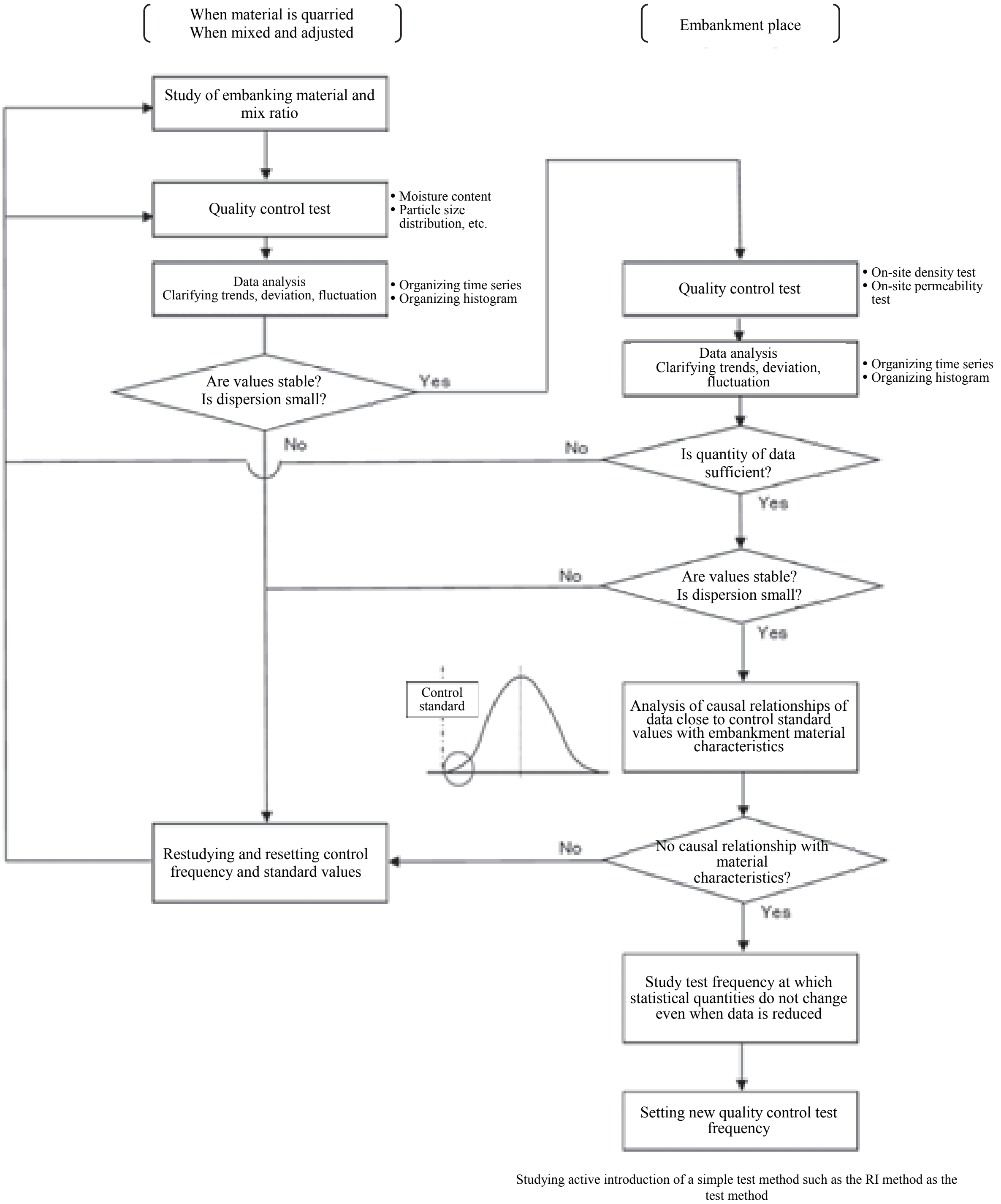

Figure 6. Rationalization of Quality Control Testing of an Embankment Dam (Proposed)